POSTURAL ERGONOMIC ANALYSIS OF MOPPING ACTIVITY

By

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CERTIFICATE

This is to certify that the dissertation entitled "Postural Ergonomic Analysis of Mopping Activity" submitted to the Avinashilingam Institute for Home Science and Higher Education for Women (Deemed University), Coimbatore, for the award of the **Degree of Doctor of Philosophy in Family Resource Management**, is a record of original research work done by **Tmt. VISALAKSHI RAJESWARI, S., M.Sc., (Kerala), M.Phil., (Bharathiar)**, during the period of her study in the Department of Family Resource Management, Avinashilingam Institute for Home Science and Higher Education for Women (Deemed University), Coimbatore, under my supervision and guidance and the thesis has not formed the basis of the award of any Degree/Diploma/Associateship/Fellowship or similar title to any candidate of any other University.

Sathyavathi Meethu

Signature of the Guide 26-3-97
with Date

DECLARATION

I hereby declare that the matter embodied in this thesis is the result of investigation carried out by me in the department of Family Resource Management, Avinashilingam Institute for Home Science and Higher Education for Women (Deemed University), Coimbatore, under the supervision and guidance of **TMT. SATHYAVATHI MUTHU, M.Sc., M.Phil., Dip.Ed., Ph.D., (Madras), Professor** and Head of the Department of Family Resource Management, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore and it has not been submitted for the award of any Degree/Diploma/Associateship/ Fellowship or similar title of any other University or Institute.

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VISALAKHSI RAJESWARI, (Selection Grade Lecturer in Family Resource Management, Avinashalingam Deemed University, Coimbatore) conducted the experimental studies in connection with her Ph.D. dissertation on "Postural Ergonomic Analysis of Mopping Activity" in the Work Physiology laboratory of the Model Centre for Occupational Health Services, Bharat Heavy Electricals Ltd., Tiruchirappalli.

It is certified that her work is original in nature. The study was conducted under the guidance of Dr. A. K. Ganguli, Dy.Manager (Work Physiologist & Ergonomist).

March 15, 1997

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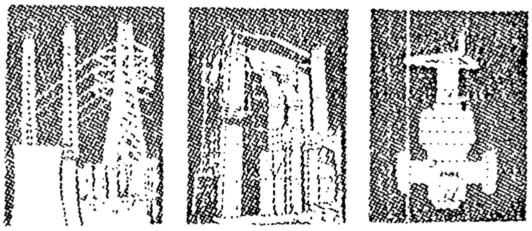

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Oh MERCIFUL GOD, PRAY BLESS US ALL

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3. Dimensions

LBM = lean body mass
BMI = body mass index
trochanteric height = hip to foot length
Sq.m. = square metres
Sq.m^{-min} = square metres per minute
Sq.m/ min = square metres per minute

4. Time

min = minute
s = seconds

5. Load

W = Watts
KPM = Kilopond meters

6. Statistical notation

M or $\bar{X}$ = arithmetic mean
S.D = Standard deviation
Mean±SD = Mean ± 1.96 SD
S.E = Standard error of mean
r = Correlation Coefficient
C.V. = Coefficient of variation in per cent
Σ = Summation
P or p = Probability
$\underline{t}$ /'t' = students $\underline{t}$ value
Equ = Equation
NS = nonsignificant

Introduction

INTRODUCTION

"The mere fact of knowing what hurts you
has an inherent curative value"

- Hans Selye

Modern age in India is marked by a remarkable progress of scientific knowledge and technology. In such a changing society, the 'family' occupies a critical position (Merh, 1984). The family is appreciated for the important socio-economic functions it performs - of preserving and transmitting cultural values. For these reasons home economists view the family as the smallest unit of economic analysis, since it uses and transforms resources. Rice and Tucker (1986) classify resources under human, economic and environmental. Human resources assume paramount importance as they have the potentialities to improve the quality of life opines, Rameshwaram (1989).

Many aspects of human life constrain the quality of life despite the tremendous changes made in technology (Ferguson, 1972). Since quality of life is partly a function of the risks to life, the human community is still subject to a state of unhealth (Dandare and Ahankari, 1983); the ultimate aim being enhancement of the human life. The question being asked is, what role should the individual play to minimise the ill effects? Welfare begins when a person sees himself/herself as a growing, changing person in attitude, behaviour and consumption pattern state, Travis, (1977) and Carroll and Miller, (1986). Ironically, as Agarwal (1989) states, the clamour for change in role expectations within the home alone continues.

Work is one of the conditions for keeping human beings alive. Everyday work with purposeful activities requires expenditure of energy states, Devadas (1987). Hence the aim of any work study of the home should be focussed upon appraising the use and conservation of the human resource due to the multiple role performed by the homemaker.

Work performance has different meanings in standardized and non standardized conditions of work. In the former it can be defined as either the response to work, as indicated by physiological indices - change in heart rate (HR), and oxygen consumption or the work accomplished for a given physiological response. In non standardized task, it is the work accomplished which depends on factors such as the rate of work, motivation and skill (Spurr, et al., 1987). Both meanings are applicable to the work in domestic parlance.

The degree of participation in household operation denotes the work load of women in the family sphere and considers the whole panoply of activities performed by them. Analysis features that different individual activities usually incorporated in one's daily routine demand different PAR - Physical Activity Ratios (James and Schofield, 1990). Albeit assigning each activity in the house as moderate-to-light (PAR value), a combination of the activities results in work over-load. Hence it is necessary to draw attention to the performance of more number of tasks by women than are physically feasible resulting in drudgery, physical stress and fatigue (Srivastava, 1985).

Physical work, demands adjustments and adaptations which affect nearly all the organs, tissues and fluids of the body. The most important manifestations are deeper and more rapid breathing, increased HR, supply of O_2 and metabolism, vasomotor adaptation, rise in BP and body temperature. The study of energy needs will help to develop a basic knowledge concerning why the human body requires energy and to appreciate how energy is measured (Dunn,1983). Moreover, Pollitt and Gorman,(1989) and Super,(1989) opine that there is a need for the creation of a typology of activities known for their energy costs which could serve as a guide for classification of the observed activities and yield information on a single dimension of action.

Most of the ordinary daily occupations - household work - belong to the category of light or moderate work (Noble,1986).The O_2 store in the muscle plus the O_2* supplied will completely cover the O_2 need in such exercise. Torun (1989) for the same categories of work has reported to consume 2.40 K.cals. min^{-1}. According to Astrand and Rodahl (1977) all kinds of housework involve a workload of less than 300 KPM. min^{-1} (50 Watts) which demand approximately less than 5 k.cals. min^{-1} of energy irrespective of the body weight of the performer. Therefore, analysis should focus on finding solutions to the interrelated and unresolved issues which have an impact on the worker - the homemaker - since she performs 90 per cent of the household chores

A successful homemaker should be prudent enough in the use of her energy resource. Previous studies throw light on a few household activities namely traditional grinding, rolling chappatis, ironing, washing clothes, sweeping and mopping as highly time consuming and fatiguing. Ergonomic studies undertaken by Dhesi and Firebaugh (1973) on rolling chappati, by Dhesi, et al (1975) on sweeping, by Devadas and Patwardhan (1976) and Oberoi, et al (1996) on manual grinding and Oberoi et al (1983) on washing clothes stand testimony to the findings that they are highly fatiguing. Only mopping has been ignored, mainly because of the postural codes dictated by tradition. Mopping involves removal of dust by wiping with a damp cloth adopting different postures (Mullick, 1981).

The frontiers of science and technology have expanded introducing automation for all activities except mopping. The appliances after a long experimentation have entered the thresholds of even middle income families

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*Refer Glossary

in India considering associated factors of feasibility, efficiency, power consumption, non-availability of paid help and affordability. The task of ironing also has been handed over diplomatically to commercial drycleaners and 'press walas' (dhobi). The only task remaining and which really takes a toll on the homemaker's time, energy and muscular fatigue experiences is mopping of floors. According to recent reports the PAR value for mopping is 3.8 (3.3-4.4) where 4^{+} is classified as heavy; and hence this task needs detailed analysis for its caloric cost and postural implications on the muscles and joints. Ohsawa and Sagawa (1992) have pointed out postures as influences of religious precepts. Though this is fine with Indian conditions which bestow great significance on the dictates of cultural values, increase in technology development, education and communication have considerably relaxed the postural codes citing the following physiological reasons.

Body posture is describable by the segments' positions relative to an inertial coordinate system. The skeletal structure of the human body is modelled by 30 rigid body segments which are cylindrical in shape and rotatable at 27 punctiform joints (Jager and Luttman, 1992). So working position must permit a posture of having a natural balance over the base of the support. In the distorted posture, the muscles have to contract unnecessarily for holding the body erect which may cause damage to vertebral muscles, report Dhesi, et al, (1975),by virtue of the back muscles which may be forced to do extra work for fighting the gravitational force leading to the compression of the discs of the backbone and the outstretching of the ligaments.

The spinal column is unique among the bony structures of the human body, in that it serves as a sustaining rod for maintenance of the upright position. As such, it is subjected to a complex system of forces and stresses of a wide variety of types. Researchers classify them as belonging to one of the three syndromes - brachialgia syndrome (stiff neck), lumbago-sciatica syndrome (lumbar insufficiency) and the dorsal spine syndrome - among which the first two are more common (Astrand and Rodahl, 1977). Both the conditions lead to severe low back ache. Rodgers (1984), Hettinger (1985), Hildebrandt (1987) and Leino and Hasan, (1987) have concurrent views on the relationship between the incidence of such disorders and heaviness of jobs. Naturally, this calls for certain changes in behavioural concepts and of acceptance of technology into life styles. Recently, systematic, concerted action has been directed towards these objectives. This general area of human endeavour has come to be known as Human Factors Engineering - HFE (Mc Cormick, 1976) or simply human factors, biomechanics or ergonomics - the major objective being maintaining or enhancing human welfare (health, safety and satisfaction). Though the initial focus of attention was on the design of a higher order, some inroads have been made into the designing of consumer products and machine tools too. In this context Bhoosnurmath, (1994) propounds HFE to create an artificial environment, both tolerable and viable for human life.

Nair (1979) states that it is essential to know more about the limitations of performance and capacities of human beings. The interdisciplinary subject (ergonomics/biomechanics) deals with one aspect of design of equipment taking into consideration the operator's capacities, anthropometric data, limitations, comforts and compatibility. Since biomechanics refers to the branch of science dealing with the effect of energies and both internal and external forces on human beings at rest or in motion, its application is mainly concerned with the practical problems of improving movements and posture of the subject concerned (Menon, 1979). Pizatella,et al (1992) opine that significant reductions in musculo-skeletal disorders are possible with a comprehensive approach. In this era of technological explosion, machines/tools have become an indispensable part of human life, to economize the consumption of one's own energy (Ganguli, 1982). As Ortiz and Morrison (1983) state use of labour saving devices make the tasks more efficient. The goal, thus, is to develop improved tools, equipments and work practices that will reduce potential risk. So, Tandon (1978) unveils the dictates of local needs, resources, culture and ethos that call for the development of indigenous appropriate technology.

There have been sustained interests in giving more systematic attention to the implications of the human factor in designing. The study of biomechanics as an interdisciplinary activity falls into two groups - (1) those potential appliers of human factors data and principles and (2) producers of human factors information like behavioural and biological scientists. The latter's role involves research inputs to generate new information about human beings that might be relevant to the human factors field and serve as consultants and advisors in the field. The homemakers in a way are potential suppliers of information regarding effective utilization of time and energy. Their requirements have practically acted as germane to many innovations in household equipment as they are the potential users and critics.

Productive activities of present day households revolve around management and performance - where the latter encompasses 'house work'. Women shoulder the brunt of all household tasks (Wadhera, 1976). So a general overall rating of satisfaction may be given to the total job of homemaking. But, most homemakers readily identified some tasks as liked or disliked. Almost traditionally, they were found to focus upon household cleaning as disliked activity. The job involves specifically sweeping and wet mopping or washing of floors. Cleaning is considered as a heavy task with respect to the implied physical labour, subjective feelings of monotony and time involved. Mopping, especially, is regarded as monotonous, strenuous and a most difficult activity.

A priori, the homemakers are desirous of engaging domestic help to reduce their feelings of fatigue. Though unemployment is rife in the country, good paid help is difficult to find. Among the activities entrusted to such helpers if available at all, mopping floors receives priority. This is so because of a few valid but logical reasons behind the activity of mopping. India is a tropical country and, naturally she is favoured with specifically two entirely different seasons of summer and winter, with a regular blessing of monsoon showers. Therefore, the environment is alternately exposed to drought and cold. At times the winds may be strong making interiors dusty and at other times it becomes increasingly impossible to enter a house without spoiling the flooring with wet mud, which warrants frequent cleaning. The spiritual anchorage which forces homemakers to maintain clean floors also has been a welcome feature (Peruvaayin Mulliyar, 1981[*] and Paventhar Bharathidasan, 1993[**]). Added to all these the type of flooring differed- mud, cement, crude concrete, redoxide coat, mosaic and marble - and all tax on the homemaker's energy for proper maintenance. Floor maintenance is a part of housekeeping activity, is periodic and suggests retention of hygiene, protection of the high initial investment on expensive flooring, and maintenance of decor or ambience (Krupa Shankar, 1993). The philosophical tradition stretching from sitting and eating to sleeping at floor level also augments the need for clean and well kept floors. So, from time immemorial, women have been silently performing the activity daily often many times a day. Recently homemakers find it practically difficult to perform the activity owing to their dual roles, poor health status, dependence on women for activities outside household premises and the like. In the absence of assistance they find this activity a drudgery, especially because of the established traditional postures which 'ipso facto' demand involvement of muscles, gasping for breath and increased heart rate compared to resting base. This calls for insight and indepth studies to ergonomically relate the postures with energy expended in mopping action and assess the postures

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[*] Author : Aasarakovai - A treatise on etiquette in Tamil

[**] Author : Kudumbavilakku - Another Tamil Aphorism

for tolerability. The assessment methods appearing most frequently include (1) study of posture from a biomechanical view point (both short and long term effects), (2) direct and indirect measurement of pressure on the intervertebral discs (long term effects), (3) EMG studies and (4) its acceptability from the psychophysical point of view (short term effects). But the criteria on which these assessments are based focus on the aspect that it is not the posture per se which is assessed but it's tolerability. One needs to analyse which postures may be considered tolerable? The hypothesis put forth by Colombini et al., (1985) states that those postures which comply with the two requirements - that it does not involve feelings of short-term discomfort and does not cause long-term morpho-functional complaints may be considered tolerable. So, if feasible, a combination of the assessment methods must be utilised while analysing work postures.

Mopping involves adoption of two postures - squatting and bending - which herald another point for consideration - the extent of 'static component' controlling the activity and posture maintenance. This aspect is an important determinant for local muscle fatigue in types of moderate or heavy dynamic cum static work. Estimations show that blood flow to human calf muscle is severely restricted at static tensions. This decreased blood flow is caused by 'mechanical occlusion' which is the main cause for muscle fatigue. The O_2 deficit paid during the recovery period is taken as a measure of anaerobic debt. Lee (1982) has concluded that anaerobic energy is more important to working muscle than aerobic energy, since the recovery rate of muscles depend on the rate of recovery which in a way is dependent upon endurance and physiological adaptations.

The term muscular 'endurance' refers to a muscle's maximum amount of prolonged or repetitive exertion against a moderate force. Many daily activities (Levy, et al, 1988) require a certain degree of muscular endurance. Physiological adaptations on the other hand advocate good body alignment and posture and due muscular involvement during performance.

Nevertheless, Indian homemakers are heedless to these dictums, which lead to permanent or temporary impairment of the spine, muscles, ligaments and joints. Mopping in the conventional postures which are true stances against one's centre of gravity therefore, reckons on an indepth study. Naturally extra calories will be needed to counteract the forces of gravity in addition to the forces both -reactive and compressive- incident on the various joints of the body involved in the posture. Waterlow, et al (1991) have thrust research needs to include measurements of activity patterns in free-living populations; that is, time-motion studies in combination with individually calibrated heart rate measurements. As rightly said, women doing housework may in fact expend more energy than men in industry (Banister, et al, 1988). With this backdrop, it was felt inevitable to design an operational criteria which includes techniques for measuring performance of body and body members in making specific types of movements. When compared to the magnitude,the researches conducted so far are regretfully scarce.

Research is to see
What everybody else has seen
And to think
What no one else has thought

Hence this 'in-situ' study on 'Postural Ergonomic Analysis of Mopping Activity' was launched as a germane to such thoughts of recapitulation, which stresses the need to ergonomically evaluate the task of mopping -a type of self-observation reafference -as is traditionally performed by housewives.

Thesis statement

An analytical description of certain functional elements of individualistic working patterns and their physiological status provided evidence for the specific theses :

1. The energy expenditure in a particular submaximal activity is the same for every one
2. The subjectively varying strain which occurs in work can be best registered objectively by continuous measurement of heart rate
3. These strain-related differences in HR, are dependent on the cardio-pulmonary fitness of the individual and show obvious changes with postural adaptations
4. Such postural adaptations effect changes in angles of body bend causing effective forces, both - reactive and compressive - in the joints concerned, and
5. The compressive load mainly on the lumbar spine can be found from the above data.

Based on these, the following objectives are addressed in the study

Objectives of the study

1. Analyse the activity patterns of selected homemakers
2. Delineate the most strenuous activity among selected household tasks.
3. Estimate the Vo_2 and caloric cost incurred while mopping in two selected postures using the derived regression equation
4. Find out the shift in angles of body bend in the concerned postures through still film analysis and posture targetting
5. Determine changes in HR corresponding to anatomical movements while adopting the two postures
6. Calculate the stress - strain concept on the musculo-skeletal system by determining the compressive force on the L5/S1 disc and assess the postures for tolerability
7. Identify mopping activity as an action involving more of a static component
8. Examine the feasibility of using manual moppers for energy conservation

The objectives were also framed based on the following assumptions.

Assumptions

1. Energy expended for a particular activity can be determined from known values of HR and a reliable regression equation.

2. Bending and squatting are not advisable postures for mopping.
3. Rate of work and recovery is less and the performance is slow in squatting posture.
4. Mopping activity involves more of static component in the squatting posture.
5. There is possibility for 'mechanical occlusion' of O_2 supply due to adoption of squatting posture leading to muscular fatigue.
6. Between the two postures squatting imposes great strain and damage on the L5/S1 disc (lumbo-sacral region).

The nature of household work ethics in the Indian society and conservatism towards household tasks cannot be changed.The fact that certain processes have always been done in one way does not necessarily mean that a better and safer method cannot be devised. Imagination and ingenuity will often suggest ways in which the process can be changed to eliminate some of the health hazards . Individuals have to accept greater responsibility for sustained health. Their active interest and participation in solving their own health problems are a clear manifestation of social awareness and self-reliance. Creating public understanding of science, in an era when 'science and technology' is permeating every fabric of society including the household sector, is the felt need of the hour. It is envisaged that the findings will impart and effect an iota of knowledge in the analysis and understanding of household work behaviour that affects human life.

Review of Literature

II REVIEW OF LITERATURE

The literature reviewed pertaining to the study on "Postural Ergonomic Analysis of Mopping Activity" is presented under the following heads :

A. Profile of women in the household milieu
B. Biomechanics of motion
C. Spatially coordinated behaviour in human beings
D. Productive capacity / performance of individuals
E. Energy - the body's potential for work
F. Ergonomics and ethos of work done

A. Profile of women in the household milieu

Homemaking is a cooperative enterprise where every individual living as a family member has a shared responsibility; to be good there must be proper and collective management of resources. Sex role stereotypes indicate that generally men and women hold responsibilities instilled by the individual parental attitudes experienced by them.

Since the creation of the human race men and women have been complementary to each other. Division of labour and duties came naturally. The onerous duty of bringing forth progeny, making the home a haven of comfort and efficient housekeeping automatically fell into the woman's lot which the girls imbibed traditionally from elder women (Tara Bai, 1977). Chakravarthy (1991) has since stated that the women's productive role is limited to household chores. Contrarily, Ramachakravarthi (1986) had portrayed women of recent days as carrying a heavy work-burden, both inside and outside the home,by being gainfully employed. Although cultural norms, continue to condition most women for passive, nurturing roles at home, recently Regan and Roland (1985) found that the number of women expecting to place their families ahead of their careers has declined and that women, rather than men, have been making the most dramatic changes in trying to accommodate both career and family. The definition of dual role as 'double shift' helps to clarify the existence of paid, labour force work and unpaid domestic work. Despite the prevailing trend of increased participation in the work force, women are still found liable for child rearing and homemaking, opine Rowland et al, (1986).

Recent studies on household work focus on how this work may (or may not) be shared by the family members. With fewer hours available for household tasks how do they get it done, and who does them? Three possible strategies that families utilize to compensate for the homemaker's decrease in available time are substituting with household equipment or husband's or children's time. However, little evidence has been found by researchers, report Sanik (1981) and Bryant (1988), to support widespread use of any of these strategies. Indications proved that durables were not substituted, but were only used as complements. Applying the capitalist economic constructs of 'work' and 'leisure' to the home they illustrate the dysfunction and bias existing in the quantification of work. The endless 'work'of the home does not distinguish between when one is at work and when one 'is not'. The division between these two states does not exist. Household work is defined as 'non-work' by implication. Therefore, work is just one example in which women's experiences and definition have been omitted, ignored, and devalued.

To determine a nation's GNP, the value of work for which wages are paid is measured. Historically, only men's work has been considered. Work goes unmeasured if produced for one's self or the family. Only since the mid-1960s, quotes Benzley (1990) from Perzeszty (1984), has the economic contribution of household work been of interest to economists, who estimate that its dollar value is equal to roughly 44 per cent of the GNP. It is no wonder that Deacon and Firebaugh (1988) have humourously stated that the acceptance of women into the world of paid employment seems easier than the reverse interest and involvement of men in household and family tasks. Household tasks make greater demands on women in the family than upon men (Walker, 1970 and Doyal, 1995). If they are ignored or are not performed adequately, women experience greater dissatisfaction than men (Willis, 1977). The same attitude towards these tasks, their lack of time to attend to household chores satisfactorily and their health status entice homemakers to engage paid help. Though women do not calculate their self-toil, they pay suitably the services rendered by employed helpers. Even then stresses and strains invariably develop in the servant maid - homemaker relationships. Despite such strained relations, opine Manohar and Shobha (1983), the contract continues, the main reason being non-availability of servant maids and the purpose for which they are generally employed like washing clothes, sweeping and mopping the floor.

Innovative labour saving devices provide another dimension in which to view women. Industrial growth, scientific and engineering achievements are the means by which a technological society converts its resources into products and services. In the main, opine Minard (1970), such growth raises living standards by reducing toil and allowing for more leisure. Perhaps this seems true when Montoye (1971) and Bradfield (1971) react to the concept of automation as one which has raised the living standards throughout the world and has led to decreased physical activity. But the household front poses a different picture because, a homemaker shows interest only in the possession of equipments/appliances that help conserve her time and energy in cooking rather than in any other activity. Naturally, she expends more time and energy on other strenuous household activities. The physiological and psychological benefits of accepting automation are still to receive women's attention. This calls for an awakening among women to realize their folly and adopt the use of mechanical equipment to perform strenuous jobs like washing clothes or household maintenance,which could definitely help them cherish the desired values and standards they expect in performance.

As Gauger and Walker (1980) observe, although disapproval of 'working' mothers has lessened considerably, societal labelling of household task as ' women's work' remains virtually intact. Women who are the agents of change should bring together science and technology on service to the needs of the family. They have all the potentials; they just have to use them. Perhaps it is the right time to comprehend the major implications they indict upon themselves by expending energy unnecessarily on certain tiresome household activities. Current research thrusts also signify the necessity to enlighten women on the close relationship between muscular performance and energy expenditure through an insight into the biomechanics of motion.

B. Biomechanics of motion

Movement and physical activity are basic functions for which the human organism was created, observe Chaney and Ross, (1971). The organisms are endowed with the ability to move different parts of the body in relation to each other and to one's environment, take up and maintain different postures, counter balance the impact of outer forces such as gravity, and transfer mechanical energy to the other world (i.e., doing work in it). Though each activity is performed differently by different individuals, similarity exists in the parts of the body used for a particular task done under similar conditions (Gross and Crandall, 1980). 'Activity' is the observable behaviour of people as they go about their daily work.

Biomechanics is defined as the application of principles of mechanics to living biological materials. It's role includes application of the principles of statics on biomechanical structures of man - the muscles, tendons, bones or joints - to determine the forces while the body is at rest. It enrolls various aspects of the physical movements of the body members and their operation is characterized in terms of Kinematics. It is the science dealing with body forces and motions or effects (Williams and Lissner, 1962).

Dynamics encompasses stresses due to the body in motion, and when subjected to vibration and impact. These concerns, accentuate, Von Gierke,(1973) the demand for a major reappraisal of the significance of studying the dynamic characteristics of human body mainly because of the factor called muscle tension. Information on the mechanical behaviour of the body and its parts is necessary, proposes Radhakrishnan (1979), for the proper design of equipments and tools too. This being so, the state of knowledge in biomechanics and physiology does not provide clear and generally applicable guidelines about suitable use of the body, says Kroemer (1992). Yet, when one considers the musculo-skeletal structures within the trunk, a variety of elements may be under stress, either singly or combined: the spinal vertebrae and connective tissues, all of which may experience 'insult', sprains or trauma. While Kandarian et al., (1994) have postulated the biomechanical loading history of skeletal muscle as a strong modulator of its phenotype, Marras and Mirka (1989) have measured trunk torque around the lumbosacral joint.

Relationships between the various joint reaction forces were deduced by Noone and Mazumdar (1992). By considering free body diagrams above each joint in question, they were able to calculate the approximate joint reaction forces at specific muscle joints. The working position that requires a segment of the body to be maintained out of natural alignment may put unnecessary pull on ligaments and tendons. If force is exerted by or in conjunction with this segment, contractions occur in localized groups of muscles, by which both ligaments and tendons can be painfully stretched or torn, resulting in a sprain. These observations thus lay a conducive atmosphere for an appraisal of spatially coordinated behaviour in human beings.

C. Spatially coordinated behaviour in human beings

This is construed as the development and maintenance of a repertoire of response patterns which are moulded and conditioned by the spatial characteristics of the body and physical work in such a way that objectives may be rapidly and accurately achieved.

The location of the hands when performing a task can be almost anywhere within the forward or sideways reach, while the worker is obliged both to bend and to twist in order to reach, making it clear that strength is affected by body posture (Grieve, 1979; Grieve, 1984; Chaffin and Andersson, 1984; Haslegrave et al., 1988 and Ayoub and Mittal, 1989). A kinematic arm for recording and computing such displacements was devised by Belli et al., (1992), while Jager and Luttman, in the same year (1992), report having used the trajectories of the body segments and the load.

Spatial behaviour in human beings is conditioned by : a) internal contraints of the body, that is, the way in which human body is constructed and (b) nature of the physical world - gravity, work space dimension and the like. These constraints are defined in physical, anatomical or physiological terms. Each joint has a limited direction, and range of movement and every movement is articulated by contraction in particular muscles, whose responses are controlled mainly by myogenic reflexes. The second category enlists the postural reflexes and reafference (consequences of self produced movement).

1. Internal constraints : Physiological traits

a. Body dimensions : Anthropometry and the closely related field of biomechanics deal with the measurement of the physical features and the functions of the body including linear dimensions, weight, volume, range of movement and the like, which in general, fall into two classes, structural and functional dimensions (Mc Cormick, 1976) where, the former are taken with the body of the subject in fixed (static) standardized positions and the latter from body positions that result from motion. The central postulate of the emphasis on use of functional dimensions relates to the fact that in performing physical functions, the individual body members normally do not operate independently, but rather in concert. For instance, the practical limit of arm reach is not the sole consequence of arm length, but is also affected in part by shoulder movement, partial trunk rotation, possible bending of the back, and the function that is to be performed by the hand. Hence it is felt imperative to study posture targetting of all possible activities.

b. Movement traits: As pointed out by Harrell (1964) the concept of movement traits of individuals as a well-known phenomenon,considered differences in physique, posture, poise and movements with hands and legs. Certain of the movements which arms,legs and other body members are capable of performing can be considered as basic. Some of these with their associated biomechanics jargon are flexion, extension, adduction, abduction,medial/lateral rotation,and pronation/supination (Inglis, 1974 and Ganguli, 1982).

Among these the first two describe functioning of muscle while others indicate direction of movements relative to the body. Nevertheless, all need coordinated action of various nerves, muscles and joints (Radhakrishnan and Naga Ravindra, 1989). However, in performing specific activities as in work, the movements of the body members can be described in more operational terms like positioning, continuous, manipulative, repetitive, sequential or static movements (Mc Cormick, 1976).

c. Posture : This is determined by the degree of distribution of muscle tone and the basis of movement, since all movements start from and end in a posture. Omino and Hayashi (1992) define dynamic posture as one in motion, in action or in preparation for action. Bhasin et al., (1989) state that posture affects the ability of a person to do work and the duration for which it can be sustained without fatigue and therefore warn avoidance of awkward biomechanical posture.

As long as the balance of head over chest and chest over pelvis is maintained at work, a minimum of muscular effort and ligamentous strain is required to hold the body upright. If working position requires the head or trunk to bend forward, the ligaments and tendons undergo strain because of dysfunction of natural balance. To alleviate this, Swanson (1981) stresses on keeping one's body aligned so as to minimize energy consumption. The decrease in knee bend and the increase in ankle bend while sitting or squatting compress the blood vessels and nerves of the posterior side of the leg. The pressure on these vessels leads to increased HR.

A basic premise of the analysis by Dhesi et al., (1975), points fundamentally that the activity in itself may not be strenuous, but the distorted posture may cause not only discomfort but also bring about some adverse changes in the body. Sen and Pal (1989) have reached a similar conclusion while stating that postural stress, caused by bad working postures, leads to discomforts, musculo-skeletal disorders and fall of productivity. Unsupported sitting resulting in disc pressures almost 40 per cent greater than during standing work was indeed reported by Nachemson (1981). A link between local muscular strain during work involving disorders of the neck, shoulder and back have also been described (Allander, 1974; Maeda, 1977; Bjelle et al., 1979; Hagberg, 1982; Kvarnstrom, 1983, and Westgaard and Aaras, 1984). Kuorinka and Viikari - Juntara (1982) have identified that the postural demands of the job place these regions in an unfavourble position and become an important factor in the development of these problems. Nickell and Dorsey (1991) consider a good sitting posture as one in which the line of gravity falls through the middle of the shoulder, hip and seat bones. Ironically homemakers forget to maintain good posture while doing domestic chores without relating the consequences to their physiology. In free positions where the centre of gravity of the limbs and/or trunk is shifted from a balanced position, activity in counteracting muscle groups must compensate; this increases the load on the muscles. The slow muscles respond with tetanic contractions even if the discharge frequency in their motoneurons is low; hence the blood flow may be obstructed, causing local fatigue. It is an interesting finding, report Astrand and Rodahl (1977) that during activity with forward flexion of the spinal column (as in floor mopping) there is a marked muscular activity until flexion is extreme, at which time the ligamentory structures assume the load and discharge from the trunk muscle ceases. When Chahal, (1972) and Dhesi (1973) have claimed that HR increases while working in the sitting posture, Jain's (1973) studies confirmed that the sitting-cum-bending position demands maximum energy. Hanson and Jones (1970) report that the HR rate differed significantly among many of the postures but not between the conditions of the task. Since working posture was known to affect the physical costs of work, photographic techniques were developed for objectively measuring the amount of postural deviation during work.

d. Range of movement: In most instances sequential movements as in mopping the floor, are of the same general kind, varying only in some differentiating features. However, a pot pourri of types of movements may occur in sequence. A review of research has led Schnappe (1965) to conclude that travel time of a body member (hand or feet) is in fact influenced by the manipulative activities of the terminals of the travel movement,and that both these are influenced by perceptional factors because they move from one place to another in a sequence.

Energy costs are related to the rate, pace and the type of activity. There is evidence that the optimum varies for different age groups (Salvendy and Pilitsis,1971) and for individuals, and that individuals seem to be able to determine the pace that is most 'natural' for themselves, which tends to be the one that involves the minimum energy expenditure for each cycle (Corlett and Mahadeva, 1970).

Momentum is the force which the muscles must overcome when work is performed with sudden stops or sharp changes in direction or circular motions; when they are practical, avoidance of unnecessary use of muscular force to overcome momentum is suggested. Since speed is one component of momentum, slow circular motions require less muscular force than quick jerky ones.

2. External constraints : As an external constraint cultural aspects of the environment include social organization and attitudes, crowding, habitual level of physical activity, gravity and invention and technology (Hildes, 1970). The two major ones are :

a. Gravity : The upright position is maintained by muscular activity against the force of gravity. In the erect posture the line of gravity runs in the midline through (i) the mastoid processes (ii) a joint just in front of the shoulder joints (iii) the hip joints (iv) a joint just in front of the centre of the knee joints, and (v) a joint (3-7 cm) in front of the ankle joint. None of the joints engaged in the erect position is moved to the extreme of their mobility. Further the free normal posture is characterized by a 'postural sway', so that the centre of gravity varies with respect to its projection on the ground with a frequency of 5-6 cycles per minute.

One is so used to living in an environment having a constant acceleration of 1g that one often forgets how much man's physiology and structure is predicted by it (Ruffell - Smith, 1967). Our scientific approach to a balanced posture is by carrying each body part in such a position that it balances as securely as possible on the part below, which acts as its base of support. When any part projects out of line and is totally or partially unsupported at its base, gravity becomes a force to pull the part further out of line and this pull must be resisted by the ligaments and muscles which hold the part of the body as in squatting while mopping. To maintain total body balance with a minimum expenditure of energy it is necessary to co-operate with the pull of gravity and to work with gravity and not against it (Kaur and Sharma, 1987).

b. Work space dimensions: The importance of a safe physical environment on worker productivity cannot be overemphasized (Anton, 1979). There is an increasing awareness of architectural design on the behaviour and reactions and attitudes of people. The design and arrangement of rooms, the related facilities and furnishings define the physical space within which people live and distinctly affect their behaviour, comfort, emotions and subjective reactions and have a say on their productivity (Wools and Canter, 1970).

Steidl (1972), to rate the housing and equipment factors that homemakers perceived as difficult, separated them into the so-called 'high-cognitive' and 'low-cognitive' tasks. Becker's (1974) assays on multifamily housing points to the tendency of homemakers' satisfaction to be greater with larger rooms. From a physiological viewpoint Goel's (1974) research findings focus on a decrease in heart rate with the increase in working space and vice versa which are but reflections of one's productive capacity.

D. Productive capacity / performance of individuals

The immediate outputs of human activity in most job situations include the execution of physical responses or communications, which accomplish some desired objective. One of the body functions essential for good health is one's capacity for physical productivity. It is dependent upon a variety of functions. A literature search has revealed Noder's (1983) opinion that the productive capacity and vitality are not absolute quantities, but are relative as far as environmental condition requirements are concerned. Sanchez and Grieve (1992) later contemplate the issue that strength in one working posture can be used to predict strength in another. In a very broad sense, physical performance is determined by the individual's capacity for energy output, neuromuscular function and psychological factors (motivation).

1. Energy output: Every dynamic activity is combined with the use of energy, where the requirements adjust themselves to the magnitude of the work and are met through the chemical conversion of energy - rich substances with the

help of oxygen; hence the higher the O_2 uptake, the higher the energy output. The limits of productivity, however, depend upon, the number of muscle fibres involved, the extent of glycogen supply, available oxygen and thus upon the productive capacity of the circulatory system.

When human physical activity in work is potentially dangerous to health and safety, some modification of the work is in order, whether by appropriate redesign of the equipment and work space, by modification of methods, or by reduction of work period or work pace (Mc Cormick, 1976), because the energy cost for certain types of work can vary with the manner in which the work is carried out. The differential cost of methods of performing an activity was studied by Datta and Ramanathan (1971) on the basis of oxygen requirements. They have reported on the significance of maintaining good postural balance. A given level of energy consumption is much more strenuous if it is achieved by using only a few muscles than if many others are employed. These facts focus light on two important aspects:

a. Maximum oxygen (O_2) uptake or Maximal aerobic power: The demand on the O_2 transporting functions varies with the size of the active muscles. It is obvious that the individual's maximal aerobic power plays a decisive role in his work capacity. The individual with a maximal uptake of $4.l.min^{-1}$ has a satisfactory safety margin if the task demands $2. l.min^{-1}$. Domestic work involves many tasks which may be classified as fairly heavy physical work.

b. Oxygen debt: There is always an oxygen debt after muscular work, which is the O_2 uptake of the resting subject, an excess of the O_2 uptake calculated for the same period of rest but not preceded by activity (Fellman et al., 1986). This is making up for shortage of oxygen by breathing more heavily. Astrand and Rodahl (1977) state that if measured after a steady state exercise it is of the same magnitude whether the work time is ten minutes or longer. Grandjean, (1985) calls this as 'out of breath'. This arises from previous consumption of energy. It is computed by adding the sequential differences between actual Vo_2 measured during recovery phase and steady state Vo_2, which corresponds to the resting Vo_2.

2. Neuromuscular function : Muscular exercise is a common place occurrence and yet the extent to which it alters the various activities of the body is seldom realised. Muscles are very special tissues appreciates Inglis, (1974) because they are capable of contracting when stimulated (Nayar, 1976), thereby exerting a force on its tendons. If the force is sufficient, shortening occurs and the two sets of filaments slide past each other, explains Murali, (1982). This muscle is devoted to developing mechanical force and work (Nair, 1979). A muscle that directly causes a motion is called an agonist, and other muscles that assist are synergists. The opposing muscles are antagonists (Basar, 1976). The intended muscle uses, opine Jagar and Luttman (1992) are calculated on the basis of the least possible antagonistic activity of the muscles.

Stretching is the basic reflex in postural control. Afferent impulses are evoked, and the muscle contracts so that the pull of gravity is counter balanced. According to Bhatnagar and Babbar (1982), the skeletal muscles are made up of individual muscle fibres, formed by a number of thin filaments (fibrils) and are arranged in parallels between the tendinous ends. Here again the contractile element of the cell is further differentiated as the 'myofibrils' which, when activated, shorten and stretch the elastic components. If the muscle varies its length when activated, the contraction is isotonic or dynamic. Those controlling the movements of limbs and other movable structures are the voluntary or skeletal muscles (Davson, 1970). The flexors and extensor muscles are the chief agents of posture maintenance. The exterior muscles also activate the body in opposition to gravity; so they are also called antigravity muscles. To enable these functions the muscles are normally set in a state of slight tension, called 'muscle tone' (Anand, 1976), while activity in a muscle is accompanied by the production of an electric current called 'action potential'.

a. Work limits of local muscle groups: Active movements are possible with the help of the muscles and tendons, the energy required for the movement is produced by the muscles and relayed by the two tendons over two bones. The tendons relay the displacement forces exerted by the muscles directly to the bones and are therefore tightly fused to them. The maximum pull a muscle can generate (force-length reaction) is determined in part by its length with respect to its resting length. Generally as muscles shorten they get weaker.

Energy requirements are dictated by the velocity of muscle shortening in addition to the tension generated and energy of activation (Bogert et al., 1973; Gaesser and Brooks, 1975; Donovan and Brooks, 1977 and Powers et al., 1984). Although overall energy cost of an activity might be within reasonable limits, it is of course possible for individual muscles or muscle groups to wear out with excessive use. If the rate of contraction of a muscle group is low enough, it can function almost indefinitely, but at higher rates it can become completely fatigued and cease to function at all.

Actually, active function in every movement is performed exclusively by the muscles consisting of the myofibrils with their cells. All such fibres are almost equal in size. The thicker the muscle, the greater is the absolute strength, but the extent of its maximum constriction is determined by its length. In addition they are elastic and flexible, the qualities having to do with the speed of constriction. This phenomenon is called local muscle endurance (Noder, 1983). But muscle contraction gradually decreases mechanical force. Duchateau and Hainaut (1985) refer to this as 'fatigue', which is one of the most intriguing observations associated with contractile activity.

Fatigue : It was argued that fatigue is peripheral during sustained voluntary contractions and resides within muscle cells. This point was questioned by Stephens and Taylor (1972) and more recently by Bigland - Ritchie et al., (1978). Prasad and Bannerjee (1985) also consider fatigue to be caused by physical strain. Fatigue is described as a sort of 'negative appetite for activity' or 'activity decrement' defined as a reduced capacity for further work as a consequence of previous activity. Grandjean, (1985) distinguished fatigue under both subjective feelings of tiredness during prolonged work and objectively measurable impairment in performance also resulting in slower movements. To support the assumption Deacon and Firebaugh (1981) highlight the length of work period and postural position as correlates to fatigue. Moreover, continuous expenditure of over four calories per minute, they say, produces fatigue. Kaur and Sharma (1987) opine that in such instances the normal resources of energy are exhausted and the activity consumes more energy than is made available.

Mathiassen and Winkel (1992) assume that even an exposure inducing short-term fatigue will eventually lead to the development of disorders. Sustained muscular contraction also leads to voluntary fatigue. But muscle tone helps to keep the structures to which the muscles are attached on their correct position, thus alleviating fatigue (Wright, 1971). So fatigue will result if a muscle is put to strain because of bad posture.

Common fatigue symptoms are weariness, somnolence, faintness, and distaste for work (subjective) or sluggish thinking, reduced alertness, poor or slow perception, unwillingness to work and decline in both bodily and mental performance (objective). Psychosomatic complaints like headache, giddiness, loss of sleep, irregular heart beat, sudden sweating fits, loss of appetite and digestive troubles in the long run are also reported.

According to De Cenzo and Robbins (1993) the personal indicators of fatigue as reflected by the following are :

Health: Exhaustion, headache, loss of sleep, BP, diabetes, asthma and muscular pain particularly on the lower back

Behaviour:Moods, hyperactivity and increased consumption of caffeine

Emotion : Paranoia, depression, increased anger and tension

Attitude: Boredom, cynicism, hopelessness

Value : Dramatic changes in values and beliefs

These observations and conclusions stress the need for a literature study to project the probable repercussions to the physiology of individuals consequent to indiscriminate use of muscles.

* Physiological reflections consequent upon indiscreet use of muscles :
The primary area of physiological and biomechanical concern has been the low back, particularly the discs of the lumbar spine (Kroemer, 1992). It is also proved that the vertebral column changes over from a lordosis to either a straight or a kyphotic shape, when the tissues are strained beyond their physiological limit and precipitate injury, report Adams and Hutton (1986).

Andersson (1981) remarks that almost 80 per cent of the population both elderly and young adults, suffer from low back pain during their life time. Among those under age 45, injury to the lower back is estimated to be the number one disabling injury (Bigos et al., 1986). Marras and Mirka (1992) hypothesize that increases in back motion characteristics increase the risk of lower back disability. The pressure in the disc amounts to about 1.5 times the vertical force exerted upon it by the overlying vertebrae. The maintenance of working position is sometimes the most fatiguing aspect of the job. The worker's body constitutes the most important item in the household work. A secure foundation for the feet during motion is of vital importance, since it is a common experience for lower back ache to occur during sudden bodily movement associated with slipping of the foot-hold. This is true as far as the conventional method of mopping in the Indian household goes. It is postulated that it is because of insufficient time for reflex contraction of the trunk muscles to occur, thus leaving the spinal column vulnerable. Unnatural motion under such stress precipitates an injury. So, Kumar and Mital (1992) suggest considering metabolic cost of tasks as an important aspect of safety of the back.

Next, the trunk muscles have a great role to play in the support of the spine. Well developed trunk muscles, including the abdominal muscles, play an important role in sparing the spine and thus avoiding strain and damage. While flabby abdominal muscles expose the spine to injurious stress, well-developed muscles on the other hand, are an important protective device. 'Dyspnea' - a condition of difficult, laboured, uncomfortable breathing - is projected by Astrand and Rodahl (1977) as a feeling of distress during muscular work. The explanation lies, of course in that the impulses from muscle spindles and thoracic point receptors appear to give to conscious awareness and distress - 'a question of length/tension'. Accumulation of metabolites in the working muscles and in the blood results because the 0_2 transport is inadequate to satisfy the requirement. This distress subsides eventually since one experiences a 'second wind', respiration increases and adjusts to the requirement. Meanwhile the respiratory muscles work anaerobically during the initial phases of work which develop a stitch on the side due to hypoxia in the diaphragm. As blood supply improves the pain disappears.

The human suffering due to low back pain as a situation analysis has been conducted by many like Frymoyer et al., (1980), Kelsey and White (1980), Spengler et al, (1984) and Kumar (1987). A wide variety of approaches have been developed in an effort to control the low back pain problems. Some investigators had used epidemiological studies (Liles, 1986; Porter, 1987 and Kumar and Garand, 1991) some, biomechanical objectives (Hansson et al., 1980 and Hutton and Adams, 1982), spinal shrinkage (Corlett et al., 1987) and spinal compression (Schultz and Andersson, 1981; Frievalds et al., 1984 and Leskinen, 1988). Still others have explored the physiological costs involved in occupational tasks (Kumar, 1984; Mital, 1984 and Mital and Faard, 1986) and even psychophysical studies (Snook, 1978; Mital, 1985 and Mital, 1987).

In Chavalitsakulchai and Shahnavazs' (1991) study the perceived lower limb muscular fatigue/discomfort was due to the working posture and repetitive movements which subsequently led to muscle stiffness and later a constant tenderness in the different regions of the body. Epidemiological studies indicate that bending and twisting are factors associated with an increased risk of low back pain. Ferguson et al., (1992) have quantified free dynamic back motion characteristics necessary to perform typical tasks. No wonder Rappaport (1970) and Ronco (1972) had stressed the profound need for the application of human factors technology to biomedical problems.

These being the major causes for fatigue, Agarwal and Natu (1994) describe fatigue as the physical and psychological condition characterized by a pause in activity, wherein the internal factors wish to stop but the external circumstances demand it otherwise. Therefore, one needs to analyse such psychological conditions too, which influence muscle action.

* Psychological reciprocation to work: How are matter, quality, action, generic and specific activities concerned with the science of life? questioned Charaka. The answer lay in their equilibrium or 'Dhatusamya' which is the basis of good health recounts Valiathan (1994) from Charaka-Samhita-Sutra (1992). Any disturbance in the Dhatusamya, he adds, leads to disease. Body and mind are the stages for interplay of disease and health, misery and happiness. To prove the validity of Charaka's statement the early works of Ikai and Steinhaus (1961) have strongly favoured the concept that in every voluntarily executed, all-out maximal effort, psychological rather than physiological factors determined the limits of performance. Prasad and Bannerjee (1985) also observe an uncomfortable psychological environment to divert the attention and reduce the alertness of the mind. Increase in the secretion of adrenalin, responsible for all kinds of stress - physical, psychical and mental - also is a causal factor (Frankenhaeuser et al., 1971).

Sandhu (1972) opines that the homemaker's attitude towards particular tasks is associated with the time spent on it. Liked activities reportedly took less time than the disliked ones. It has also been postulated, though not proved,that they tend to expend more energy on things they enjoy more, drawing upon their psychological energy. Mc Cormick's

(1974) observations have revealed individual differences in value systems, indicating that some people do not like 'enlarged jobs', that is those which require skill. All these highlight the psychical state of the mind of homemakers. The urge to perform work well is called 'motivation or drive' - the neural process which impels the individual to certain actions in pursuit of specific objectives. But Astrand and Rodahl (1977) reason out that emotion influences one's HR at rest and during submaximal work, but the circulatory parameters usually are not affected by psychological factors when the work becomes strenuous. Hence such kind of feeling associated with one's psychology cannot be called fatigue but as any one of the phenomena like monotony, boredom, frustration or stress.

*Monotony: is a characteristic not of a particular job, but of the relationship between the job and the worker at a particular time, the primary causes being repetition or lack of variety and unfavourable situation but not emotional dislike.

*Boredom: The reaction of an individual to monotony is called boredom - characterized by depression and a desire for change of activity tinged with attitude and emotional distaste. Boredom occurs when an individual uses energy for actions that are repetitive, or are not satisfactory (Swanson, 1981).

*Frustration: If the goal is not reached, the individual becomes emotionally uneasy, antagonistic and will show signs of frustration resulting in reduction of psychological efficiency (Rudrabasavaraj, 1980).

* Stress and strain: Stress refers to any aspect of human activity or the environment acting upon the individual which results in some undesirable cost to, or reaction upon the individual (Singleton, 1971). Strain in turn, is the 'cost' or effect of stress on the individual.

These observations portray fatigue as a desire for a change of activity rather than for relief from work altogether; it forestalls a decline in quantity of work for a given level of effort. The physiological and psychological effects of a given calorie output is, therefore, determined by the homemaker's maximal aerobic power, size of the engaged muscle mass, posture, whether work is intermittent at high rate or continuous at a lower intensity, and by environmental conditions. Even if her output is relatively low, a housewife may strain herself as much during domestic work opine Astrand and Rodahl (1977) as a lumbar jack, a farmer, or a miner whose work requires a higher calorie output.

Physiological responses to muscular activity: As stated earlier fatigue is a very complex conception especially since activity loads respiration, circulation as well as the neuromuscular function. The disposition to subdue the feelings of fatigue is individually very different because one needs to analyse whether it is central or peripheral in nature. The following discussion is therefore, limited to the 'physiological responses' to muscle in action because they may serve to quantify the level of activation (Barnes, 1980).

During effort, a muscle increases its need for blood several fold, and to supply this the most important adaptations of the blood system are increased pumping of the heart (accelerated heart beat), blood pressure (BP) and enlargement of the blood vessels that lead to the muscles (Green, 1972 and Chatterjee, 1981). The circulation in a muscle is estimated to be 4 ml/min/100g muscle during rest and to increase to 80 ml/min/100g muscle during moderate work (Grandjean, 1985). So, for contraction the muscle consumes energy. Dynamic contraction leads to swelling of the active muscles which become hard. This may raise the arterial BP to its peak (upto 200 Hg), thereby, completely or partly blocking the blood flow through the muscles. The time for maintained tension in a maximal static effort is only a few seconds. Therefore, the body mechanism initiates responses such as increased sweating and vasodilatation of blood vessels (Raja et al., 1989).

Since hemodynamics is closely related to the overall metabolic rate, an evaluation of daily life responses must include measurements of O_2

uptake of the various work tasks, reviews Asmussen, (1968) about which, Bhatnagar and Babbar (1982) justify stating that the requirement for a given act is the sum total of 0_2 necessary for the performance of the act and for subsequent recovery. A given task's requirement for 0_2 diminishes with effective use of muscles and elimination of extra movements.

According to Thews (1986) the 0_2 supply situation of the working muscle is comparable to the condition of 0_2 uptake in the lung since the maximal 0_2 consumption $V0_{2(max)}$ is limited essentially by the 0_2 transport system (Di Prampero, 1986). However Kaijser's (1970) validation studies have proved interplay of several other factors. It has also been recognized that 0_2 uptake increases linearly with the work load (Bell et al., 1970 and Arieli et al., 1985) and a given rate of work has a profound effect on 0_2 uptake.

In arm exercise, the $V0_{2(max)}$ uptake is about 70 per cent of what is attained in leg exercise. Consequently, arterial BP and HR rate also are increased leading to heavier load on the heart when the individual is apt to hold his breath. The demand on the 0_2 transporting functions varies with the size of the active muscles. It was found that work with arms plus legs curtails further increase in 0_2 uptake and cardiac output. Based on these though the pumping capacity of the heart is projected as a limiting factor, there are observations that speak against the possibility. In coordinated efforts of arms and legs at various work periods, the work time is supposedly prolonged without apparent increase in 0_2 uptake. Evidently the individual will be able to tolerate a prolongation of the work period when a larger mass of skeletal muscle is activated. At this juncture it is important to project that this aspect of the physiological reaction still is in literature form. South Indian homemakers should go a long way to realize the constraint they are indicting on their physiology by adopting conventional methods of mopping by squatting and moving on the floor or by bending when the same activity can be effortlessly carried out using a long manual mopper. An incremental factor is that BP rise is reportedly less in exercise of speed than in activity of strength. By using a mopper the homemaker can successfully achieve speed too, thereby preventing increase in BP. Moreover, arterial BP rises to significantly higher levels in tasks involving arms than in those involving the use of legs.

Though ventilation increases relatively rectilinearly with work, when it becomes strenuous, the increase becomes relatively steeper with factors like age and $Vo_{2(max)}$ (Babsky and Zubkov, 1970, Robinson et al., 1973, Robinson, et al, 1976; Montoye ,1982; Patrick et al., 1983; Pimental et al., 1984; Svedenhag et al., 1984 and Yerg et al., 1985). Hesser and Lind (1984) have analysed the interdependence of respiratory drive and ventilation during physical activity while performing on a cycle ergometer. These aspects, therefore, should be made known to homemakers so as to safeguard their physiology by adopting appropriate postures and shun such baseless beliefs as 'used-to' postures and conventional methods. They should also be enlightened on how energy is used up while performing activities.

E. Energy - the body's potential for work

The principal function of a living organism is the exchange of matter and energy, a complex of chemical and physical change and of transformations of matter and energy that take place constantly and continuously. Energy is the power, capacity and body's potential for work. It is the underlying cause of all vital phenomena and an essential element of almost all human activities (Gabor et al., 1978). According to Swaminathan (1983) energy is required for the functioning of the cells of different tissues during rest and also for doing physical work. The normal healthy state of body depends upon proper thermodynamic balance between input of energy, work done and energy dissipated or stored in the body. A sound body contains a sound mind (Yogacharya, 1986).

Energy is defined as an inherent or internal power and a capacity for action and good health is the prerequisite to abundant energy. It is intangible. Evidences of its existence can be demonstrated by the tasks accomplished, the activities undertaken and the speed at which these are completed. Hence research in the field of human energy is recommended. It measures energy expenditure of the total body activity - the rate of oxidation in the body as a whole - but not fatigue.

For grouping people based on physical activity for epidemiological investigations Buskirk et al., (1971) regard use of job analysis which provide a three category clarification - sedentary, moderately active and active. Individual variation in the amount of energy spent in performing a given task or activity may be considerable because total energy expenditure shows high correlation with body weight and LBM. Over weight women tend to spend more energy than normal weight women (Bandini et al., 1990 and Welle et al., 1992). Perhaps Wright's (1971) recommendations on assessment of the caloric cost of activity either by direct measurement of oxygen or from published tables spring from this. However, there is paucity of information on the norms of patterns of energy costs of household work. A resume of methods used and research findings on energy costs of household activities provide generalizations on methods and conditions of work, the energy costs of different activities and the use of body to help in developing effective patterns of work. In order to arrive at such patterns of energy costs, the biomechanics of motion and muscular action as consumers of energy need to be analysed through some methods of measurement.

1. Measurement of general physiological demands: Durnin (1989) points to the use of pedometers, accelerometers, actometers, video-recording and heart rate recording as a few direct objective methods to measure activity. Four groups had successfully used actometers, to record acceleration and intensity of movement as indirect estimates of energy expenditure (Saris and Binkhorst, 1977; La Porte, et al., 1979; Tryon, 1987 and Avons, et al., 1988).

a. Heart rate: Agan et al., (1972) call extra heart beats as a measurement of work cost of an activity. Dauncey and James (1979) tried assessment of HR method for determining energy expenditure in man using whole body calorimeter, while Spurr et al., (1988) and Ceesay et al., (1989) have compared the estimates using bicycle ergometry. Spurr and Reina (1989) have suggested finding minute-by-minute measurement of HR as useful for obtaining the activity pattern of individuals. One such approach was described by Acheson et al., (1980) where they measured the 24-hour energy expenditure by accumulation of heart rate (f_H) for this period for which Tremblay and Bouchard (1987) recommend measurement of Vo_2 and f_H while performing activities. Evaluation of the HR method to determine the daily energy expenditure in juvenile diabetics was done by Warnold and Lenner (1977).

b. Oxygen consumption: To determine the energy cost of activities, Torun (1989) reports on extensive use of open-circuit indirect calorimetry with portable respirometers (Kofranyi Michaelis type), collection of exhaled gas in a Douglas bag, individual HR to oxygen consumption calibrations and integrating motor pneumotachograph by various researchers. Weismann et al., (1985) state that measurements of 0_2 consumption and CO_2 production can be used to calculate energy expenditure. A recent technique is the use of doubly-labelled water system to find out subsequent 0_2 consumption and energy expenditure using a standard equation (Schoeller and Van Santen, 1982; Coward et al., 1984, Klein et al., 1984; Schoeller et al., 1986 and Schoeller, 1988). Gudinchet et al., (1982), Reichman et al., (1983) and Puttet et al., (1984) have gone a step further by using published information on respiratory quotient to calculate energy expenditure from CO_2 production rate determined by the isotope method. Christensen et al., (1983) have evaluated energy expenditure estimated based on 0_2 consumption/heart rate curve. Since the two are directly related Grandjean (1985) also is of the same opinion when he suggests indirect measurement of energy from 0_2 uptake. These facts establish the validity of using 0_2 uptake as a basis for measuring energy expenditure. Nevertheless, it should be borne in mind that the O_2 uptake measured during physical activity of high intensity does not represent the total energy cost of that activity if anaerobic processes contribute materially to the total energy metabolism. Following the cessation of the work in such cases there is a 'repayment' of the 'O_2 debt' incurred during the work period, and this amount of O_2 should really be added to the O_2 uptake measured during the activity to arrive at the total cost of that activity. Therefore, the standard method most commonly used for the determination of O_2 uptake during physical work especially is the bicycle ergometer (Lind and Hesser, 1984) and treadmill. While using these methods the parameters studied are to be transmitted, recorded and displayed. These methods are generally telemetered for ease in comprehension. Hence as a rule of thumb, telemetry is coupled with ergometry or treadmill.

c.Telemetry: There are many instances where (Cromwell, et al., 1991) it is necessary to monitor physiological events from a distance. This is where existing methods of measuring physiological variables are adapted to a method of transmission of resulting data. This is the branch of biomedical instrumentation known as biomedical telemetry or biotelemetry - the measurement of biological parameters over a distance. Measurements can be applied to two categories - (i) bioelectric variables like EMG and ECG and (ii) physiological variables that require transducers, like HR, BP and temperature. For the same, Tiwari et al., (1976) had used a high frequency oscillator outside the body as an external circuit.

Currently, the most widespread use of biotelemetry for bio-electric potential is in the transmission of the electrocardiogram (ECG) which is useful and adopted in human performance laboratories. (Berg, 1971; Bradfield 1971; Gandra and Bradfield, 1971; Heywood and Latham, 1971; Spurr et al., 1975, Spady, 1980 and Spurr et al., 1986).

d. Local muscular work: One of the measures of 'local' muscular work is electromyographic recording. Cromwell et al., (1991) call this as the bioelectric potentials associated with muscle activity. These are linked tracings of the electrical impulses that occur during work, and provide estimates of the magnitude of voluntary muscular activity. These potentials may be measured at the surface of the body near a muscle of interest or directly from the muscle by using needle electrodes. Khalil (1973) through his studies provided some evidence regarding its suitability for both static and dynamic muscular exertion, and evaluation of the expenditure of effort on work activities. Examples of the use of EMG technique have been found in the research publications of Agarwal and Gottlieb, 1970, Jain and Dasgupta, 1976 and Yates and Karwowski, 1992. Burke and Edgertons' (1975) research findings using EMG showed that muscles with predominantly ST fibres fatigue only with difficulty. Clamann and Broecker (1979) accord the age of the muscle as affecting its behaviour in terms of exertion and fatigue. For the calculation of unknown forces Scholten and Rohrle (1978) had used EMG while,Seireg and Arvikar (1973) and Arcan et al., (1977) devised mathematical models. Recently, there has been numerous studies employing surface EMG to assess skeletal muscular fatigue (Komi and Tesch, 1979; Bigland-Ritchie et al., 1981; Petrofsky and Phillips, 1984 and Moritani et al., 1985). Studies of Moritani (1981 and 1982) indicated recruitment of additional motor units to compensate for the loss of contractility of fatigued units. Kwanty, et al.,(1970) suggest that the RMS value of suitably filtered EMG is proportional to muscle tension. Jain and Nair, (1976), Haridasan et al., (1978), Kumar and Davis, (1983), Andersson and Ortengren (1984) and Granstsram, et al., (1985), all have speculated on the use of EMG to determine muscle activity during standing or sitting postures and tasks.

e. Body moments - angles of body bend : Analysis of the quantity of energy used in household tasks early indicated that the part/parts of the body used affected energy output. Their weight was projected as a decisive factor by Gross et al., (1980), for, moving a body part required increased energy in proportion to increased weight. Later research concentrated even more definitely on energy costs of specific body positions and movements, rather than upon total costs. Bending the body was found to be more costly in energy than reaching up with the arms because of moving more of the body weight in doing so. Dhesi and Chahal (1975) have reviewed the use of angles of body bend as measures to determine the effect of postural changes on human body. A technique for numerically defining a posture was proposed by Priel (1974). According to Dhesi and Firebaugh (1973) measurement of angles of body position make it possible to analyse ill-defined household tasks in areas with limited apparatus and laboratories. Knowles in 1946 used motion pictures and made frame-by-frame measurements of the angle of trunk bend, quote Steidl and Bratton (1980).

f. Postural analysis for shift in centre of gravity: Inadequate postures, when adopted for long, cause bodily damage and ill-health (Van Wely, 1970 and Grandjean and Hunting, 1977). Sen and Pal (1989) have reviewed the methods developed to record postures like the Benesh Movement Notation (Benesh and Mc Guiness, 1974), OWAS (Karhu, et al., 1977) and posture targetting (Corlett et al., 1979). Subsequent to such a literature search they have developed a new set for posture targetting - a technique for recording working postures - which is inexpensive and simple with provision for sequence of postures, movements of different body segments at different angles and postural strain on each body segment.

The body is kept in the erect posture in overcoming gravity by the muscle actions, and the limbs are moved in a coordinated fashion making locomotion possible. The muscles are in turn (Berme, 1980) controlled by the neuromuscular signals. It has been shown that the tibialis anterior muscle is almost silent in EMG recording in normal standing. The activity of the muscle during the squatting posture (with feet flat on the floor) also has been reported earlier to relate the function of the reference muscle in squatting through EMG. Observations confirmed the correlation between the activity of the muscle and the shift in the centre of gravity of the body (Simard and Balakrishnan, 1971 and Natarajan et al., 1974).

These investigations stress the need to dogmatise the work ethos of Indian women in anticipation of an obviation of all apprehensions regarding their blind - fold acceptance of conventional dicta. Since an activity reflects forces and energies, the mechanical energy changes during activity can be studied. While Winter (1979) attempted modelization of the human body with rigid segments, Fukashiro et al., (1981) and Sakurai and Miyashita, (1985) used film or video analysis and Cavagna (1975) and Kram and Powell (1989) used accelerometer transducers or forceplates. These methods were also used in combination with physiological measurements (Luhtanen and Komi, 1980; Williams, 1985; Bobbert et al., 1986; Mero and Komi, 1986; Fukashiro and Komi, 1987 and Williams and Cavanagh, 1987).

The methods explained hitherto reiterate (or time and again stress) the need for understanding the relationship between the 'worker', the 'work' and the 'work environment' (Bogert, 1982). The raison d'etre behind this write up is that one's physical structure and movements, stance and other actions tend to increase or decrease one's energy expenditure and warrants a review on the ergonomics and ethos of work done in the household milieu.

F. Ergonomics and ethos of work done

Ergonomics is a study of the relationship between human beings and the working environment. Murrell, (1979) accords the term environment to have taken to cover not only the ambient environment, but also the tools and materials, methods of work and the organization. It is a subject, opine Mc Atamney and Corlett (1992), which looks at how things, jobs and environments are matched to people's sizes, strength, abilities and other human attributes. However, they add, there are many cultural influences which restrict the content or characteristics of jobs. So studying a task without looking at it from a person-centred-perspective, may be of an organizational or a cultural convention. The probability of missing many opportunities for improvement by being entangled in an inappropriate frame of reference would persist. Ergonomics, therefore, is not about forces and postures; it is about how all relevant factors would influence a person's ability to perform a job.

An essential part of ergonomic strategy is that it involves participatory ergonomics, especailly, in the process of improvements (Kogi, 1991). In this process different stages can be discerned, opine Noro and Imada (1991) and Vink and Kompier (1991), like initiation, problem identification, selection of solutions, implementation and evaluation. Berndsen, et al., (1991) state that to choose ergonomic solutions, tools also can be employed in addition to the work content and formulation of improvements. Tiwari (1994) advocates a system which provides opportunities for satisfying natural interests, developing mind and body, simultaneously, making use of personal traits and abilities for common good.

The status and role of women are conditioned by the society's organisation and ethics (Phadnis and Malani, 1978). In this context Varghese et al, (1994) focus upon values which are the ways behind one's actions. The homemaker's interest and desires together with her attitudinal patterns lead to the realization of values. Some such values related to homemaking tasks and the homemaker, 'the worker' - are work convenience, efficiency, economy, safety, physical health and achievement. One's goals and standards develop from such values.

Standard setting is the reconciliation of resources with demands. The resulting standards then represent the 'operational criteria'. They communicate the expected outcomes from the use of resources to accomplish goals. French (1990) calls this as job description which are statements of what activities are to be performed, describing what is considered acceptable and attainable performance on a particular job. Performance standards, therefore, make explicit the quantity and/or quality of performance expected on the basic task set forth in the job description.

Indian homemakers, especially, have set standards for household maintenance. Mopping the floor is a daily exercise performed in the conventional posture with set standards of performance and implied sentiments. As rightly pointed out by Kashiwazaki et al., (1986), due to few reliable methods to measure habitual physical activity, there is paucity of information in identifying and understanding such variation in habitual physical activity within a population even though the tenets of the scientific management approach have greatly influenced work method and production techniques.

1. Work simplification : techniques seek to discover and apply improved ways of doing work widely useful in conserving time, money and energy in all walks of life including management of the home. Nickell and Dorsey (1980) suggest changes in hand and body motion, in work and equipment and improvement in one's method of work to profoundly enhance one's productivity. It has been proved in biomechanical terms, that controlled arm movements that are primarily a pivoting of the elbow, with fairly nominal upperarm and shoulder action, tend to be more accurate and to take less time than those with a greater degree of upperarm and shoulder action. Since productivity is associated with task accomplishment and conservation of energy on the part of the homemaker, the quantity and accessibility to needed equipment also require special attention. In this connection Gross, et al., (1980) put forth suggestions for the effective use of muscles,taking advantage of momentum, considering the centre of gravity and strict elimination of unnecessary muscular movements as guiding principles. It calls for scientific management of job analysis identifying the one that is inefficient and effecting plausible improvements in the same.

* Tool and equipment engineering: The study of work methods has been extended to include this aspect too because they are an integral part of the work situation. The trend is to design tools and machinery which are more compatible with observed characteristics of the human beings who use them. Man has demonstrated amazing ingenuity in designing devices for accomplish-

ing things with less wear and tear upon himself. Such hand tools essentially are extensions of the upper extremities opines, Mc Cormick (1976).

Jones (1967) has classified household activities under manual system which is operator-directed and flexible involving one human factor with hand tools and aids as components. As a frame of reference it is suggested that virtually all the things they use and the environments in which they live and work be viewed in terms of their possible human factors or ergonomic implications. Human physical responses and activities, states Meister (1971), have implications for many aspects of human factors, such as: the design of control devices, hand tools, handling materials, work methods and procedures. Therefore, individual's anthropometric data can have a wide range of application in the design of physical equipments and facilities. The objectives of human factors are those of achieving functional effectiveness of whatever physical equipments/facilities they use and of maintaining or enhancing human welfare (health, safety and satisfaction) by appropriate design because the comfort, physical welfare and performance of people can be influenced for better or worse by the extent to which such facilities 'fit' people. Ultimately the central focus of ergonomics relates to the consideration of human beings in the design of the man-made objects, facilities or environments that people 'use' in the various aspects of their lives.

Ironically, none of the designs in household appliances are conceptualized focussing attention on such human factors. As Ashizawa et al., (1994) lament, despite the growing importance of both human interface design and number of working women, their working spaces and tools receive least consideration. Hertzberg (1972) suggests that determining body dimensions is of great importance to the design of both such physical facilities as well as objects. Work may be accomplished with increased ease and at higher standards by use of equipments because it enables individual to perform a job more easily and thoroughly and entice a few to undertake jobs that were not formerly done.

* Physical facilities: This aspect has gained impetus under scientific management ideas. Individual responses to housing and available space vary with backgrounds, preferences and values. When space is seen as adequate, there is an uncrowded feeling; conversely, psychological or physiological stress occurs. Human performance, which depends on the energy-yielding processes of the body concomitantly shows variation along with a change in the factor (Chandra et al., 1994). The household space use and equipment available affect household work. Perhaps the view point that city houses with limited space, use more hours in caring for the home sounds true.

By considering the application of anthropometric data to the design of physical facilities and objects one uses, it is obvious that such intrinsically interesting data play a live, active role in the real, dynamic world in which one lives and works. This will also help magnify the performer's operational criteria, performance standards held, adherence to work simplification principles, utilisation of tools and equipments and improvement of physical facilities. The ensuing section explains the "modus operandi" of the present study which aims at projecting the selected samples' 'status quo' related to the concerned study.

Design of the Study

III DESIGN OF THE STUDY

The art of homemaking lies in the effective use of energy, an intangible resource which is by far the most crucial of the resources to accomplish work. Human energy is dispensed during all homemaking tasks, may it be light or strenuous. But individual variation in the quantum of energy spent in performing a given task may be considerable.

Since performing household activities is a type of manual system using one's own physical energy as a power source involving posture,relevant information about human (homemakers) characteristics and behaviour needs to be elicited. Therefore research in this field is recommended. Bradfield (1971) and Wright (1971) have suggested one method - the activity questionnaire - schedule - to assess the energy expenditure of individuals. Another suggestion comes from Katch and Mc Ardle (1983) and Mclean and Tobin (1988) as estimation of extra heart beats which indicate directly the variation with activity level. Earlier Wolff (1970) has accredited measurement of heart rate using Telemetry SAMIS while exercising on a bicycle ergometer as the only socially acceptable device available for assessing energy expenditure. So an effort to bring out a data base of human factors in terms of energy consumption relating to selected household activities, thereby identifying the one that is most strenuous, has been attempted (Fig.1) through selection of two dependent variables namely;

A. Human criteria

B. Systems criteria

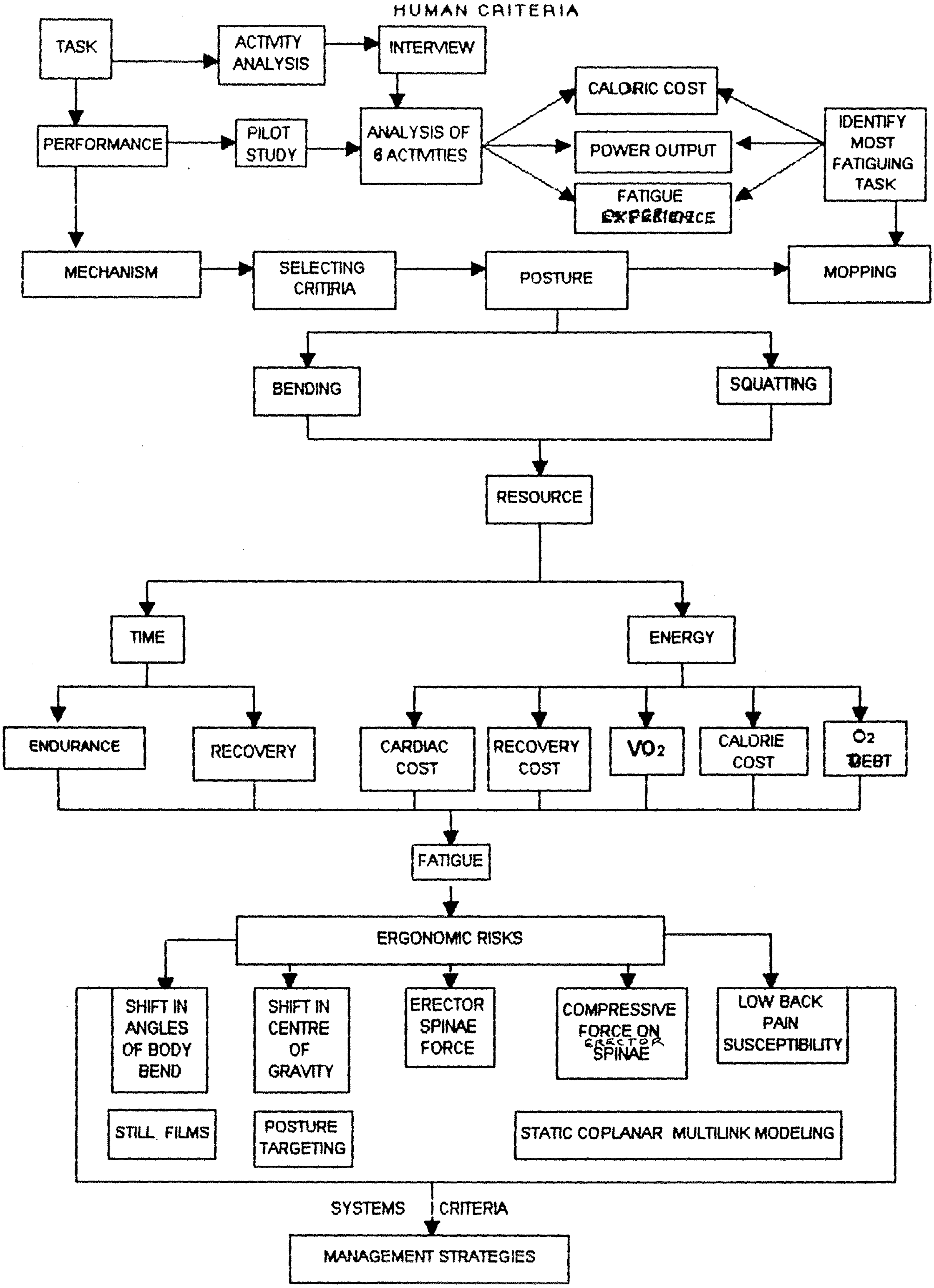

FIGURE.1 TAXONOMY OF THE DISSERTATION- HUMAN AND SYSTEMS CRITERIA

A. Human criteria

This covers relatively four different types of human criteria, namely;

1. Human performance measures
2. Physiological indices
3. Subjective responses
4. Accident frequency.

1.Human performance measures: It is considered in terms of various mental and motor activities, since performance is inextricably intertwined with the performance characteristics. This aspect satisfied the requirements of research - relevance and reliability - for choosing the topic through :

a. Situation analysis

b. Identification of tasks and techniques for detailed study

a. Situation analysis: Survey is a process of collecting data from existing units with no particular control over factors that may affect the population (Gupta, 1991). They are concerned with describing, recording, analysing and interpreting conditions that either exist or existed (Kothari, 1995). These facts motivated conduct of a survey to facilitate analysis of the situation to identify individual activity patterns and fatigue conditions of selected homemakers at the household level. This part, therefore, encompasses:

i. Selection of the area: Kailasapuram, the BHEL (Bharat Heavy Electricals Limited) township at Tiruchirapalli (Tamil Nadu, India) and the adjoining residential areas - Bhelpur, Ganesapuram and Tiruvengadanagar located within 3 Km radius of the BHEL occupational health unit were selected for conduct of the survey. The availability of precision equipment and the cooperation extended by BHEL authorities were the major reasons for the selection of the locality. This choice helped develop the necessary rapport with the homemakers and motivate and make them understand the purpose of the study.

ii. Selection of the sample: Five hundred families residing in the selected areas were chosen for the study. Information collected on number of households (families) in the selected areas pointed to the following :

Bhelpur - 106; Ganesapuram - 352; Kailasapuram (B-3 type) - 276 and Tiruvengadanagar - 274. On the whole eight houses were deleted because of obvious reasons like single parent households, inmates out of station and non-cooperation from the members. For uniformity 50 per cent of households (i.e., homemakers) from each locality was selected adopting convenience sampling.

iii. Selection of the method: The method followed was direct personal interview with observation. This method offers greater depth and support, flexibility, clarity and stimulation to respondents, to give more complete and valid answers and creates chances of collecting supplementary information (Wilkinson and Bhandarkar, 1982; Weinberg, 1983 and Tripathi, 1991). As noted by Adiseshiah (1989) uncontrolled observation which enables a spontaneous picture of life and persons, and a naturalness and completeness of behaviour that allow sufficient time for observation was resorted to. Certain queries incorporated in the schedule warranted simultaneous observation of the living conditions too, to ensure content validity of the responses. A casual 'walk-in' into the household aided the development of the much needed rapport to collect relevant information.

iv. Selection of the tool and formulating the interview schedule: Logging procedures like maintaining diaries of activities are cumbersome and interfere with the sample's usual activities state Kashiwazaki et al., (1991) and project the interview schedule as the best tool for overcoming these problems. Responses to pertinent personal information, performance of household activities, perceived feelings of comfort, discomfort/fatigue and where and when they occurred and measures adopted to counter fatigue were solicited. The schedule appeared to be a promising tool for assessing variations in habitual physical activity pattern within a population.

Deacon and Firebaugh (1981) state that the cost of work (in human resources) input may be considered to have four components, namely, the affective, cognitive, temporal and physical. The work specialist is to assume all the four components while studying work. Therefore, the schedule was drafted to include queries on :

General family background

Affective components : Attitudes, interests,preferences and dislikes related to household activities.

Cognitive components:Goal setting and accomplishment, planning and coordination of the use of external/internal resources.

Temporal components:Time expenditure pattern and leisure.

Physical components:Posture, perception of fatigue and its management.

v. Pre-testing the schedule: Pre-testing is a means of correcting any possible omission, elimination, non-clarity and insufficiency in the prepared schedule (Hartmann et al., 1989). Therefore, a pilot study was conducted choosing ten samples from the same area. In the light of the findings the framed schedule was modified (Appendix I).

vi. Conducting the survey and consolidating the data: Homemakers were approached during leisure hours and the purpose of the study explained. The needed information was collected. Simultaneously the living conditions pertaining to the study were also observed. The data was analysed, consolidated and is presented under Chapter IV.

b. Identification of tasks and techniques for detailed study: As defined by Watson and Hill (1991) a pilot study is a preliminary testing, in which the researcher seeks to try out a new idea, system or approach, to determine whether an intended study is feasible to clarify assumption and improve instruments of measurement. The Occupational Health Services (OHS) unit of BHEL was the venue selected for conduct of the tests (Plate 1). The laboratory conditions, however, do not accommodate testing of all known domestic tasks for energy consumption. Hence, to identify the most fatiguing household activity amongst a gamut of all domestic tasks specific task analysis was felt inevitable.

i. Identification of activities for the pilot study: The six activities ranked as highly fatiguing by the 500 selected homemakers were taken as a guideline to streamline the pilot study and was evolved to quantify the energy cost of the activities, namely, grinding chutney, rolling chappati, ironing, washing clothes, sweeping and mopping and to identify the most energy consuming task among the six.

ii. Selection of sample for the pilot study: A heterogeneous group of sample was desired for the pilot study since the energy expended on household activities would be expressed in terms of individual body weight. Systematic sampling was the procedure chosen. This method is used, opines Gupta (1991), where a complete list of the population from which the sample is to be drawn is available. Ten homemakers - five gainfully employed and five fulltime - were chosen from among the 500 samples. The systematic arrangement of the samples, all serially numbered based on the occupational status of homemakers itself enabled getting a uniform number of samples from both employed and fulltime homemakers.

iii. Selection of the method: Ergometry coupled with telemetry was the method chosen to find the physiological responses and energy expended on household activities. For estimating the physical work capacity, Sjostrand's (1961) method, which basically involved measurement of heart rate at known levels of generalised work as performed on a cycle ergometer, was used. Noder (1983) calls an ergometer as an instrument for the quantitative measurement of physical stress.

iv. Selection of precision equipment: An ergometer and a telemeter were used to determine corresponding changes in HR and skin temperature due to load variation in ergometry and performance of household activities. The telemetry system Meditel A 150 can be applied for wireless transmission of physiological parameters. It allows measuring signal transmission of ECG, HR, BP, respiration and temperature which enable estimation of the O_2 consumed with performance. Electronic BP monitor was used to measure BP. The precision equipment used (Plate 1) for the experimental study included:

Telemetry system Meditel A-Hellige Servomed

Electrical ergometer-Venky-the pedalling type with adjustable seat

Transmitter with three transducers

Electronic BP monitor

Electrodes (three) for telemetry

Temperature probe

Stop watch

v. Selection of tools for pilot study: The tools used for the experimental pilot study were :

Ironing : A Bajaj automatic iron box and a cotton saree (5.5 m in length)

Washing clothes : A plastic bucket, detergent soap and a soap dish, brush and a polyester shirt

Grinding chutney : Ammikkal with Kuzhavi*. a plate to keep the ingredients -one green chilly, three teaspoons of roasted bengal gram dhal, one cup coconut scraping, a bowl of water and salt to taste

Rolling chappati**: Rolling pin, board, 12 balls of kneaded wheat flour (300 gm) and flour for rolling out

Sweeping : A soft broom and a tray

Mopping : A bucket, mop cloth# and mopping stick

vi Environmental situation: Borrini and Margen (1990) summarize that the efficiency with which a person performs a given task results from the interaction between factors intrinsic to the body and the factors specific to the tasks and the environment in which the task is performed. Therefore, the following factors were considered from the environmental view point.

Work area: The rate of consumption of energy in task completion is affected by the work area which is composed mainly of the height and available

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* Ammikkal A rectangular granite stone of convenient length, height and width

Kuzhavi A cylindrical stone of proportionate size to be moved with both hands over ammikkal effecting forward and backward movements used for grinding

** Chappati Flat, unleavened bread

\# Mop cloth A kind of duster used specifically for mopping floors space of the work surface, accords Swanson (1981). To be consistent with this idea the height of the work surface was maintained at 0.75 m from floor level. This level allows an 8 to 18 cm margin below the elbow of the sample and the work surface. Similarly, the washing area allotted for washing a shirt was 0.50 m x 0.23 m.

Temperature and humidity: The samples were allowed to work under stable environments to prevent external influences. The mean temperature of the room was 25°C and the relative air humidity 55%.

vii. Preparation of the sample: The samples were given proper orientation before preparing them for the test. The three electrodes were fixed in place following Einthoven Lead I system (Fig. 2) to ensure good wave form with

0 (black) : right, posterior mid-axillary line at about the level of the sixth rib

1 (red) : Sternum at the level of the second rib

2 (yellow) : Left, posterior mid-axillary line at about the level of the sixth rib

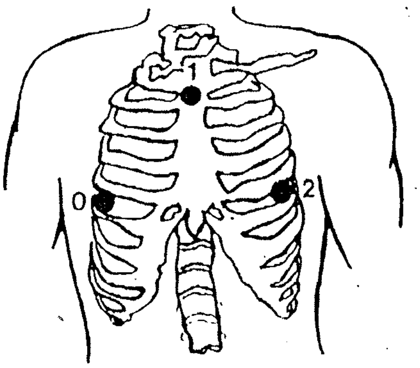
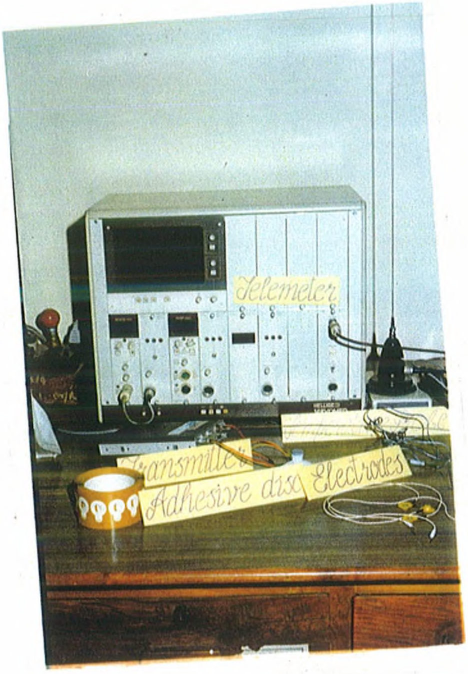


Fig.2

adequate amplitude and a minimum of noise. Adhesive electrodes were used to keep polarizing potentials and motion artefacts to a minimum. After placing the ECG electrodes, the temperature probe was fixed in the sternum at the level of the 2nd rib. Thereafter, the electrodes and probe were connected to the transmitter - an accessory bag fastened to the subject's body allowing freedom of movement. Now, if switched on, the instrument picks up the samples' ECG and transmits it to a receiver and a recorder which in turn displays it in the digital system and the scope. The resting HR, skin temperature and BP were noted in the sitting, squatting and standing postures because these were the ethical stances adopted by the samples while performing varied household activities (Plate 1).

BHEL - (OHS)



Precision equipment

Sample sweeping

Sample on ergometer

Plate .1. SCHEDULING THE TEST PROCEDURE

viii. Conduct of the study: Bicycle ergometry was selected because it is the most preferable instrument,which involves a simple technique, predicts O_2 uptake with greater accuracy and above all (within limits) mechanical efficiency is independent of body weight. It involves an electro dynamic loading system, so designed that if a given load is set on the machine, it maintains practically a constant load, irrespective of the pedal speeds (rpm) between 50 to 70 rpm. During submaximal work a pedal frequency of 40 to 50 rpm produces the lowest O_2 uptake, the greatest mechanical efficiency and a relatively low pulse rate (Astrand and Rodahl, 1977). This indirect test is based on submaximal loads. In the present programme, the samples (after getting accustomed to the cycling) pedalled at varied loads of 20, 30 and 40 watts and the corresponding changes in HR and skin temperature (ST) were recorded.

The samples were requested to perform the six specific activities selected for the pilot study both in the squatting and standing postures continuously for five minutes each. The 3rd, 4th and 5th minute readings of HR and ST were recorded to avoid possible errors. Similarly, the performance induced BP (after completion of task) was recorded.

ix. Presentation of the findings: The results of the study are presented under Chapter IV. The findings enabled identification of mopping as the most strenuous task and proved that the technique of using HR-VO_2 slope for arriving at calorie profile as reliable.

2.Physiological indices: Physiological variables are used as indices of the physiological effects on people of various methods of work, effect of equipment on work and work periods.

Physical infrastructure and clean residential environment are significant prerequisites to human settlements, and an important indication of the level of living (Mathur, 1989; Narayana and Ramanjaneyulu, 1989 and Pandey, 1989). The major task carried out in this environment is homemaking, shaped by societal and cultural traditions. Indian women are actively engaged as housewives and they have a unique adaption to postures during household activities compared to Westerners, whose domestic task performance is dependent on the stool or chair-table interface. So this part deals with :

- Task analysis
- Postural ergonomics of mopping activity

a. Task analysis : Couched in human terms, domestic work requires energy and mechanical work. Therefore the energetic demands of the 'tasks' need to be analysed. The survey and the preliminary study made evident floor mopping adopting both the two ethical postures of squatting and bending as the most strenuous. The traditional approach to the study of work enlists job description, job analysis and job evaluation. The frame of reference developed was work, worker and the concept of the human costs of work. According to Mc Cormick (1976) the two major objectives of task analysis are to (i) describe the job as it would in fact exist, and (ii) to contribute to further improvement in the typology of work. Therefore, the task analysis enrolled included :

i. Selection of the area
ii. Selection of the sample - the worker
iii. Plan and procedure
iv. Selection of the parameters of performance - human costs of work

i. Selection of the area: The area selected was the Occupational Physiology Unit attached to the National Model Centre for Occupational Health Services (OHS) at BHEL, Tiruchirapalli. This OHS model centre is well organised with various functional units which facilitate high quality technical expertise and includes prominence as a training centre of international excellence. Having guided 67 academic projects stands testimony to its service orientation in encouraging research studies. The attributes which contributed to the selection of the area are :

- Well established rapport with the authorities while undertaking studies conducted earlier
- Availability of the required precision equipment
- Encouragement from the dynamic personnel on the staff who showed a genuine interest, offered sustained assistance and guidance towards conduct of experiments and interpretation of data
- Easy approachability because of the familiarity with locale
- Identification of cooperative subjects who evinced curiosity in both the conduct and outcomes of the study.

ii. Selection of the sample - the worker: The nature of the study decides sample selection (Best and Khan, 1987). Steidl and Bratton (1980) viewed limited number of subjects as a characteristic of biological studies since they are expensive and time consuming. The authors have reported on an important energy cost reference, where the data for laundry activities and cleaning the floor was obtained from a single female subject. Similarly, Dhesi and Firebaugh (1973) also had studied the changes in HR of five female subjects while making chappatis. Taking these as guidelines the sample chosen for the study included 32 healthy full time homemakers. The other practical reason for selecting only 32 subjects is the time limit. The training centre of the BHEL, could extend their good offices for conduct of the experiments only for a maximum period of 90 days, so as to comply with their administrative norms.

The samples were drawn from the locality nearest to the Model Centre for Occupational Health Services, spread over - the BHEL township (Kailasapuram), Tiruvengadanagar, Ganesapuram and Bhelpur. The sampling procedure naturally was 'purposive'. To keep in with the viewpoints of Sharma et al., (1989) who state that in purposive sampling items for the sample are selected deliberately by the researcher especially when his/her choices concerning the items remain supreme, great care was invested in the selection of the 32 samples. From the total of 500 samples selected for the household survey eight from each area within the age range 38-42 years (maximum represented in the household survey) were selected who satisfied the following requirements of:

- being busy, fulltime homemakers
- performing part of the household activities by selves
- offering cent percent cooperation
- willing to endure the physiological tests
- being non-sensitive to laboratory conditions
- being physiologically unaffected while working in an alien environment
- expressing genuine interest in estimating their own energy expenditure patterns
- not being known cases of any health disorders like diabetes, hypertension and the like.

Thus a heterogeneous group with due respect to their socio-economic status, corporate life and perceptions of fatigue and drudgery was solicited.

Besides these, great caution was bestowed on choosing samples based on individual anthropometry. For the ergonomic measurements, simple explanation of landmarks and/or measuring methods with few illustrations are given (Appendix II). The original data on the concerned anthropometry are also appended (Appendix III). Only those measurements found relevant and pertinent to the structural framework of the concerned study were measured. The tools used for measurement included a frequently checked and well calibrated beam scale (Avery) for measurement of body size; a stadiometer for measuring stature and a standard tape for measuring other dimensions. The right side of the body was taken for the symmetrical points. The forthcoming Table presents the anthropometric profile of the selected sample.

Table 1 : Anthropometric profile of the selected sample

Morphological particulars*	Mean	S.D	C.V %
Age (years)	40.13	1.66	4.14
Body size (Kg)	61.13	9.70	15.87
Body fat (%)	0.33	0.77	21.21
LBM**	40.27	5.08	12.61
BMI@	24.47	3.70	14.53
Standing			
Stature	154.86	3.19	2.06
Arm reach	71.20	2.66	3.74
Elbow-finger tip	43.47	1.79	4.12
Shoulder-elbow length	31.56	1.39	4.40
Trochanteric	99.09	2.57	2.59
Knee to foot length	45.66	2.41	5.27
Thigh length	54.59	2.47	4.53
Elbow height (from floor)	96.94	4.32	4.46
Foot length	24.05	0.92	3.83
Squatting			
Squatting height	93.78	5.54	5.91
Buttock height (from floor)	17.34	2.52	14.53
Elbow height (from floor)	39.75	4.92	12.39
Upper arm height (shoulder to floor length)	70.09	8.13	11.60
Bending			
Bending height	91.72	5.93	6.46
Elbow height (left)	56.75	7.98	14.06
Elbow height (right)	40.72	5.60	13.75
Upper arm height (left)	77.56	7.24	9.34
Upper arm height (right)	69.66	6.12	8.78
Hand dimension			
Hand breadth	10.00	0.19	1.93
Wrist circumference	15.13	1.27	8.39
Hand circumference	18.73	1.23	6.54

*Unless otherwise specified all dimensions are in centimetres
**Derived as per formula given by Hoeger, (1989)
@Derived as per formula given by Lucas (1989)

On comparison the data obtained for mean values of stature, elbow height and wrist circumference showed remarkable likeness with the works of Ray et al., (1990). The elbow height of the samples (standing) was also on par with the statements of Grandjean (1985). These facts prove the appropriateness of the selected sample.

Inspite of the above documents which substantiate the quality of control considered in the selection of the samples, the major influential determinants in work performance like age, stature, body size and body fat were correlated for possible associations. The details are given in Table 2.

Table 2 : Intercorrelation between morphological indicators of the selected samples

Factors correlated	r	Level of significance
Body size Vs body fat	.6420**	
Body size Vs LBM	.7157**	
Body size Vs BMI	.9634**	
Body fat Vs BMI	.7096**	
LBM Vs BMI	.6122**	(p <0.01)
LBM Vs stature	.5644**	
Body size Vs stature	.4252**	
BMI Vs stature	.1711	Non-significant
Body fat Vs LBM	-.0669	"
Age Vs all anthropometric variables	-	"

A striking variation was observed with the age factor which showed non association with all the other morphological characteristics. Since known associations are available, it can be stated that the population selected is normal and the parameters of quality control are well satisfied.

iii. Plan and procedure: The plan and procedure for the selected study included :

Exercise test on selected sample

Performance study of selected samples while mopping

Exercise test on selected sample: The test was conducted to determine the maximal aerobic power which reflects the physical fitness of the selected sample. This is dealt under :

Choice of sample: With due consideration to availability of time, laboratory facilities and subjects, their willingness to undergo the tests and expenditure incurred, the exercise test on submaximal loads was performed only on eight samples selected from the 32 chosen for the experimental study based on convenience sampling.

Selection of precision equipment: The pilot study conducted identified ergometry coupled with telemetry as a feasible method to measure physiological indices of homemakers. So, the following equipment were made use of for conducting the experimental study.

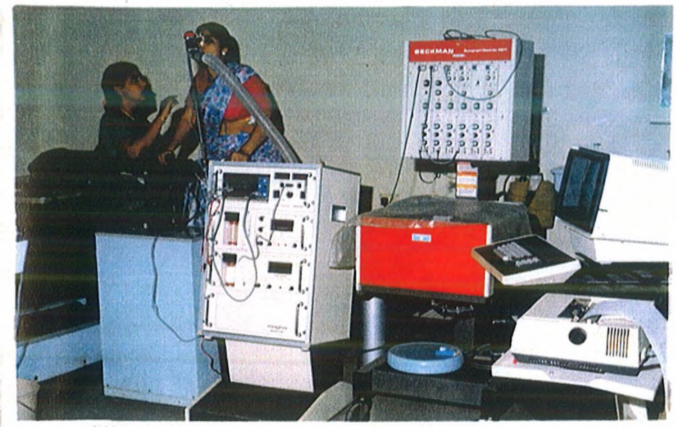
An ergometer - telemeter - micro computer configuration (Wyvern Software - Morgan) [Plate 2]

Electrodes and transmitter (Plate 1)

A sling psychrometer - to measure temperature and humidity (Plate 1)

The experiment strategy: Experiments conducted have proved that individual $HR-VO_2$ slopes of samples on submaximal loads could be drawn based on published/predicted data on $HR-VO_2$ for specific submaximal loads. Hence, the eight subjects (after affixing with electrodes) were put to an exercise test on submaximal loads on an electrical cycle ergometer connected to monitor array, gas analysers, Co_2 and 0_2 ventilometer and ECG and a Z80 micro computer, which acquired the data during the test and performed the analysis. Appendix (IV) presents the configuration. The samples were fitted with the electrodes, a mouth piece and a nose clip and were allowed to practise both breathing through the mouth and pedalling (both unusual situations) for a few minutes before the onset of exercise (Plate 2). Later, adhering to the procedure published in the instruction manual of the equipment (Hellige GMBH, 1976), the test was performed by increasing loads at appropriate intervals. The exhaled air was analysed for 0_2 and CO_2 (to be specific). Raw signals such as VE, 0_2 and CO_2 per cent, ECG and HR were analysed by the Morgan on-line computer system connected to the ergometer. The computer, through its analog to digital convertor, counted digital 'ticks' every one second in order to build up a data base of measured

Fixing electrodes



Ergometer - Telemeter
Configuration

Sample on ergometer
(Exercise test)

Mopping 9.2 sq.m
(Bending)

Mopping
(Squatting)

Plate .2. AGENDA OF THE EXPERIMENT

ventilation, RR,HR, mixed expired O_2 per cent, mixed expired CO_2 per cent and work load. Every 15 seconds, the computer prepared a full set of measured and calculated data and printed all of these parameters as the test progressed and the printer in turn printed out the outputs on individual HR-VO_2 slopes for all the eight samples. A run-time graph also was made available on the screen. The test was continued until it satisfied test requirements. The criteria for terminating the submaximal test was attributed to any of the following reasons:(a) completion of protocol, (b) exhaustion of the subject (c) HR had crossed 85 per cent of the predicted value or (d) change in the ECG.

At this time, the sample was relieved of all paraphernalia and allowed to relax while slowly pedalling on the ergometer. The details on the changes in HR due to varied loads in ergometry and calculations on the samples maximal aerobic power and a regression equation for estimating the O_2 consumption incurred with performance was derived and are presented under Appendix V.

Performance study of the selected samples while mopping: This aspect of the study included details on:

Selection of the area for mopping: The occupational physiology unit of the OHS, BHEL Trichy, was designed to conduct only physiological tests involving treadmill or ergometry, catering to the medical examinations of the personnel at BHEL. Because such experiments involving household activities were not envisaged by the authorities the area available within the laboratory had to be taken best advantage of. Therefore, from one side of the laboratory not occupied by any of the instrument configuration, an area of 100 sq.ft. (9.2 sq.m) was marked to be used for mopping by the selected samples (Plate 2). The household survey pointed that modern households show a preference to 'Mosaic' for interior flooring of houses. It was sheer coincidence that the flooring in the laboratory was also laid with mosaic.

Experimental protocol: The protocol decided for experimental study of mopping is explained below:

> The two postures selected were bending and squatting. The postures were standardized for the task performance (Plate 2).
>
> All the experiments were scheduled to be conducted during the morning session because the samples would have warmed up a little after performance of work at home, had a refreshing bath and breakfast and would have rested a while after performing many chores before reaching the OHS unit.
>
> Prior to the test the samples were allowed to relax and get accustomed to the laboratory situations. Then they were prepared for test by attaching the electrodes following Einthoven lead I system (P.51, Fig.2) and fitting them with the transmitter bag.
>
> The purpose of the study and the postures to be adopted were explained to the samples before the onset of exercise.
>
> Great caution was shown in the conduct of the study to avoid cumulative effects on heart rate due to previous exertion. To facilitate this, alternation of postures was scheduled, that is, if subject A performed the activity in the bending posture first, subject B was required to first mop in the squatting posture, so on and so forth.
>
> Determination of skin temperature and arterial BP was not included in the current experimental agenda.

The environmental conditions (T and Humidity : 23.11±1.86 and 56.47±2.41 respectively) prevailing within the lab was recorded and checked regularly to ensure accuracy. The data satisfies Astrand and Rodahls' (1977) view point.

Factors under control were environmental indicators, flooring (mosaic), mopping cloth and alternation of postures. Factors beyond control were autoselection of the task, rate of work and the pressure applied while mopping.

Conduct of the study: After satisfying the experimental protocol the subjects were requested to perform the activity adopting the postures. The details on parameters of performance considered are explained below.

Photographs of the samples in various stances of each posture namely - flexion, abduction, adduction and extension - were filmed prior to launching into the experimental study. This enabled a two fold function - 'warming up' of the subjects and telemetering of HR deflection due to anatomical movements to be recorded for film analysis and posture targetting (Plate 3).

iv. Selection of parameters of performance: The concern for the household environment in relation to work brings forth three kinds of influences on work - the time cost of the activity, the physical cost of the body and the feelings of comfort, discomfort and tiredness associated with the activity. It is rightly said 'ergonomics' is the study of the capabilities and limitations of people, as they relate to products and their environments (Ong, 1991); hence, this experimental study was designed to record the physiological responses of the samples while mopping. Perhaps, the factor that physiological studies relating energy metabolism to the work demand is totally absent in India would have been more than a catalyst to the idea. Therefore, the procedure included two distinct phases :

Physiological responses to mopping a specified area

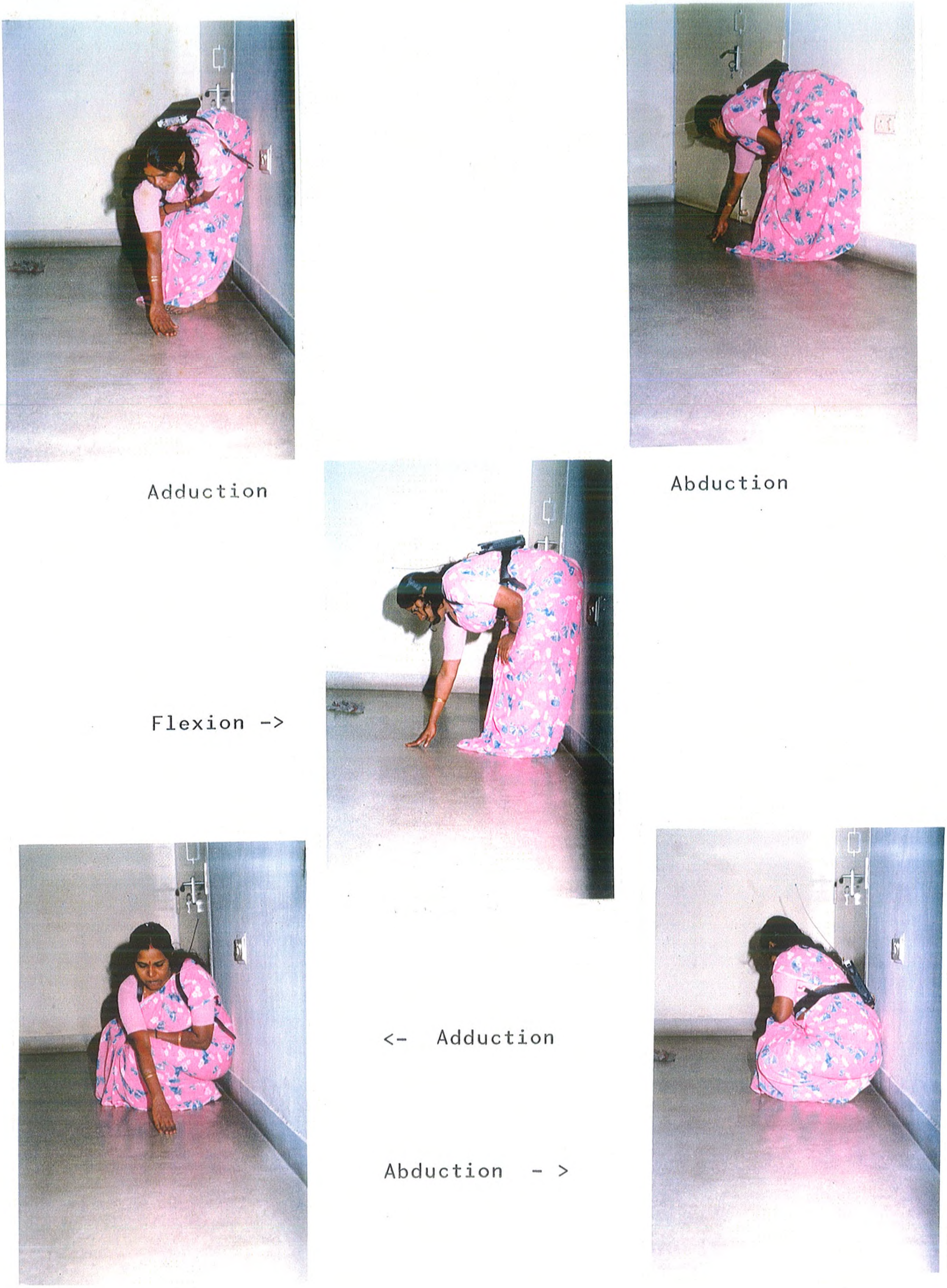
Mopping till endurance

Physiological responses to mopping a specified area: The framework of this part of the study included:

Selection of the dimensions of the specified area: The minimum carpet area of rooms other than kitchen, bath and toilets as observed/reported in the household survey was 10 x 10 ft (100 sq.ft). Hence the minimum area for mopping was decided as 9.2 sq.m (100 sq.ft.). Moreover, it was felt necessary to find out exactly how much time the samples took to mop the specific area and realise how it affects the physiology of the samples. The following items were identified based on individual performance while mopping 9.2 sq.m.

Work time : The time consumption pattern of the selected sample for mopping the specified area was recorded.

Cardiac response: A systems approach to the study of the cardiac responses was undertaken. Basar (1976) defines a system as a collection of components arranged and inter-connected in a definite way where the input may be a



Adduction

Abduction

Flexion ->

<- Adduction

Abduction - >

Plate .3. ANATOMICAL MOVEMENTS WHILE BENDING AND SQUATTING controlled stimulus, with a recorded response as output and the system blackbox as the physiological system under investigation. In the present study the stimulus was the mopping action, response was HR and system investigated was cardiovascular dynamics. Hence, details on the following were elicited :

Heart rate : Since in a given person there is generally a linear relationship between O_2 uptake and HR, the HR or pulse rate under certain standardized condition may be used as an index of O_2 uptake in a given task opine, Astrand and Rodahl (1977). The cardiac responses thus recorded (while the samples mopped in the selected postures) were analysed based on the classification published by Grandjean (1985). Since mopping is more or less dynamic-cum-static in nature the definitions proposed as explained below were accepted.

*	Resting pulse	:	average HR before the work begins
*	Working pulse	:	average HR during the work
*	Work pulse (Incremental cardiac cost)	:	difference between the working and resting pulse

Caloric cost of the activity: The O_2 consumption of the individual samples was estimated as a product of the regression formula developed from the data on maximal aerobic power and individual changes in HR. When one litre of O_2 is consumed in the human body there is on an average, a turnover of 5 k.cals of energy which is called the calorific value of oxygen (Grandjean, 1985). Therefore the calorific cost of the O_2 consumed was calculated based on the formula:

$$\text{Work calories } (\text{K.cals. min}^{-1}) = [\text{oxygen consumption } (\text{l.min}^{-1}) \times 5]$$

The caloric cost of mopping 9.2 sq.m of floor area is tabulated and presented under Chapter IV. Statistical analyses using paired t test and correlation were done. Similarly, inter-correlations between performance parameters were also studied.

* Relative aerobic strain (RAS) : RAS is the percentage of $Vo_{2(max)}$ to working oxygen consumption ratio. The formula is:

$$\text{RAS (\%)} = \frac{\text{Working oxygen consumption}}{Vo_{2(max)}} \times 100$$

RAS enables comparison of the work effort taking into account the individual's physical fitness. Since the area allotted for mopping is fixed here, it was felt that it will be appropriate to estimate the RAS of the individual samples using details on their individual oxygen consumption patterns for mopping the specified area, and thereby identify the stress on the subjects due to performance. The ratio of RAS to individual body weight was also estimated. The following chapter presents the data.

Mopping till endurance: According to Willmore (1977) endurance is defined as the ability to perform prolonged bouts of work without experiencing fatigue or exhaustion. In Hoeger's (1989) viewpoint endurance is the ability of a muscle to exert submaximal force repeatedly over a period of time. Using this as an experimental direction, the samples were requested to perform mopping in both the selected postures till the time they felt that they could endure no longer. The area mopped within the endurance limit and the work time they were able to endure - were recorded. Appendix VI presents the formulae used for various calculations. Apparently, the details on endurance are analysed under the following heads :

Working pulse and incremental work pulse : The absolute and real increase in HR due to performance is explained through the two terms respectively (put forth by Grandjean, 1985).

Range of movement : The samples were requested to squat or stand (and then bend) in an area marked for the same and make a single sweep of the hand (in both postures) as is natural in their individual mopping action. The arc, the inner and outer radius formed by the sweep of the hand and number of degrees (the angle of their shift from left to right*) a joint can move

---

*South Indian homemakers are right handed in action through were observed. The area selected was a room laid with red oxide flooring to enable ease in measurement of the range of arc. A draughtsman's protractor was made use of for measuring the angles (Plate 4). The range of movement of the individual samples thus determined, and its dependence on selected anthropometric variables was studied through correlation matrix.

Endurance limit: The period of work time was recorded from the beginning to the cessation of work. The end point denoted the time above which the samples could continue work no further and this point was characterised by symptoms like muscular pain, exhaustion, fatigue or breathlessness.

Area mopped : The total area which the samples could mop till they reached their endurance limit in both the selected postures was measured and recorded. This data highlighted their maximum performance or input to the activity indicative of their individual productivity in relation to mopping activity.

Recovery time: In the view points of Babsky et al., (1970) the first few minutes after the work has ended is known as the period of recovery and it extends until the time, the heart resumes to resting levels. This time may vary considerably with varying loads. The findings of the pilot study with reference to mopping activity had projected that the recovery time may be comparatively higher for the same in terms of the inherent energy consumption. Hence the recovery time of the individual samples was recorded. The samples were allowed to conveniently sit on a chair and relax while this was recorded (Plate 4). The time taken by the samples to resume their individual resting values of HR was noted. This value stated in terms of time illustrated how far the cardiac muscle was strained during performance. The interpretations identify a small recovery time as to indicate less strain while a long recovery period its converse.

Recovery cost: By recovery cost is meant the sum of heart beats from the cessation of work until the pulse returns to its resting level (Plate 4). This involved recording of the HR after the lapse of every subsequent minute

Range of movement

Recording recovery time and cardiac cost

Plate .4. PERFORMANCE CRITERIA

after endurance which connotes the total recovery cost. From that data the incremental recovery cost was estimated.

This value was estimated for each minute of recovery time and the total of incremental pulse for the total recovery time summed up. Because, recovery cost and time reflect management profile of the cardiovascular dynamics to the extra demand, these two parameters were given special impetus and great care was bestowed on rendering them in a perfect manner.

Rate of work: This indicates the area mopped to endurance ratio. Calculation of the rate of work enabled analyses of the samples for their previous experience in mopping, their pace of work, technique adopted and their speed of action. This parameter again was correlated with performance criteria like area mopped, endurance and incremental work pulse to relate possible association.

Rate of recovery: Rate of recovery expresses the recovery time to endurance ratio. This factor established the relationship between endurance and recovery time and the strenuousness of the activity and also highlighted the physical fitness of the samples.

Oxygen consumption: The oxygen consumption pattern of the selected sample was analysed using the regression formula developed. Both the formulae are explained under Chapter V.

Working VO_2 and Incremental VO_2 : The term working Vo_2 explains the oxygen consumption incurred for both voluntary and involuntary action. It denotes the cumulative value of 0_2 uptake for resting pulse and incremental pulse due to action. Incremental VO_2 defines the incremental VO_2 required for the performance of the activity over and above the requirements for life processes (resting base of HR).

Oxygen pulse: Oxygen pulse means the Vo_2 incurred with each beat of the heart. This clearly picturizes the impact of performance - stressful or not - on the cardiac muscle with every beat.

Work calorie profile: The calorific value of the 0_2 consumed due to performance in the two selected postures, both for the working pulse and incremental work pulse (working calorie and work calorie) was calculated by finding their multiples of five respectively. The data was analysed with both, physiological attributes (like, age, stature and body size of the selected samples) and performance parameters to establish possible associations. The variation regarding these two parameters in the concerned postures was also analysed using paired t test.

Oxygen debt or incremental recovery VO_2 status: It should be emphasized that for a work that is partly aerobic the oxygen uptake must be measured not only during the work period but during the recovery period also (O_2 debt). As was done with change in HR, the VO_2 incurred for the incremental recovery pulse was calculated using the same regression equation substituting the incremental recovery pulse for working pulse or work pulse. It is the oxygen required to repay the debt incurred within the muscle due to performance or in other words it is the recovery VO_2. From this data the recovery calorie status was estimated using the same formula substituting the value of recovery pulse in the place of work or working pulse.

The details on all the cardiovascular expressions were analysed and is presented under Chapter IV.

b.Postural ergonomics of mopping activity: People differ very well in their postural styles. There is a whole complex of factors - anatomical, physiological, psychological, cultural and technological - which determine the postural habits. Therefore postural habits need to be considered. Due to the 'postures' they adopt while working, women suffer from many problems - prominent among those is the low back pain syndrome (Mc Atamney and Corlett, 1992).

Measurement of angles of body bend make it possible to analyse ill-defined household tasks in areas with limited apparatus and laboratories (Dhesi, 1973). It helps in establishing the limits at which there could be a stress and strain in the muscles. The development and evaluation of the design of the study is geared to include the following criteria.

i. Posture analysis - anatomical movements at the extremities

ii. Posture targetting

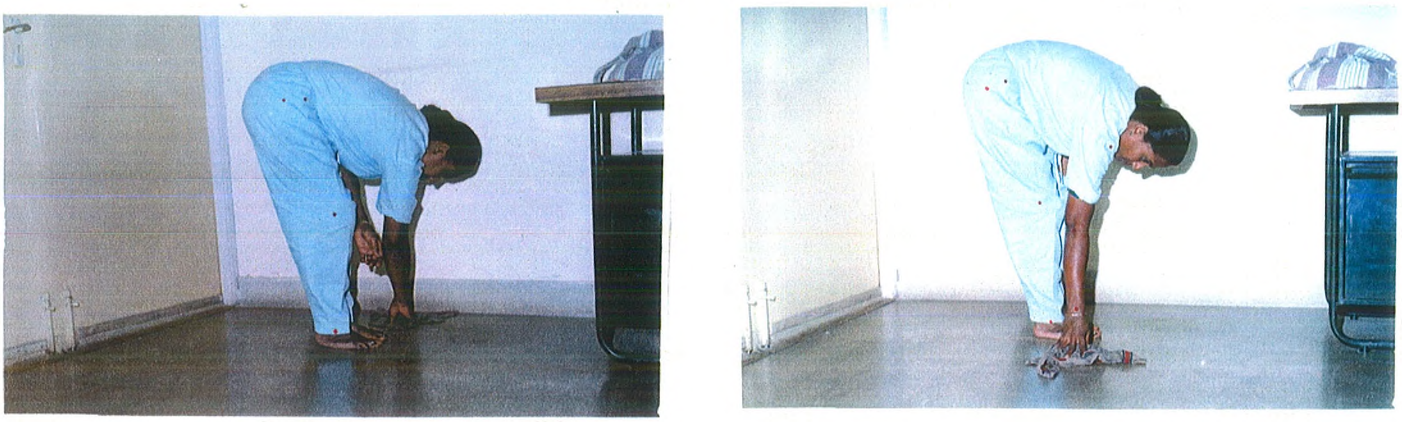
i. Posture analysis - anatomical movements at the extremities:The bony skeleton of the body may be considered as the framework upon which the remainder of the body is built. It consists essentially of two major systems of levers - the arms and legs - joined together by an articulated column - the spine. The movements possible in joints are flexion, extension, adduction, abduction, circumduction, rotation, and flexibility is the ability of a joint to move freely through its full range of motion.These factors stirred an interest to study possible changes in body bend due to postures while mopping floors.

As explained, before the onset of the test exercise the samples were requested to pose in postures explained by anatomical movements (Plate 3) and subsequent analysis of the posture in terms of their anatomical movements was made possible through measurement of angles of body bend. This was facilitated by making use of film analysis and posture targetting.

Still film analysis: As early in 1967, Trevathan and Maloch had used angles of body bend as a measure of postural changes in household work. Even earlier Keiser and Weaver (1962) had made adaptations of the technique of postural measurements from films - one of which was angles of knee bend. They specified uniform placement of the camera in relation to the subjects during photography. Since body positions as measured by body angles are related to HR and energy expenditure, attempts to use this criterion as an indication of energy cost, without the use of elaborate apparatus are to be strengthened recommend, Mrunalini (1992). Therefore an attempt was made to analyse postures through still photographs.

The samples were affixed with a marking specifying the particular joint under consideration. Markings corresponded to the shoulder, elbow, wrist, hip, knee and ankle joints (Plate 5).

BENDING



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SQUATTING

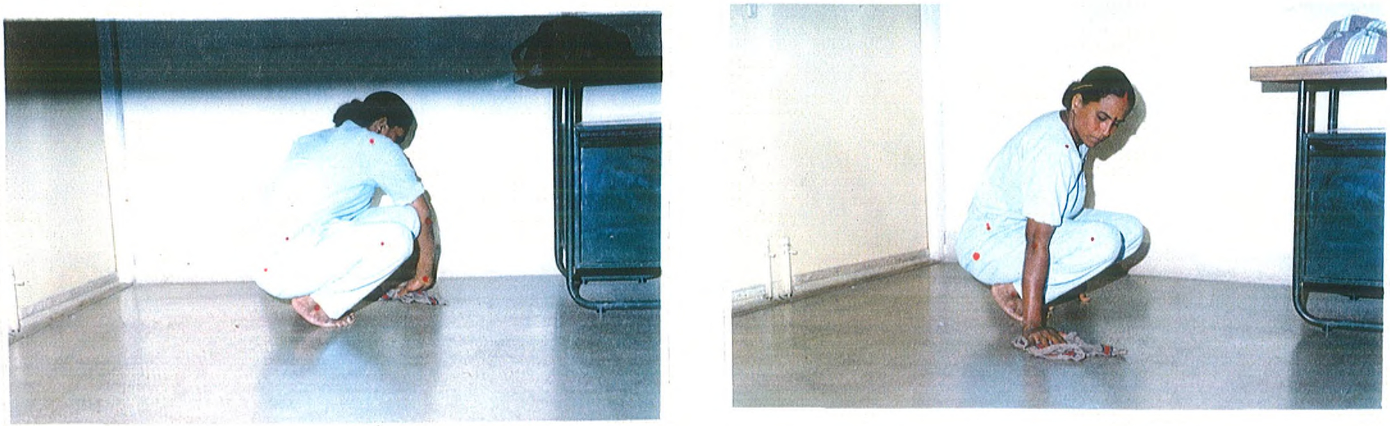

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Plate .5. MEASURING ANGLES OF BODY BEND

The natural stance in both the postures is mopping with their right hand. Still photographs were taken showing the right side of each subject at the selected stages in the mopping process in both the postures. They indicate action - a shift towards left and then to their right. The camera distance from the sample was 213.36 cm and its height above the floor 45.72 cm.

Measuring angles of body position: Eight angles were measured from still photographs of the samples in each stage of mopping in both the postures. Markings facilitated defining and measuring the angles of body bend. The deviation of any body limb and trunk from the standard position from vertical in the sagittal plane was measured for posture analysis and is presented under Chapter IV.

ii. Posture targetting: Postural stress is one of the major occupational problems in modern society whether at home or occupational level. To achieve better work performance by improving posture there must be efficient methods for recording postures. Therefore, the angles of movements which are more or less possible and occur during mopping work in the two concerned postures were incorporated. The method of recording the shift in body angles using a posturegram was attempted .For this, posture analysis of all the 32 subjects was done by the method introduced by Corlett et al., (1979) and later modified by Sen and Pal (1989). This method enables simultaneous assessment of postural strain and also tends to substitute the socially unacceptable, costly, time consuming method of EMG, to assess postural strain during work. Another reason for choosing this method was because EMG studies could not be undertaken here since Indian women would not controvert the dogmatic beliefs and appear in garments suitable for fixing electrodes without being an impediment.

The recording method: The method considered each limb, the torso and the head as parts of the body linked to each other and to the trunk. On a diagram of the body each part is provided with a set of segmented concentric circles or targets as shown in Appendix(VII) where they are drawn adjacent to their body parts, and the body is shown in a 'standard' position. When any of the body part departs from this position a marking is made on its associated target; otherwise no mark appears.

The method of marking the diagram is explained in relation to figure (b) , which shows numbered versions of one of the targets from figure (a) (see Appendix VII). Any deviation from the standard position from vertical in the sagittal plane is marked between or on the concentric circles, the arrow in the centre indicating the front of the body. The circle marked 1 (the innermost circle) represents 45^o from the standard position, the next consecutive circles represent 90^o , 135^o and so on. For instance, the small cross shown on the target if referring to the forearm, would indicate that the arm was pointing horizontally at an angle of 90^o to the front back (sagittal) plane.

The working diagram and its use: Once the standard position is known clearly state, Sen and Pal (1989) that is, an upright stance viewed from the rear or side, there is no need to reproduce it on each occasion.

Recording angles of body bend: The samples were allowed to work in their natural pace. While they performed the activity the shift in the body part with reference to a pivot point was marked and the angle was entered in the individual posturegram forms. The angles were also marked on the floor and measured using a draughtsman's protractor. These enabled counterchecking of errors made if any, in the markings made in the posturegram. The readings were made only for two operations in both the postures respectively. A model posturegram showing the deviation of body members while performing the activity is presented under Chapter IV.

3. Subjective responses

Mc Cormick (1976) states that subjective responses of people can also serve as appropriate criteria. Therefore, the 'modus operandi' of the present study included identifying the fatigue experiences of the sample.

a. Perception of fatigue/drudgery as related to mopping activity: The process of fatigue is a complex phenomenon caused by the working state of a biological system and influenced by many external and internal factors such as attitude, orientation and adjustment of the worker (Chavalitsakulchai and Shahnavaz ,1991). Hence it was imperative to identify the feelings of fatigue/drudgery as perceived by the selected sample. So, a rating scale was drafted and was administered on the sample.

i.Drafting a rating scale: A typical scale consists of series of carefully formulated short statements or propositions dealing with several aspects of issue under consideration. The individual reacts verbally expressing approval or disapproval to the items on the scale. These reactions purport to measure a person's response to the issue on hand. Likert type scale or Summated scale is by far the most popular of all methods (Kothari, 1995). Therefore, the use of this scale was considered most appropriate for the study. Black and Champion (1976) accord scaling as a process of developing a measurement standard whereby individuals may be compared relative to one another regarding the properties they possess.

ii. Collection of items for the scale: The validity of the scale depends on the extent to which it covers the relevant subject matter. As a first step in developing the scale, a set of major criteria was listed by inviting comments from the subjects on their perception of factors limiting their performance of the task of mopping. Statements were collected from the 500 samples who had responded for the household survey. Fourteen categories were generated from the data which were not pre-defined (ref.P152).

Under each of the major criteria a list of subitems was added in the light of previous research reports, detailed discussions with faculty members of Family Resource Management and Physiologists. Informal talks with the same subjects enabled further addition of subitems to the list. From all these sources a total number of 74 statements could be elicited. Care was taken to see that each statement listed was clear, brief and presented a distinct single idea.

iii. Rating of statements by judges: For greater reliability of the data, Smith (1975) suggests fewer categories, precise definition and lesser influence in making classification. Since the total number of statements collected were too many to be used as a measuring instrument, further editing was done where 25 selected judges comprising a fine blend of full time and gainfully employed homemakers from Coimbatore rated the statements. Sufficient time was given for evaluation and the schedule was recalled the same day. The scores awarded for each statement were duly consolidated.

iv. Items analysis and final selection of items: Each statement was tested for significance using t test. The 't' value of each statement (ranging from 0.73 to 11.06) helped to determine their rank order in which they were selected for inclusion in the final rating scale. The statements having more than 3 as t value were considered (the mid range of scores being 3). The selected items were arranged according to the hierarchical order of t values. The first 40 statements having a high critical ratio were selected and included in the final rating scale and these again were classified under four major heads to make it more meaningful because as Lee (1996) puts it the causes of fatigue range from changes of muscle cell biochemistry to boredom. This type of item selection helped to reinforce the validity of the scale. Additional refinements were effected before finalising the scale.

v. Reliability of the scale: Reliability refers to test consistency (Borg and Gall, 1983). Split half method was employed to test the internal consistency of this scale as suggested by Black and Champion (1976). The agreement between scores on each half of the scale was determined using Pearsonian correlation co-efficient. In such instances, if the degree of correlation between the two scores is high, state, Ghosh (1985), then the scale may be regarded as reliable. The reliability co-efficient obtained in this context was .8321 (highly reliable).

vi.Administering the scale and interpreting data: The scale (Appendix VIII) was administered on the same 32 samples immediately after they completed the experiment in order to ascertain true feelings as experienced moments ago. They were requested to assess individually for the two experimental postures. The ratings were entered by them by marking a tick against the appropriate response. The scores awarded by the subjects to each of the statements in the scale were analysed individually and collectively for the postures and the findings are presented under Chapter IV.

4. Accident frequency

Human criteria tend to reflect something about the systems involved. Since 'posture' is the independent variable, the dependence of the other factors have to be analysed for probable ill effects or consequences. In addition, the 'postures' have to be analysed for their implications on 'human factors' - their impact on human values (safety, health, satisfaction and human welfare). Therefore this examines the:

a. Biomechanics of mopping activity: Posture is recognised as an important aspect of work loading, often acting to limit the time or effectiveness of the worker's performance. As yet, repent Corlett, et al., (1979) there are only a few criteria to define 'adequate' postures or for how long it is safe to adopt a given posture. Schneider (1985) urges modern ergonomic researchers to expand research horizons so as to include the influence of correct posture, body measurements and the like on improving productivity.

Colombini, et al., (1985) in their publications have highlighted that recent epidemiological surveys have emphasized the existence of a clear causal relation between postural stress at work and musculo-skeletal pathology, particularly in the lumbo-sacral region. All such literature reviews kindled a natural interest to estimate the compressive loads on the lower back while mopping floors. Since biomechanics allows, as Andersson (1985) comments, to predict quite accurately the compressive load on the lower back, an integrated approach wherein biomechanical, physical and physiological criteria was considered, was launched. Therefore this part of the study included:

i. Shift in angles from horizontal in the sagittal plane

ii. Physiological response to shift in angle

iii. Static Co-planar multi-link modelling system.

i. Shift in angles from horizontal in the sagittal plane: For measuring angles of body bend to study the stress - strain concept, the same photographic technique (Plate 5) was used. The angle was measured taking deviation from the horizontal of the basic situation in the clockwise direction (zero degree is at horizontal to the front of the joint). The deviations of five prominent joints from the basic situation in both the postures while shifting to the left and right respectively, were considered. The angles measured involved the joints of the elbow, shoulder, hip (L5/S1), knee and heel. The details on the deviations are presented under Chapter IV.

ii. Physiological response to shift in angles: The samples were requested to retain the positions so as to enable recording of HR inflicted by the shift (either towards left or right) from basic situation (Plate 3). The mean values recorded pertaining to the two postures with regard to shifts to the right and to the left - were recorded and are detailed under Results and Discussion.

iii. Static Co-planar multi-link modelling system: The action lines of the forces within a system are all parallel to each other but not in a line. Since the human body is a system of linked segments, parallel forces often cause rotation of the parts about their anatomical axes. Both muscle and gravitational forces are extremely important in producing these turning effects which are fundamental in body movement. To measure the same for mopping in two different postures, a static co-planar multi-link modelling system was used. In approaching problems of parallel forces in a plane, generally a reference point is selected to determine forces which act clockwise or counter-clockwise about this point. The two basic problems faced are finding a resultant and the equilibrium position in which the object concerned is known to be at rest. This part of the study included locating :

- Load moment around L5/S1 fulcrum
- Force generated
- Shift from centre of gravity
- Anti-clockwise moment and erector spinae force.

* Load moment around L5/S1 fulcrum: To find the resultant all the forces in one direction are added (a) and all the forces in the opposite direction (b) are subtracted from it that is, (a-b). The answer gives the magnitude of the resultant force ($R=\sum F$). The sign of the answer gives the direction of resultant force. But here the position of the action line is unknown. To locate it the 'principle of moments' was made use of. The moment of a force about any point is defined as equal to the magnitude of the force multiplied by the perpendicular distance from the action line of the force to the point. This perpendicular distance from the force to the fulcrum or point selected is known as the arm (l) of the force. 'Torque' is another term used to designate a force time its lever arm. A moment, then, is the product of a force and distance($M= F\times l$). It gives the turning effect of a force about the selected point. The effectiveness of the force in rotating the object depends on its distance from the fulcrum. Figure 3 offers an illustration on how the load moment is generated at the upper extremity. Considering such precise calculations, the load movement

B x d = moment of biceps pull

G x d' = moment of gravitational force

A = Force at joint

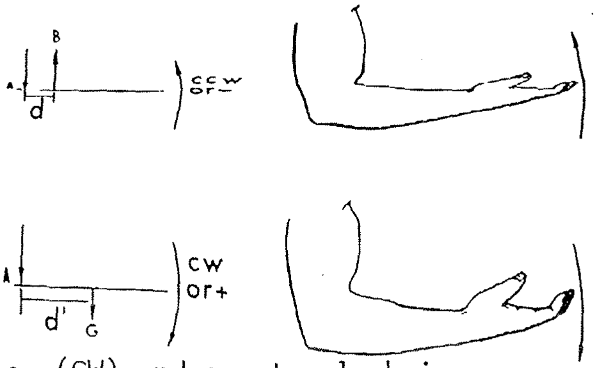


Fig.3 Designation of clockwise, (CW) and counterclockwise, (CCW) turning forces

around the L5/S1 fulcrum was measured. It denotes the distance of individual body parts from L5/S1. It was similar to the illustration (Fig 3) but the fulcrum and the body part alone differed. This figure is given only for ease in comprehension.

Static contractions are necessary for the maintenance of body postures, for supporting the arms when operating with tools, or fixing articulations during complex movements. Static contractions may be continuous or intermittent (Monod, 1985). So for the analysis of biomechanical forces and torques the concept of 'free-body-diagram' was employed in this model using three body segments - the upper limbs (segment 1), the lower limbs (segment 2) and the trunk above L5/S1 level including the neck (segment 3).

* Force generated: In body movement two basic sets of forces are considered (1) gravitational forces, which give the body stability and (2) muscular forces which interact with and oppose gravity to maintain posture and produce movements like ambulation and manipulation of objects. In the case of movements of gravitational forces, one element - the lever length - can be altered; but in the case of moments of muscle force both the magnitude of all the forces and its lever arm change as the body segment is moved. However, the shift in lever arm is restricted to a rigid path by anatomical limitations as explained through details on reactive force and moments of gravitational forces.

* Reactive force: When anatomical arrangement of muscles in relation to joint movement are analysed, it is customary to place the arbitrary turning point about which the moments are taken at the anatomical axis of the joint (Fig 4). When this is done the moment of the joint reactive force is zero since its action line passes through this point.

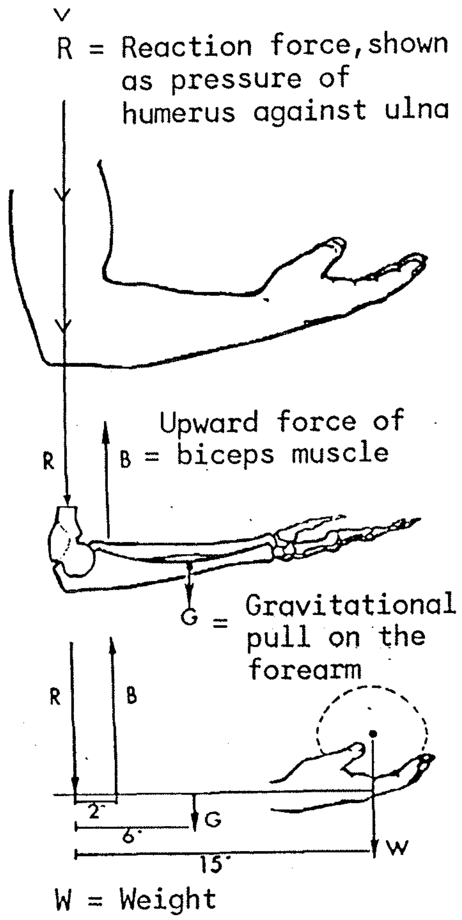


Fig. 4

A parallel force system acting on the forearm

At the elbow level gravity tends to pull it away from the upper arm. When the arm is extended in the sagittal plane as in mopping there is some reaction keeping it together. But because of the weight held (say the mopping cloth), it tries to fall down. But some force is counteracted to keep it in place; so the force should be equal and opposite. This happens only if the load (weight) is counteracted. If the load is not opposite it will move in some other direction. If not it will move up or down. In this current context, this is what is happening at the elbow joint. So the reactive force incident at shoulder joint will be the cumulative loads of upper arm and forearm. This goes on increasingly at the hip joint, knee and heel in a sequence. It will be maximum at the heel.

The computer was programmed to analyse the system. So, when details on the shift in angles because of posture were introduced as inputs, the joint reactive force and the load movements were naturally arrived at as output. Thus, the reactive force is the sum of the weights of the body above L5/S1 and the load; and the torque is the sum of the products of the weights of the load and body segments and their lever - arms in relation to the lumbosacral disc. Horizontal forces are zero. The details of the joint reactive forces are presented under Chapter IV.

Fully aware of these factors and knowing that a shift in the angle of the body part around the fulcrum from any basic situation would shift the centre of gravity and would generate a cumulative force, the angles of body bend of the samples were measured, as explained earlier.

Moments of gravitational force: Just as a muscle pulls at its anatomical attachment on a segment, the force of gravity exerting a downward pull at the centre of gravity (CG) of the body parts should also be considered. Since the CG moves in space as the part moves, the lever arm of gravitational pull (perpendicular distance from the action line of gravitational force to the axis at the joint) changes according to the position of the part. Analysis of posture and movement is based on an understanding of the leverage afforded gravitational force by body position. It is inevitable that individuals should know how to conserve energy and to prevent strain and injury to joint structures. Low back injury commonly results from ignorance regarding techniques which minimize gravitational efforts. Arm and shoulder strain may result from prolonged use of the hands away from the midline of the body. This aspect led to locating the :

* Shift from centre of gravity: While mopping many joints are involved which undergo considerable stress and strain. The effect of posture on the forces which can be exerted, report, Davis and Stubbs, (1977) and the time for which work can be done are equally important. Low backache is preventable since it is often caused by physical inactivity, poor postural habits and body mechanics and excessive body weight (Hoeger, 1989). What needs to be explored is how postures are related to low backache.

The centre of gravity is an imaginary point at which the entire weight of the body may be thought to be concentrated - the centre of weight or mass. For women, this point lies within the pelvic region at 55 per cent of the standing height, report Steidl and Bratton (1980). This centre shifts when one assumes a sitting or squatting position. Hence the static co-planar multilink modelling system enabled finding out what is happening while mopping at the elbow in the first instance and thenceforth at the joints beyond. Since concern is with mopping involving the upper extremities, lower extremities and the trunk, the forces incident on the erector spinae warranted analysis. The procedure followed to determine the anticlockwise moments generated at specific joints is explained with respect to upper extremities alone. The procedure applies to the other joints too. *Anti-clockwise moment: If the load is held at an end as in mopping, the load will simply come down; but in anti-clockwise movement the load swings in a circle. Naturally a moment will be there to make it swing in the clockwise direction. In order to prevent this, an anti-clockwise torque is applied. A moment of the resultant force about any arbitrarily selected point must be equal both in magnitude and direction to the algebraic sum of the moments of the individual forces of the system about the same axis. So for this purpose what needs to be known are the weight of the body part and the location of CG. From the location of CG the distance of the moment arm (i.e., fulcrum to CG) was calculated. Since the forces act vertically the angle (a) should also be known. Here, weight indicates the weights of forearm plus weight of load if any; but since no apparent load is involved, only the weight of forearm and other body parts are involved. All such data are based on anthropometry, that is location of the CG in that body part and segmental weight in proportion to the whole body weight. Whole body weight is obtained from actual individual anthropometric data (Ray et al., 1981). All these computations were made by a computerized programme by feeding in the details on the joints involved and the corresponding angles formed due to posture, as inputs. Figure 5 and the equations state how the anti-clockwise moments at specific joints were evolved.

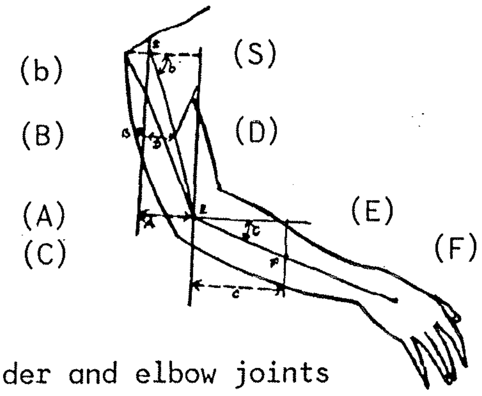


Fig. 5 Anti clockwise moment at shoulder and elbow joints

Glossary of terms

F_{Elb} = Force at elbow; F_s = Force at shoulder; CG - Centre of gravity

FA = Forearm; UA = Upper arm; Dist = Distance; Wt = weight

A = Horizontal dist of elbow joint to shoulder joint

B = Horizontal dist of CG of UA to shoulder joint

C = Horizontal dist of CG of FA to elbow joint

b = Angle formed by UA at shoulder

e - Angle formed by FA at elbow

S - Shoulder joint; E - Elbow joint

D - CG of UA ; F - CG of FA

Equations

$$F_{elb} = Wt_{FB} \times C = Wt_{FA} \times (EF \times Cos\ e) \quad .... \text{(Equ. (1)}$$

$$F_s = (Wt_{UA} \times B) + (F_{elb} \times A)$$

$$= Wt_A \times (SD \times Cos\ b) + F_{elb} \times (SE \times Cos\ b) \ ...\ \text{Equ. (2)}$$

Next, the force at hip joint includes the forces at elbow and forces at shoulder. So this adds up for all the other joints involved like hip, knee and heel. Based on these details the compressive force generated as a cumulative effect on the erector spinae was estimated.

* Erector spinae force (ES force): The compressive loads imposed on the spine structures are to a large degree created by the trunk muscle contraction forces required to equilibrate a given external movement. These moments are partly from task execution and partly from body segments weights acting at different moment arms. The spine compression loads lead to deformation of collagen tissues of the motion segments, which in turn can lead to local regions of increased strain with the segment; perhaps more important in postures, close to the limits of range of motion of the segment than in more common intermediate situations. Thus, posture essentially

determines the total compressive load on the spine, as well as the load distribution within the spine (Andersson, 1985).

During such a kind of clockwise swinging (Fig 6) the erector spinae has to counteract the clockwise moment. Erector spinae is a deep muscle of the back (Gray, 1992). So here the ES force is found out by making use of the lengths of the ES and the clockwise force which it has to counteract by the anti clockwise moment which it has to generate (Fig 6).

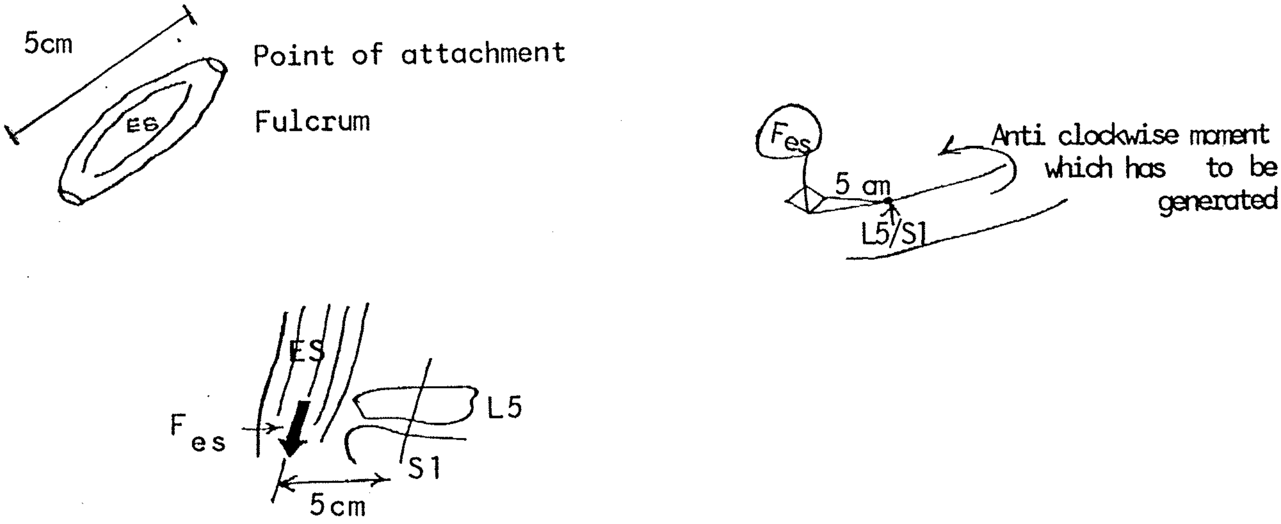


Fig. 6 Force on the erector spinae

From the results obtained for the reactive force, anti-clockwise moment and the erector spinae force, the stress-strain concept of mopping activity due to adoption of ethnic postures is made evident. The possibility of low back pain was also estimated. The findings are presented under Chapter IV.

B. Systems criteria

Better management forestalls the effects of catastrophic effects, or a gradual depletion of resources, stands good with human resource conservation. So, having found mopping as a weariness-inducing activity, it has to be simplified by introducing a labour saving device into Indian households.

Systems criteria are those which relate to system performance or output, or in other words, those which reflect something about the degree to which the system achieves its intended use. The system identified here is manual moppers devised by various agencies and commercially available in the local market.

A priori the design of the present session is streamlined to include the following;

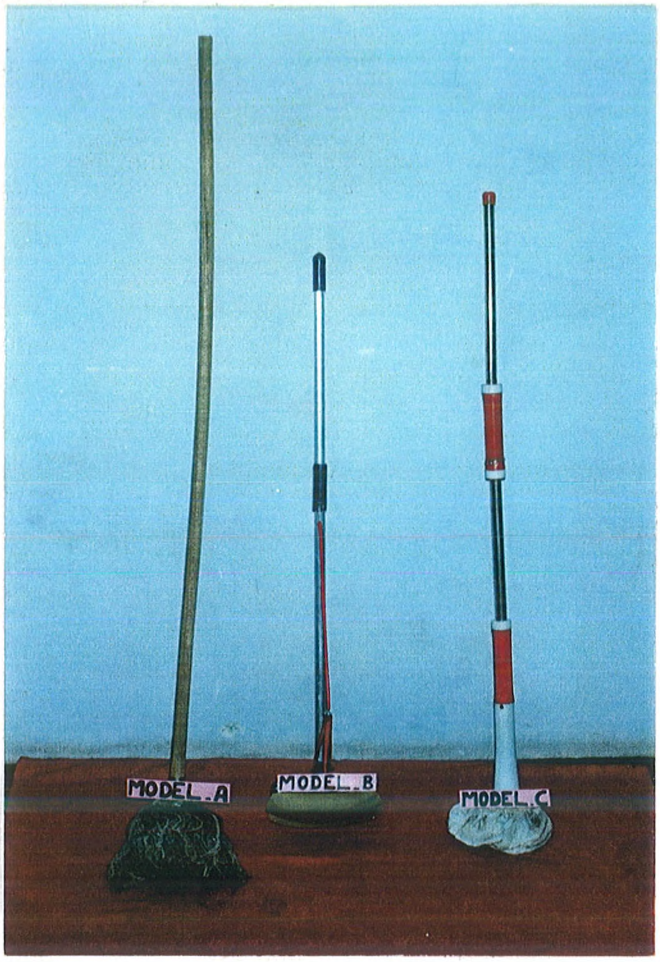
1. Market analysis: A market survey selecting fifty shops dealing with the sale of manual moppers, and, a production unit was conducted to elicit information on the availability and demand for manually operated moppers in Coimbatore city. Gandhipuram, Townhall, Saibaba Colony, Rathinasabapathy Puram and Ganapathy were the areas selected for the market survey, mainly because they are the major commercial centres and also for their ease in approachability.

The shops were selected adopting purposive sampling and the method chosen was the interview using a structured schedule.

An interview schedule enlists queries designed to elicit the required information in the form of short answers filled into the blank spaces besides the questions, propose, Chaudhari (1989) Gupta (1991). The tool formulated incorporated queries requesting details on fabrication, operation and availability of manual moppers (Appendix IX). The dealers were approached during passive business hours, the purpose of the study stated and necessary information collected. Analysis of the data is presented under Chapter IV.

2. Evaluation of existing models of manual moppers: Systems criteria is also intended to elicit details on the anticipated life of a system, ease of operation and use, maintainability, reliability and operating cost. The following procedure describes the methodology adopted.

Varied types of manual moppers (Plate 6) commercially available/ marketed were selected for evaluation. The models varied mainly with respect to the mopping component. Otherwise, all were upright models operated by the user in the standing posture.



Three models of moppers

Demonstration of
Model 'D'

Sample operating
Model 'D'

Plate .6. MANUAL MOPPERS

A demonstration of the innovative product - the fourth model (Model D) was arranged in the Family Resource Management laboratory, Avinashilingam Deemed University, Coimbatore, to facilitate ease in analysis and warrant response, where 127 members benefited. Similarly a method demonstration of the product was made at Tiruchirapalli in one of the subject's residence (Plate 6). The product was demonstrated in five sessions consisting of 6-7 subjects each mainly to enable individual trial runs and evaluate the products with practical knowledge. Since all of them were allowed to try the model, they found it easier to evaluate and comment on the products. The responses were consolidated. Chapter IV portrays the findings.

3. Performance impact of the selected models of moppers on end-users:

Having ascertained from the biomechanical study that mopping especially in the squatting posture is very strenuous and the posture is in fact responsible for the stress on the lumbosacral region, it was decided to evaluate the performance of samples while mopping with manual moppers and comparing the performance parameters with those obtained for conventional mopping. In order to facilitate comparison the design was formulated to include the following:

a. Job analysis of mopping using manual moppers:

i. Selection of the sample and area: The same sample was used for this comparative study too because they were well acquainted with the test procedures, remote recording of HR and the postural details. The OHS unit of BHEL, Trichy again formed, the area.

ii. Selection of the method: The test batteries framed for the task analysis were modified a little in this context. This test involved remote recording of HR while the samples operated manual moppers in the standing posture. Here, along with endurance limit, the fitness of the samples to mop until a specified time was also recorded. Since mopping until a specified time was not done earlier, here, the subjects were asked to mop in the conventional squatting posture till the lapse of a fixed time.

iii. Selection of manual moppers : The two upright models evaluated as best by the samples were chosen for comparison with performance in traditional squatting posture.

iv. Analysis of the data: The subjects were requested to record a few practical suggestions to improve the working/operating efficiency of the manual moppers used for the comparative study. Chapter IV delineates the findings recorded on the parameters studied and highlights the suggestions put forth for effecting improvement in the selected moppers.

The ensuing Figure (7) presents the conceptual framework of the study.

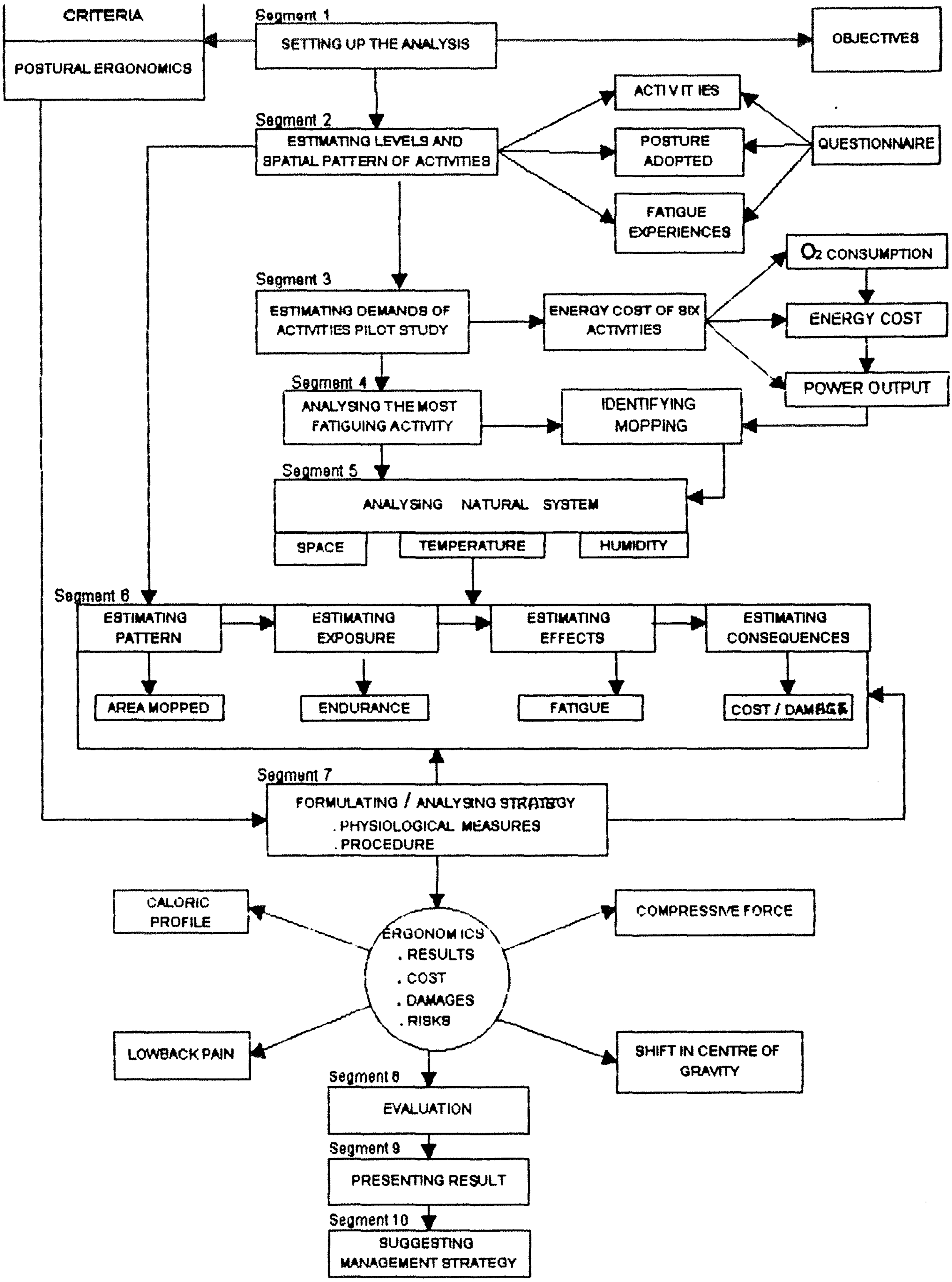


FIGURE 6. CONCEPTUAL FRAMEWORK OF THE STUDY

Results & Discussion

IV RESULTS AND DISCUSSION

The data on "Postural Ergonomic Analysis of Mopping Activity" is analysed and discussed under the following headings :

A. Activity analysis

B. Delineation of the most fatiguing task amongst the most stressful tasks

C. Outcome of the exercise test

D. Findings of the task analysis

E. Posture targetting - Angles of body bend

F. Fatigue/drudgery index of mopping

G. Stress on the musculo-skeletal system in the sagittal plane

H. Feasibility of using manual moppers

A.Activity analysis

Accepting Kothari's (1995) viewpoint on survey as concerned with conditions or relationships that exist and processes that are going on, a household survey was conducted. This enabled analysis of the household activities. The findings pertaining to the responses of 500 samples selected for the study are classified under :

1. Socio-economic profile
2. Perception on household activities
3. Satisfaction of cognitive aspects
4. Management of time as a resource
5. Management of the physical component - human energy use

1.Socio-economic profile

This aspect covers the social, educational, occupational and economic status of the selected sample.

a. Social status: Social profile of the selected sample is depicted under Table 3.

Table 3 : Social profile

Particulars	Details	Percentage of sample (N-500)
Religion	Hindu	67
	Christian	30
	Muslim	3
Household structure*	Nuclear	90
	Joint	10
Household size (according to Devadas, 1983)	Small (1-3)	72
	Medium (4-6)	18
	Large (above 6)	10
Age of homemakers (in years)	28-32	12
	33-37	6
	38-42	74
	43-47	8

Nuclear : Independent family of small units.

Joint : United family of small units, under one (elderly) head.

Hindus predominated (67 %) followed by Christians in the families surveyed. A majority of 90 per cent of the families were nuclear highlighting the gradual disappearance of joint families in the Indian society. According to the World Development Report (1995) the average household size comprised of five members, but concrete evidence for the adoption of small family norms is portrayed through the 72 per cent whose family size is below three. As regards age of homemakers the age range between 38-42 years ranked first with 74 respondents while 12 per cent were almost younger by a decade.

b. Educational status: To comprehend the socio-cultural status of the population studied, it is necessary to examine their educational level (Table 4).

3

Table 4 : Educational status

Level of literacy	Percentage of sample Heads of families	Homemakers
Literates	100	99
Literacy level		
Elementary	2	1
Middle school	18	8
Higher secondary	31	51
Graduate/post graduates	27	24
Professionals	22	15

The sample constituted high percentage of literates. The significance of education to living standards has been well understood. Their educational status, the homemakers agreed had helped to achieve self reliance and widen their comprehensive power, perception and judgement with respect to household management.

c. Occupational status: Women are emerging as a concrete workforce (Mathur, 1988). By sheer coincidence 50 per cent of the total sample (homemakers) reported to be employed.

Teaching and nursing emerged as the best vocations as represented by 34 and 30 per cent of the homemakers. Evidently the factors which influenced seeking employment corresponded to the hierarchy of needs theory postulated by Maslow (1970). The factors identified and ranked first by the homemakers belonged more to the lower-need satisfactions. Those of a higher-need gratification were realised only by a lesser proportion highlighting its subjectivity, less urgency and risk involved.

Women who do not hold a paid job are counted as labour surplus (Reddy, 1995); nevertheless, accepting career jobs, heralded a few problems. The following Table gives the representative problems put forth by the selected sample.

Table 5 : Problems encountered due to employment

Origin	Problems stated	Percentage of sample (N-500)
Personal	Physical exertion	100
	Fatigue and exhaustion	100
	Drudgery	97
	Stress	95
	Frustration	93
	Aversion to household work	92
Time related	for efficient execution of household activities	100
	to maintain house	100
	to attend to household maintenance	100
	to nurture children	100
	to attend to personal health	95
Lack of time	to indulge in recreational pursuits	86
	to entertain unexpected guests	79
	for socialization	66
	to celebrate festivals and functions	43
Human resource-related	Lack of assistance at home	100
	Nonavailability of trustworthy domestic help	100
Miscellaneous	Night shifts (duty)	30
	Leaving the house before children leave	10
	Distance of work spot from home	8

Personal factors were the predominant problems of the selected sample. Lack of time to attend to many of the household related and personal affairs, coupled with non-availability of assistance augmented the problems. Hert (1980) and Avery (1987), have rightly stated that majority of women with career experience conflict between their job and their 'home responsibilities'.

d. Economic status: According to Bhushan and Sachdeva (1994) income is the primary determinant of social stratification. The ensuing part projects the mean monthly income of the selected families.

Table 6 : Projection of the proportion of families in income levels

Categorisation*	Monthly income (range in Rs)	Percentage of respondents (N-500)
Economically weaker section	< 1250	1
Low income group	1251-2650	21
Middle income group	2651-4450	23
High income group	> 4451	55

Source of classification : Eighth Five Year Plan Norms and Ceilings (1992-1997), A Government of India Publication.

Analysis of the family income, revealed that a majority of 55 per cent belonged to the high income group followed by 23 per cent in the middle income strata.

2. Perception on household activities

The affective component of the cost of the worker input concerns with the worker's personal feelings about the activity, her attitudes, interests, preference and dislikes. Satisfaction derived shows, contributions made by her through feelings of working hard or easy. The information collected is described under:

a. Division of labour: Kashiwazaki et al., (1986) calls the household as a basic unit of production and consumption where members share their occupational and domestic works and leisure time activities depending on gender, age and role status in a household. Table 7 presents the division of labour followed in the selected households.

Table 7 : Division of household labour

	Percentage of sample					(multiple response)				
Activities	HM*	S	C	DH	Others	HM	S	C	DH	Others
Preparation and cooking	100	5	20	35	10	100	-	31	50	5
Care of others	82	18	20	70	8	76	6	12	70	2
Household maintenance	20	-	-	100	-	10	-	4	100	-
Washing clothes	66	-	10	81	24	42	15	-	92	-
Marketing	58	39	27	-	-	45	50	5	40	-

*HM = Homemaker, S = Spouse, C = Children, DH = Domestic help

Employment status and relief from household work seem to be a false dichotomy. As Kaur (1987) states despite changes in their roles outside the home, homemakers were yet responsible for household chores. Household maintenance was the sector for which homemakers depended mainly on employed help.

b. Attitudes and mindsets towards performance of household tasks:Attitudes are subjective attributes of people (Mc Cormick and Tiffin, 1979). They label the affective component as 'attitude'. Almost all the household activities performed by the homemakers, are drudgery and stress-causing opine Deol and Dhesi, (1976) and Kalbagh, (1992). Therefore the perception of homemakers about preference for household activities was solicited and is presented under Table 8.

Table 8 : Attitude towards household responsibilities

Activities	Percentage reporting activities disliked	Reasons for dislike
Care of children and family	12	Strain
Cooking	36	Monotony
Preparation for cooking	43	Monotony
Washing clothes	68	Strain and posture
Washing utensils	70	Strain
Marketing	70	Not enjoyable
Gardening	77	Not interested
Bedmaking	78	Monotony
Sweeping	83	Health grounds
Ironing	85	Strain
Mopping	90	Strain,posture and time involved

For 12 per cent of the homemakers care of children and other family members was a source of stress and strain which culminated in a dislike for the activity. Preparation for cooking in the Indian condition which involves a host of powdering, grinding, rolling, and scrapping failed to cater to the taste of 43 per cent of the homemakers. Ultimately 'mopping' of floors(90 %) emerged as the most disliked activity. Steidl and Bratton (1980) had pointed out household cleaning being disliked for obvious reasons like being tiresome, time consuming and frequency of performance. Ramapaduka (1986) and Bharathi and Jacintha (1994) also in their studies had found homemakers relating mopping as the most strenuous and disliked of tasks among all household tasks. Washing clothes and mopping were mainly disliked for their respective strenuousness and posture adopted during performance. So, it is evident that posture is a source of fatigue.

3. Satisfaction of cognitive aspects

The cognitive component describes the contribution of thinking using knowledge and defining goals. It serves two functions - first, to plan and coordinate the use of external resources and secondly, to bridge the gap between the goal and its accomplishment. Here, the homemakers analyse the various inputs and outputs.

a. Domestic help enjoyed: Employing servant maids is a characteristic feature of a 'feudal society' opine Manohar and Shobha, (1983), but the situation had changed during this decade. Collected data proved 80 per cent of the homemakers (cumulative) enjoy assistance from paid help. Among employed homemakers 84 per cent had engaged domestic help. Factors of employment of paid help and family income did not show association but a high significance between monthly payments to maids and family income levels was found evident. This feature highlights that payment to maids (monetarily) is directly proportional to the family income level.

As explained earlier the helpers were completely entrusted with the activities of washing dishes and clothes, sweeping and mopping and yard cleaning. The findings support Gupta's (1990) observations. Senior (1975) and Hemalatha (1988) also found that regardless of the plan of residence, homemakers used the available help for cleaning and care of the house more than any other type of service.

b.Goals and aspirations identified: The survey revealed that the homemakers were mentally rich in their goals and aspirations for future. Goals and standards of families are undergirded with values held state Deacon and Firebaugh, (1988). Among those listed out values of good health, prudence, perseverence, realization of goals, security, religion, responsibility, resourcefullness, good planning, strong family relations, enjoyment and love and affection were cherished by all.

c. Gratification of housing requirements: With reference to housing the survey revealed 48 per cent to be living in BHEL quarters,* 28 per cent in own houses and 24 per cent living in rented houses. Naturally the housing conditions differed. Therefore it was felt necessary to enquire about the physical characteristics of the houses (Table)

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* Quarters : The residential building owned by the company and given to its own employees at a subsidized rent.

Table 9 : Physical characteristics of houses

Particulars of the house	Percentage stated as satisfied
Adequacy of area	70
Copious/potable water supply	70
Space organisation	68
Allocation of area considered	65
Spacious rooms	65
Proper circulation ensured	65
Privacy assured	65
Structural aspects	62
Bathrooms of adequate size	59
Good flooring	55
Convenient placement of toilets	48
Provision of bath/toilets consistent with the size of the family	47
Proper drainage ensured	45
Kitchen counters at comfortable height	40
Convenient kitchen counters	40
Adequacy of storage facility	38
Space for gardening	35
Proper set-back for the house	28
Thermal comfort	12
Comfortable kitchen	9

Living environment which includes the major aspects of housing contributes not a little to one's health. According to Moorthy (1982), the fundamental psychological needs of privacy, family life, avoidance of fatigue in household tasks and cleanliness should be provided for better life. It was observed that the minimum carpet area of rooms (except kitchen

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Living environment which includes the major aspects of housing contributes not a little to one's health. According to Moorthy (1982), the fundamental psychological needs of privacy, family life, avoidance of fatigue in household tasks and cleanliness should be provided for better life. It was observed that the minimum carpet area of rooms (except kitchen and bath-cum-toilets) was 100 sq.ft. The data revealed that the livability aspects of the house gratified only approximately two-thirds of the sample, while the factors relating to convenience of working, especially ergonomic aspects were not upto the expectations. The structural aspects, similarly, were also not found to be satisfactory.

d. Possession of labour saving devices: Hardinge (1973) had stated that while muscular work greatly strengthens physical power, many inventions have left little use for the use of muscles. To find out if this is true with the selected group an inventory of the major electrical appliances possessed by the homemakers was elicited.

The homemakers had preference for appliances that saved labour involved in activities of cooking (grinding, pounding and blending) followed by ironing. The other activities for which they required automation was washing clothes and household maintenance. Unfortunately appliances to reduce the stress of mopping has not yet been much commercialized.

Among the non-electrical appliances those which almost 90 per cent of the homemakers possessed were gas stove, pressure cookers, pressure pan, milk boilers, egg beaters, iddli cookers, hand toasters and casseroles (for keeping food warm). The reasons attributed for possession of both types of appliances were to save time and energy expended on household activities and to reduce feelings of drudgery associated with certain tasks.

Household work has been described by Devi, (1987) as being almost void of cognitive aspects due to its respective fragmented nature. But the knowledge and perception of the selected homemakers on the aspects discussed above do not support the statement. It is considered therefore, that household work is an area which provides a wide range of cognitive aspects which demand global consideration. So, as Gita, (1989) explains when assessing the work of women, three important considerations must be borne in mind. They are : (i) the limited physical facilities available for simplifying work, (ii) the additional burden of physical work (for gainful employment) and (iii) the limited time available for housework.

4. Management of time as a resource: Time is classified under temporal component. An objective of studying this component of the cost of work is to identify those factors which affect the utilization of time for various household tasks and the resultant energy expenditure. This part covers :

a. Time expenditure pattern: In order to calculate the energy expended for physical activities it is necessary to keep an accurate record of the kind and duration of all activities. It was clear that fulltime homemakers expended more time comparatively on cooking (150-180 min), preparation for cooking (60-120 min) and cleaning utensils (30-60 min), while employed women had to 'ration out' the available time on priorities (90-110, 35-60 and 35-40 min respectively). Irrespective of their employment status all of them agreed to be spending on an average 30 minutes daily on sweeping and mopping respectively. No wonder Deacon and Firebaugh (1988) classify cleaning surfaces under psychomotor resources.

The World Development Report (1995) states that the conventional definition of 'work' mischaracterises relative effort, because time allocated to household activities is rarely counted. The researchers who put forth the HDR (Human Development Report) prepared by the UN Development Programme distinguish non-economic activities from economic activities, where the latter is again classified as market oriented (included in the SNA System of National Account) and non-market oriented activities (non-SNA eg: household chores) and information about time allotted to all economic activities was calculated which pointed out that, of the time spent by women in economic activities, 66 per cent is in the non SNA work and 34 per cent in SNA work (Reddy, 1995). The selected sample prove that their contribution is more to non SNA work.

b. Peak load experiences: All the homemakers interviewed experienced peak loads in the morning when the house is agog with activity. The difference was mainly observed with the timings of peak loads. The reasons cited centred around the cultural demands which forced them to undertake multiple jobs at-a-time like cooking combined with household cleaning, washing of clothes and personal affairs. The associated problems of domestic help for instance, absenteeism or late arrival - added to the situation. Such a plethora of problems created peak loads for the homemakers.

The homemakers agreed to be efficiently managing peak loads through proper pre-planning of activities, 'sandwiching' activities, simplifying tasks of cooking, completing a few tasks during weekends and holidays and the like.

c. Management of time: Management of work time is an efficient method of conserving energy. Strategies adopted are given under Table.

Table 10 : Factors contributing to management of time

Factors	Percentage of sample
Use of labour saving devices	92
Employing paid help	86
Cooperation of family members	73
Simplification of work methods	67
Maintaining mental work plans	41
Prioritizing activities	40
Discharging duties energetically	35
Small family size	15

Factors highlighted stand testimony to the truth that the homemakers are intellectually experienced to manage this limited resource in the most appropriate manner possible.

5. Management of the physical component - human energy use

The component is widely concerned with the physical cost of the work. The cumulative effect of the homemaker's talent to tackle the needs of the family and how it gets done are analyzed to pinpoint the natural sequel of efficient management on the physiology of the homemakers. This aspect therefore analyses the ergonomic stress, fatigue experience and perception of fatigue of the homemakers.

a. Ergonomic stress: Ergonomics literally means the customs, habits and laws of work, where the benefits are measured in terms of human comforts, efficiency and well-being. According to Shramsakthi (1987) physical stress is caused by postures, which is a primary factor in ergonomic studies. Ergonomic stresses can impair the health and efficiency of the worker as significantly as other environmental stressors. The reasons for ergonomic stress includes restricted movement, unusual position and twisted/contorted postures in the work place which affect health. The consequences are purely physiological. So, a direct enquiry was made and is discussed under :

Posture adopted while performing activities: To avoid strain and to develop good body carriage it is understood that attention should be given to good posture while at work. Table 11 presents details on posture adopted while performing tasks.

Table 11 : Posture adopted while performing activities

Activities	Percentage of sample			
	Posture adopted			
	Standing	Sitting	Squatting	Bending
Cooking	100	-	-	-
Sweeping	100	-	-	-
Cleaning utensils	100	-	-	-
Preparation for cooking	72	18	10	-
Washing clothes	53	-	47	-
Ironing clothes	67	-	33	-
Mopping	-	-	71	29

Standing posture was preferred while cooking, cleaning utensils and sweeping. For individual groups of 71, 47 and 33 per cent of the sample, squatting was the liked posture for mopping, washing clothes and ironing clothes respectively. For 29 per cent alone bending was preferable to all other postures while mopping. The activity itself was reported to be difficult because of the conventional stressful posture they adopted.

b. Fatigue experiences: Time and motion studies cannot solve the problem of activity analysis because the demand for energy cannot be described in terms of force into distance. Therefore it is necessary, to qualify human physical effort in terms of amount of physiological strain. Fatigue was experienced only in the evening and night, after all work was completed. Fulltime homemakers did not complain as much as the gainfully employed. It is really difficult to gauge the subjectivity or objectivity of fatigue as related to household activities. The interrogations made on this score are presented under Table. The statements ascribe feelings as related to the 'activities stated as highly fatiguing'.

Table 12 : Perception of drudgery related to household work

Activities	Percentage stating (as per ranking) Perception on drudgery		
	Highly fatiguing	Moderately fatiguing	Not at all
Mopping	100	-	-
Washing clothes	100	-	-
Ironing clothes	100	-	-
Sweeping	100	-	-
Cobweb removal and dusting	100	-	-
Grinding masala	88	12	-
Child care	80	20	-
Rolling chappati	79	21	-
Washing utensils	63	17	20
Cooking	38	62	-
Care of family members	7	20	73
Marketing	-	100	-

The activities identified as highly fatiguing 'Una Voce' are mopping and cobweb removal, washing clothes, ironing, and sweeping (as per the ranking given by the subjects). Seventy three per cent expressed care of family members as light.

Perception is a subjective phenomenon and varies with individuals; but these individual images come together to form group images (Gould and Lewis, 1985). So the feelings of the homemakers reflect their true experiences which gain shape through the symptom they identify as fatiguing because of the posture and dislike for the activity. Since mopping has emerged as the most stressful task (as per homemaker's ranking) the major factors causing fatigue while mopping are elicited.

Table 13 : Triggering factors of fatigue as related to mopping

Causal factors	Percentage of sample
Posture adopted	100
Activity causes physical pain	100
Muscular effort	100
Dislike for the task	100
Time involved in the job	93
Space available for work	90
Interruption in work	90
Job is monotonous/uninteresting	87
Ill-health	84
Stressful situations	80

Totally 10 fatigue - triggering factors as related to mopping were identified. Human fatigue is a blanket term. Srivastava (1985) described drudgery as mental and physical strains, fatigue, monotony, helplessness, pain and other stresses. Singh and Bhattacharya (1990) also project physical and mental fatigue as indicators of drudgery kindled by stress. It can be concluded from what the homemakers have cited that the net result of their feelings of such fatiguing situations is drudgery. Table 14 provides succinct information on the measures adopted by them to alleviate fatigue.

Table 14 : Measures adopted to alleviate fatigue

Measures adopted	Percentage of homemakers
Substitution of machinery	98
Effecting changes in task	73
Creating interest in the work itself	71
Alternating light and heavy job	50
Provision of rest period	32
Careful planning	32
Improve routing of work	30
Elimination of unnecessary steps	28
Effective muscle involvement in work	27
Proper posture adoption	27

The measures adopted were multiple and varied. These factors prove that the homemakers were well aware of the physiological strain that household activities induced. Only 27 per cent had thought effective muscle involvement and good posture could help alleviate fatigue. But it was evident that they had identified the main factor, triggering fatigue as 'the task itself'. So the programme to analyse the task for strenuousness is justified.

B. Delineation of the most fatiguing task amongst the most stressful tasks

The situation analysis brought to light six activities as highly fatiguing other than child care; since child care cannot be standardized under laboratory conditions, focus was laid on the other six, namely washing clothes, ironing clothes, rolling chappati, grinding, sweeping and mopping. Apropos, the pilot study to identify the tasks and techniques was done and the findings are described under:

1. Response to ergometry: The parameters recorded while the ten selected subjects performed on an ergometer are discussed under:

a. Resting values for physiological parameters: The mean values for the three major physiological parameters in the subjects' resting state are presented under Table.

Table 15 : Mean resting values for physiological parameters

	Posture		
Particulars	Standing	Squatting	Resting on chair
Heart rate (bpm)	85.1	78.9	82
Skin temp (°C)	34.4	34.4	34.4
Mean arterial BP	90.7	86.7	88.7

The data proved minor changes in posture to cause deflection in the HR and BP profile of the subjects. Hanson and Jones (1970) complain that consideration of small postural changes taking place during an experimental session or the differences in habitual posture (from subject to subject) as being least reported. Increment in HR has been accepted as a measure useful for even small changes in posture which help to highlight the action potentials of the cardiac muscle.

b. Physiological responses to ergometry: Table 16 presents details on the same. Individual observations are presented under Appendix (X).

Table 16 : Physiological responses to ergometry

		Submaximal loads (watts)					
Parameters	Resting value	20		30		40	
		Mean change	% above resting	Mean change	% above resting	Mean change	% above resting
Heart rate(beats)	82	126	53.7	135	64.6	145.5	77.3
Skin temperature(°C)	34.4	-.3	0.87	-.2	0.58	-.2	0.58
Actual VO_2 ($l.min^{-1}$)	0.20	0.05	25	0.17	85	0.29	145

The samples pedalling on the ergometer displayed considerable increment in their HR profile. Variations showed linear increase in HR to corresponding increase in loads. This proved that HR and subsequently VO_2 showed linear increases with muscular effort. On the other hand skin temperature (though negligible) showed only decrease. The corresponding oxygen consumption (VO_2) for given loads was referred from the Table for VO_2 (Podlesak, 1982). Having established that HR and VO_2 show linear increase with work loads, it was decided to develop a regression curve as a data base using the information presented in Table 16.

2. Developing a regression line and interpolating HR values for performance

The HR was correlated with work loads, expressed usually in watts. A regression curve was drawn from the HR_w recording in the submaximal loads and the corresponding values of VO_2. The HR-VO_2 regression line drawn for all the samples was corrected for external influences by translation to resting values by calculating the resting VO_2 based on body surface area using the formula of Banerjee et al., (1958). Thus the regression line obtained by ergometry provided the individualized HR-VO_2 slope (which depended on the individuals fitness parameters) and the resting value provided the Y axis intercept. Thus a linear regression line for HR and VO_2 was established by plotting the resting HR and VO_2 parallel to the original HR-VO_2 regression line. This provided the base line to plot the mean changes in HR for each activity, while the corresponding line for VO_2 gave details on the O_2 consumption incurred with performance of all the six activities in the two postures (Appendix XI). The mean arterial BP was calculated based on the formula suggested by Grollman (1974) and Cromwell et al., (1991) given in Appendix (VI).

3. Physiological responses to six selected household activities: The responses displayed were tabulated and are presented under Table 17.

Table 17 : Physiological responses to six selected household activities

Activity	Posture	Physiological responses Incremental HR Mean	SD	Paired t value	Arterial BP Mean	SD	Paired t value	Skin temperature Mean	SD	Paired t value
Ironing	Standing	12.0	6.50	3.75**	-4.78	6.25	3.23**	0.50	0.64	0.38
	Squatting	18.9	9.97		4.93	8.39		0.44	0.58	
Rolling chappati	Standing	18.0	8.97	1.26	-1.77	7.55	1.83	0.37	0.82	0.58
	Squatting	20.9	9.21		3.41	7.38		0.48	0.56	
Grinding	Standing	28.5	10.34	1.10	2.73	3.47	1.49	0.16	0.67	1.70
	Squatting	31.3	8.19		6.81	6.94		0.50	0.45	
Sweeping	Standing	27.8	12.36	3.76**	4.11	7.27	2.74*	-0.02	0.88	1.58
	Squatting	39.5	11.14		13.14	9.29		0.17	0.60	
Washing clothes	Standing	26.7	8.78	1.06	4.35	3.86#	5.06**	0.75	1.19	0.59
	Squatting	30.9	7.48		13.40	5.44		0.53	0.83	
Mopping	Standing	37.2	7.66	0.74	5.98	6.24	3.62**	0.32	1.00	1.17
	Squatting	41.9	13.28		14.20	8.20		0.46	0.79	

* Significant at 5% level   ** Significant at 1% level
# Results on par with the findings of Oberoi and Miglani (1984)

Among the activities studied, the subjects showed statistically significant variation in terms of incremental HR for sweeping and ironing alone, but significance was evident for four activities with regard to arterial BP. Activity wise, ironing and rolling chappati do not influence cardiac responses. For all others physical exertion is more. Table 18 reveals that sitting or squatting for all activities raised the HR above resting considerably well. While arterial BP also showed notable change, skin temperature showed only a negligible change. Since the physical environment was conducive enough ergonomically the subjects would not have generated more heat (25^{o} C and 55% T and humidity respectively).

4. Details on oxygen consumption and energy expended: Subsequent to the plotting of the individual HR for activities the VO_2 incurred was interpolated and calories expended commuted.

Table 18 : Distribution of subjects based on caloric profile

Activity	Mean $\dot{V}O_2$ (l.min^{-1})		Posture Energy expended (K.cals/min)				Paired 't' value	Power Output*
	St.	Sq.	Standing		Squatting			
			M	SD	M	SD		
Ironing	0.45	0.45	2.25	0.57	2.47	0.74	0.10	light
Rolling chappati	0.57	0.53	2.79	1.02	2.69	1.02	1.13	light
Grinding	0.64	0.64	3.21	1.02	3.22	0.67	0.06	light
Washing	0.52	0.55	3.10	1.07	3.84	1.06	1.07	light
Sweeping	0.63	0.66	3.14	0.85	3.43	0.96	1.08	light
Mopping	0.82	0.92	3.99	1.43	4.69	0.85	2.25 ($p<0.05$)	Moderately heavy

*Source : Sen (1969) Appendix (X)

The calculations projected that mopping followed by sweeping is the most taxing activity in terms of VO_2 and calorie consumption among the six activities chosen for the experimental study. Mopping was the only activity for which interposture variation was observed with regard to energy expenditure and was classified as being moderately heavy on the homemakers as per standardized norms. Other factors being equal, 'posture' influenced energy expenditure. Therefore mopping activity was adjudged as the one that warranted indepth study. Since the activity demands both torsal and pedal effort too in tune with postural adaptation, this 'task analysis' threw light to focus on an ergonomic study of the concerned activity in terms of its postural influence on cadiovascular dynamics, posture analysis and compressive load on the system.

Now that it is proved that VO_2 profile of the sample can be estimated using regression lines incorporating HR and $\dot{V}O_2$ (both from published sources and from body surface area of subjects) decision was taken to arrive at O_2 consumption data by translating the values obtained for ergometry to a reliable regression equation which can be successfully applied on the selected sample. This was the technique identified for the study.

C. Outcome of the exercise test

The physiology of cardiopulmonary exercise testing states that to determine the extent of exercise limitation and work impairment, an incremental exercise test can estimate the subject's short burst work capacity ($VO_{2(max)}$), and the magnitude of endurance work the subject can perform. From the details recorded by the printer while the eight selected subjects performed on a cycle ergometer - gas analyser monitor, the following inferences were arrived at as explained under :

1. Performance criteria
2. Human performance indices
3. Evolving a data base - a regression equation

1. Performance criteria:Table 19 depicts details on performance criteria of the selected sample.

Table 19 : Performance criteria

Particulars		Responses of sample (serial no.) 1	2	3	4	5	6	7	8
Endurance (time in s)		210	150	330	330	120	360	300	210
Work accomplished	Watts	31	31	60	60	30	45	45	30
	KPM	190	189	365	366	183	277	272	185

Inter-individual variation in performance criteria was observed. It was evident that with increased endurance, work output showed linear increase. Maximum work that the subjects could endure was 30 watts which was achieved when they reached 85 per cent of their maximal aerobic power. This projects that at a specific time the subjects will not be able to perform a task typically exceeding 30 W in power equivalents.

2. Human performance indices: The physiological indices recorded were analysed and explained in Table 20.

Table 20 : Human performance indices

	Serial order of subjects							
Indices recorded	1	2	3	4	5	6	7	8
Heart rate (bpm)	107	111	137	135	122	157	137	126
Ventilation (L)	19.50	23.36	32.22	25.98	29.59	24.81	14.27	44.20
VO_2 ($ml.min^{-1}$)	562	639	1023	810	807	650	467	770
VCO_2($ml.min^{-1}$)	416	298	752	771	724	662	456	802
VO_2 /Kg	10.05	10.04	14.61	13.39	9.49	11.53	7.56	11.46
O_2 pulse ($ml.beat^{-1}$)	5.23	5.74	7.47	6.02	6.62	4.13	3.42	6.13
RQ (RER)	0.74	0.47	0.74	0.95	0.90	1.02	0.97	1.04

Among the samples, subjects 3,4 and 6 were found to be comparatively better off in their physical fitness than the others. They could withstand upto 60, 60 and 45 watts respectively though they did not display a steady performance. This also proves that HR increase is linear with endurance. Though subject 7 also appeared to be withstanding upto 45 watts she became steady when she reached 30 watts. It is clear that under standard conditions irrespective of their physical fitness the samples would perform more or less in the same manner showing almost uniform changes in physiological indices.

3. Evolving a data base - a regression equation

The details on HR and VO_2 (68 observations) obtained for all the eight subjects on various submaximal loads were used as inputs to two separate linear regression programmes (a) the LOTUS 1-2-3 and (b) linear least square regression in BASIC (LSR). Both the programmes gave a collective HR-$\dot{V}O_2$ slope (Appendix XI). The regression equation for VO_2 ($ml.min^1$) obtained from the two methods are :

a. $\dot{V}O_2$ = [6.899273 x (HR) - 273.174] [Lotus] - Equ. 1

b. $\dot{V}O_2$ = [7.895298 x (HR) - 403.0145] [Basic] - Equ. 2

These two programmes were tested for reliability using correlation and t test (Appendix V). Based on the t values, LSR was chosen and this regression equation was made use of, to estimate VO_2 of all the 32 samples. Individual observations are presented under Appendix (XII). $VO_{2(max)}$ and max HR (for all) were estimated using the regression equation used by the computer and presented under Appendix (XII).

D. Task analysis

With the understanding that physiological measurements provide for efficient evaluation of physical work load, this aspect is dealt under the following headings:

1. Physiological responses to mopping a specific area
2. Details on endurance

1. Physiological responses to mopping a specific area: Energy expenditure is an objective, but, classical work physiology parameter (Jorgensen,1985), which can be measured indirectly rather easily from HR and $\dot{V}O_2$. Therefore the HR was telemetered while the samples performed the activity, that is, mopping a specified area of 9.2 sq.m. The details computed from the records of HR for all the 32 subjects are presented under:

a. Work time: The mean time the samples spent, for mopping the specified area was recorded and is presented under Table 21 and Figure 8.

Table 21 : Work time for mopping 9.2 sq.m

Work time (s)	Posture Bending % of sample (N=32*)	Mean	S.D	Squatting % of sample	Mean	S.D	Paired t value
1 - 30	25.0	45	21.12	12.5	52.2	17.04	
31 - 60	56.2			68.8			2.40
61 - 90	12.5			18.7			(p<0.05)
91 & above	6.3			-			

* Unless otherwise specified N = 32

The observation revealed that a majority of 80 per cent could complete mopping the specified area within 60 s. It was also clear that more than 55 per cent required between 31-60 s to perform the same. Another observable feature was that a section of the sample took more than a minute to finish working on the specified area in the bending posture. Naturally they were more consistent (CV=32.6%) in the squatting posture. The variation between postures was found to be significant.

b. Working pulse: The mean record of HR for the time of activity to complete mopping the specified area is presented under Table.

Table 22 : Working pulse while mopping 9.2 sq.m.

Working pulse (beats)	Posture Bending % of sample	Mean	S.D	C.V. %	Squatting % of sample	Mean	S.D	C.V. %
96-105	18.8	118.6	13.2	11.1	-	122.2	10.8	8.9
106-115	25.0				31.2			
116-125	31.2				34.4			
126-135	12.5				25.0			
136-145	12.5				6.3			
Above 146	-				3.1			

The working pulse of 70 per cent of the sample ranged between 116-146 beats. For 34 per cent of the sample a remarkable recording between 126-146 beats was noticed in the squatting posture. As per the CV value the samples seem to be more uniform in their working pulse (8.9%) in the squatting posture.

c. Incremental work pulse: The data obtained for incremental work pulse (for performance) of the activity in the two specified postures is classified under Table and Figure 8.

Table 23 : Incremental work pulse for mopping 9.2 sq.m

Incremental workpulse (beats)	Posture								Paired t value
	Bending				Squatting				
	% of sample	Mean	S.D	C.V. %	% of sample	Mean	S.D	C.V. %	
15-24	6.2	42.5	10.85	25.3	-	46.1	10.50	22.7	2.27 (p<0.05)
25-34	9.4				9.4				
35-44	46.9				37.5				
45-54	21.9				37.5				
55-64	15.6				9.4				
65-74	-				6.2				

For performing the activity in the bending posture the range of increase above resting noticed was between 15 to 64 beats with a majority lying between the 35 to 44 range (46.9%). When compared with the incremental work pulse too, more than one half (53 %) of the samples showed an augmentation in heart beat from 45 to 74 in the squatting posture. Performing in this posture though was found to be the habitual one, reality proved that it tended to increase the strain on the cardiovascular system. It is worth observing that none of the samples recorded the minimal range of increase (15 to 24 beats) in the squatting posture. To analyse as to what extent the activity has augmented HR in terms of per cent above resting was calculated. Table 24 and Figure 8 present the data.

Table 24 : Percent increase in work pulse above resting base

Percentage increase above resting base	Percentage of sample Posture Bending	Mean	S.D	Squatting	Mean	S.D	Paired t value
21 - 40	12.5	56.47	14.91	6.3	62.91	18.27	
41 - 60	40.6			50.0			
61 - 80	43.8			31.1			2.38
81 - 100	3.1			6.3			($p<0.05$)
Above - 101	-			6.3			

The distribution was more compact in the bending posture than with the other one. Therefore the data plotted against work time to identify if time factor had influenced this variation, showed nonsignificance. Hence work time could not have influenced these results.

Analysis done to find out association between work pulse and selected independent variables (age, stature etc) proved nonsignificance between the variables.

Varieties of physical work can be classified into dynamic and static depending upon the level of movement, number of repetitions within a single work cycle or absolute changes in body posture during exertion. While pure static work is rare in every day life and in most activities, there is no type of work without some static component, for instance, stabilization work and/or maintenance of posture; so it is an important determinant for local muscle fatigue in types of moderate or heavy dynamic work. Mopping as such involves both static and dynamic components.

Models which are available for comparison (stature, body size and resting HR) are predominantly for dynamic work. The models are not valid in a posture where there is a high static component involved; time also is not controlled. That might have had an effect on the work pulse and the two factors of 'posture' and 'time' would have contributed to this. If time had been controlled like area, the two variables - body size and work pulse - could have shown significant correlation.

d. Working VO_2 : The demand for oxygen incurred for mopping in the two different postures is presented under Table 25.

Table 25 : Working oxygen consumption

Oxygen consumption (VO_2)	Posture							
	Bending				Squatting			
	% of sample	Mean	S.D	C.V. %	% of sample	Mean	S.D	C.V. %
Range (l.min^{-1})								
0.35-0.44	21.9	0.53	0.10	19.5	-	0.56	0.09	15.2
0.45-0.54	31.3				56.8			
0.55-0.64	28.1				25.0			
0.65-0.74	18.7				15.1			
0.75 and above	-				3.1			
Range (ml.kg.$^{-2/3}$ min^{-1})								
11 - 20	3.1	34.3	7.10	20.4	-	36.1	5.9	16.2
21 - 30	25.0				15.6			
31 - 40	50.0				62.5			
41 - 50	21.9				21.9			

$\dot{V}O_2$ required when classified based on both the units (l.min^{-1} and ml. kg$^{-2/3}$ min^{-1}) exposed none of the samples to consume the minimal range (0.35 to 0.44 or 11 to 20 respectively) in the squatting posture. Another characteristic feature noted was that almost 56 per cent of the sample consumed only between 0.45 to 0.54 l.min^{-1} for the activity but while expressed in terms of ml kg$^{-2/3}$ min^{-1}, more than 80 per cent expended between 31 to 50 (in the squatting posture) as against 72 per cent who consumed that much in the bending posture. In order to locate which factor induced these results the following factors were determined.

i. Rate of work for mopping 9.2 sq.m

ii. VO_2 for the incremental work pulse

i. Rate of work for mopping 9.2 sq.m: The details are presented under Table 26 and Figure 8

Table 26 : Rate of work for mopping 9.2 sq.m

Rate work (sq.m/min)	Posture								Paired t value
	Bending				Squatting				
	% of sample	Mean	S.D	C.V. %	% of sample	Mean	S.D	C.V. %	
5.1 -10	21.9	14.66	6.0	40.6	40.7	11.76	4.00	34.0	3.72 (p<0.01)
10.1-15	34.3				43.7				
15.1-20	28.1				12.5				
20.1-25	6.3				3.1				
Above 25.1	9.4				-				

Though according to the previous table the working VO_2 was comparatively higher for the squatting posture, in reality the rate of work was found to be lower in that posture. Almost 80 per cent performed only at the rate of 5.1 to 15 sq.m. min^{-1}. Though in a negligible proportion (9.4%) evidence of performance to the tune of more than 25 sq.m. min^{-1} was recorded in the bending posture. None of the individual attributes (body size, body fat, age etc) when correlated with rate of work showed significance. But a striking feature was that body size Vs rate of work in the bending posture showed a very low degree of negative correlation while the same in the squatting posture showed a mild correlation in the opposite direction. The samples presumably were very slow in action in the squatting posture. Table 27 analyses its relationship to the actual work time. The greater the proportion of mechanical energy to go into static effort, the lower the efficiency. This is particularly true opines, Grandjean (1985) that when work is carried on with a bent back there is more stress on the operator. Energy consumption by static muscular effort is distinctly more tiring than if it is applied to dynamic work.

Table 27 : Work time Vs rate of work

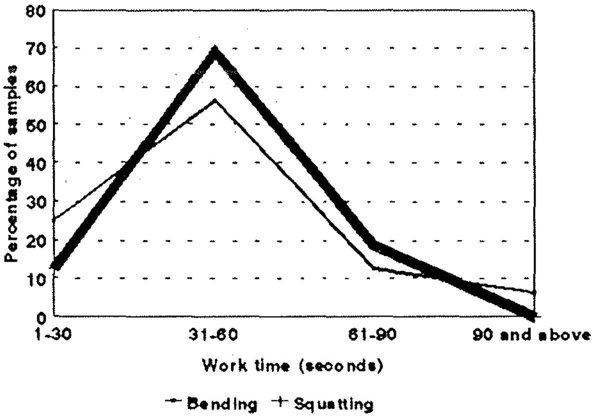
Work time (s)	Posture B-Bending S-Squatting	Percentage of sample Rate of work (sq.m.min^{-1}) 5.1-10	10.1-15	15.1-20	20.1-25	above 25.1	'r'
1-30	B	-	-	9.4	6.3	9.4	-.8887
	S	-	-	9.4	3.1	-	-.9109 (p<0.01)
31-60	B	3.1	34.3	18.7	-	-	
	S	21.9	43.8	3.1	-	-	
61-90	B	12.5	-	-	-	-	
	S	15.6	-	-	-	-	
91 and above	B	6.3	-	-	-	-	
	S	3.1	-	-	-	-	

Statistical analysis proved high significance between the two variables in both the postures. The only feature was that it helped to identify the aspect of rate of work which significantly influenced the working $\dot{V}O_2$. Evidently the significance was in the expected direction; when work time increased, the rate of work decreased.

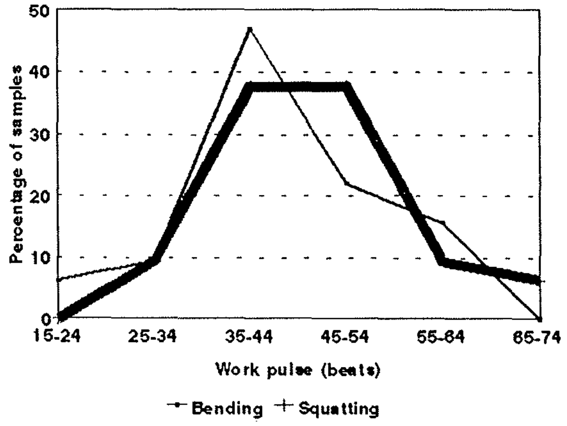
ii. Oxygen consumption for incremental work pulse : Table 28 throws light on the actual intake of oxygen over and above the resting base for mopping 9.2 sq.m of area for the actual work time.

Table 28: Incremental oxygen consumption (9.2 sq.m)

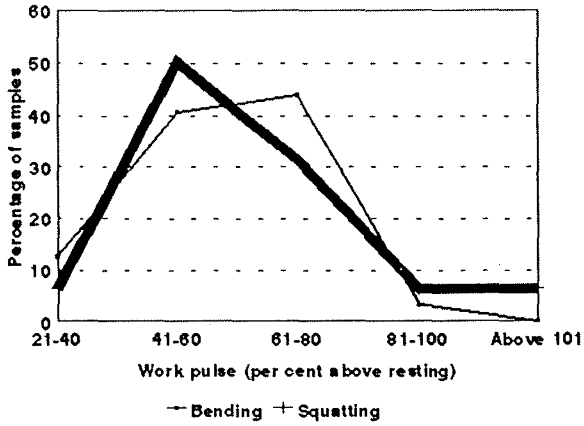
	Posture						
Incremental VO_2 (l)	Bending % of sample	Mean	S.D	Squatting % of sample	Mean	S.D	Paired 't' value
0.01-0.10	9.4	0.26	0.15	-	0.32	0.14	
0.11-0.20	34.4			21.9			2.61
0.21-0.30	28.2			31.2			(p<0.01)
0.31-0.40	12.5			21.9			
0.41-0.50	6.2			9.4			
0.51-0.60	3.1			12.5			
0.61-0.70	6.2			3.1			



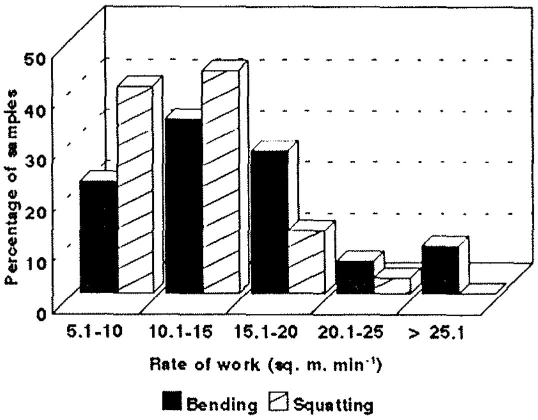
Work time



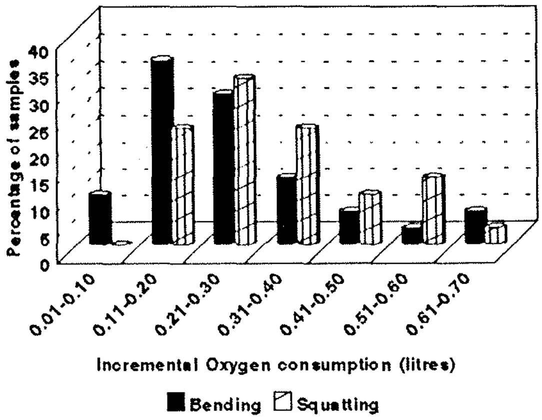
Incremental work pulse



Per cent increase in work pulse



Rate of work



Incremental oxygen consumption

Fig.8.Performance characteristics while mopping 9.2 sq.m

While almost four-fifths of the sample were spread out in the, below 0.40 l., range in their O_2 requirement in the bending posture, three-fourths joined them in the range in the squatting posture (Fig 8). Exactly one-fourths of them required between 0.40-0.70 l. in the squatting posture. To a certain extent it can be assumed that between the postures studied for a lower rate of work squatting posture demands more oxygen than the other. Any way, to highlight possible association correlation analysis was done (Table)

Table 29: Rate of work versus actual incremental oxygen consumption

Rate of work (sq.m/min)	Posture	Percentage of sample Oxygen consumption (l) 0.01-0.10	0.11-0.20	0.21-0.30	0.31-0.40	0.41-0.50	0.51-0.60	0.61-0.70	r value
5.1-10	B	-	-	3.1	3.1	6.3	3.1	6.3	-.8326
	S	-	-	9.4	12.5	3.1	12.5	3.1	-.7641
10.1-15	B	-	6.3	18.7	9.4	-	-	-	(P<0.01)
	S	-	9.4	21.8	9.4	6.3	-	-	
15.1-20	B	-	21.8	6.3	-	-	-	-	
	S	-	9.4	-	-	-	-	-	
20.1-25	B	3.1	3.1	-	-	-	-	-	
	S	-	3.1	-	-	-	-	-	
Above 25.1	B	6.3	3.1	-	-	-	-	-	
	S	-	-	-	-	-	-	-	

The data revealed a higher degree of negative correlation between rate of work and oxygen consumption. The above revelation points out that they are inversely proportional to each other. The relationship was more so comparatively in the bending posture.

Work time Vs actual incremental VO_2 : The association between the variables is presented in Table 30.

Table 30 : Work time versus actual incremental oxygen consumption

Incremental VO_2 (ℓ)	Percentage of sample Posture Work time (in s) 0 - 30		31 - 60		61 - 90		91 and above		r value	
	B	S	B	S	B	S	B	S	B	S
0.01-0.10	9.4	-	-	-	-	-	-	-	.9151	.8238
0.11-0.20	15.6	12.5	18.7	9.4	-	-	-	-	(p<0.01)	
0.21-0.30	-	-	28.1	31.3	-	-	-	-		
0.31-0.40	-	-	9.4	21.8	3.1	-	-	-		
0.41-0.50	-	-	-	6.3	6.3	3.1	-	-		
0.51-0.60	-	-	-	-	3.1	12.5	-	-		
0.61-0.70	-	-	-	-	-	3.1	6.3	-		

Table indicates 28.1 per cent to be clustered in the mean work time (45 s) and mean VO_2 (0.26 l.) in the bending posture and 21.9 spread over in the mean work time (52.2 s) and mean VO_2 (0.32 l.) in the squatting posture. Between postures the variables indicated significance at 1 per cent level (.6286). The Table also shows a neat scatter of subjects and therefore proves that in both the postures the incremental VO_2 is directly proportional to work time.

e. Energy expenditure: The energy expended for performing the activity was calculated based on the values obtained for VO_2 and is discussed under:

i. Incremental energy expenditure for mopping a specified area

ii. Total energy expended for mopping a specified area

i. Incremental energy expended for mopping a specified area : The energy expenditure calculated pertaining to the values obtained for actual incremental work pulse is classified under Table 31 and presented under Figure 9.

Table 31:Actual incremental energy expenditure for mopping a specified area

Incremental energy expenditure (K.cals)	Posture								Paired *t* value
	Bending				Squatting				
	% of sample	Mean	S.D	SE	% of sample	Mean	S.D	SE	
0.01-0.50	9.4	1.32	0.76	.13	-	1.63	0.69	.12	
0.51-1.00	34.4				21.9				
1.01-1.50	28.2				31.2				2.693
1.51-2.00	12.5				21.9				(p<0.01)
2.01-2.50	6.2				9.4				
2.51-3.00	3.1				12.5				
3.01-3.50	6.2				3.1				
Confidence interval									
95%	1.07 and 1.56				1.40 and 1.87				
99%	0.99 and 1.66				1.32 and 1.94				

For mopping a limited area of 9.2 sq.m, 31.2 per cent required between 1.01 to 1.50 K.cals in the squatting posture as against 28.2 per cent who demanded the amount in the bending posture. At the same time a group of almost 34.4 per cent had shown requirement only between 0.51 to 1.00 K.cals in the bending posture. This necessitated locating the modal value. Evidently it was 0.90 K.cals for bending and 1.26 K.cals for squatting posture. Since this data reflects their actual energy expenditure for the performance of the activity, the strenuousness of the activity for the short work time can be very well imagined. The mean and SD values depict squatting as the more demanding posture between the two in terms of energy expenditure. But correlation values between the postures proved significant association (.5949) at 1 per cent level. Calculation of the confidence interval also have proved that squatting for the activity demands more energy than bending for the same. Table 32 illustrates possible associations.

Table 32 : Incremental energy expenditure Vs selected performance variables

Variables studied with actual incremental energy expenditure	Correlation co-efficient(r) Posture	
	Bending	Squatting
Work time	.9144(p<0.01)	.8252(p<0.01)
Rate of work	-.8321(p<0.01)	-.7656(p<0.01)

Both the variable combinations studied were highly correlated, the former positively and the latter negatively. Here time factor is not controlled. Though it shows high association, it is evident that the samples had not reached the steady state. Since the work time and rate of work are correlated, rate of work with incremental energy expenditure showed correlation in the right direction. At the same time it also points to a lesser physical fitness of the samples. If they work slowly, the natural sequel is higher energy expenditure.

ii. Total energy expended for mopping a specified area : The total energy expended (for the working $\dot{V}O_2$) was calculated and is presented under Table 33 and Figure 9.

Table 33 : Total energy expended for mopping 9.2 sq.m

Energy expenditure (K.cals.min^{-1})	Posture							
	Bending				Squatting			
	% of sample	Mean	S.D	C.V %	% of sample	Mean	S.D	C.V %
1.50-2.00	12.5	2.67	0.52	19.50	-	2.81	0.43	15.2
2.01-2.50	25.0				28.1			
2.51-3.00	43.7				37.5			
3.01-3.50	9.4				25.0			
3.51-4.00	9.4				9.4			

It is evident that for almost 72 per cent of the sample the energy expenditure incurred while performing in the squatting posture ranged between 2.51-4.00 k.cals.min^{-1}, while 62 per cent required this quantum of energy in the bending posture. The postures though were not equally taxing on the samples, uniformity was observed with approximately ten per cent each who required 3.51 to 4.00 k.cals.min^{-1} to perform in both the postures. The results also pointed to more than 65 per cent each to require between 2 to 3 k.cals. min^{-1} for performance in both the postures. These results are on par with the values put forth by earlier and recent scientists alike in the field (Steidl and Bratton, 1980 and Banister, et al., 1988) who state that the average k.cals.min^{-1} requirement for mopping as between 2 and 3. But Grandjean (1985) proclaims that individuals may even require between 2 to 5 k.cals.min^{-1} depending upon the degree of cleanliness desired. Incidentally the sample selected were very conscious about cleanliness. Therefore the findings of the present study support all the statements illustrated above. The parameter was analysed to study the relationship with individual personal attributes of the samples.

Among the attributes studied with energy expenditure, body size, body fat and BMI showed low degree of positive correlation, while age and stature showed very low degree of negative correlation. The analysis ultimately proves the following assumptions:

* More body weight and body fat, and BMI (above normal) indicate less fitness and more energy expenditure

* More LBM indicates more muscle, more fitness and less energy expenditure

Since the results point to the independence of energy expenditure, the percentage incremental energy expenditure (per cent increase of actual incremental energy expenditure over and above resting) was calculated. Table 34 projects the same.

Table 34: Percentage incremental energy expenditure

Increase (%)	Posture					
	Bending			Squatting		
	% of sample	Mean	S.D	% of sample	Mean	S.D
VO_2 (1)						
Below 25	21.8	44	27.7	9.4	55	24.8
26 - 50	46.9			40.6		
51 - 75	18.8			28.1		
76 -100	9.4			18.8		
101 -125	-			3.1		
126 -150	3.1			-		
Incremental calories						
0 - 25	21.8	26.9	6.20	3.1	28.3	5.46
26 - 50	43.9			46.9		
51 - 75	21.8			28.1		
76 -100	9.4			18.8		
101 -125	-			3.1		
126 -150	3.1			-		

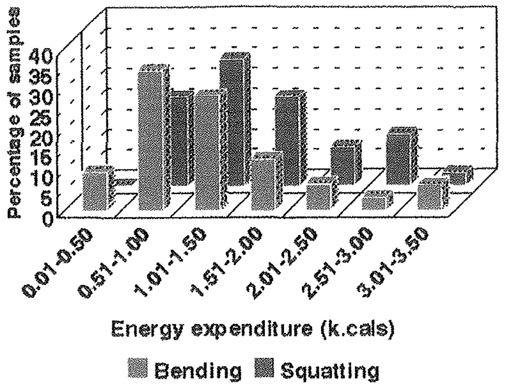
The mean increase recorded was more than 50 per cent of the metabolic cost in the squatting posture for the actual work time (Figure 9).

f. Relative aerobic strain (RAS): Table 35 and figure 9 depict the details on the RAS profile of the selected sample for mopping 9.2 sq.m..

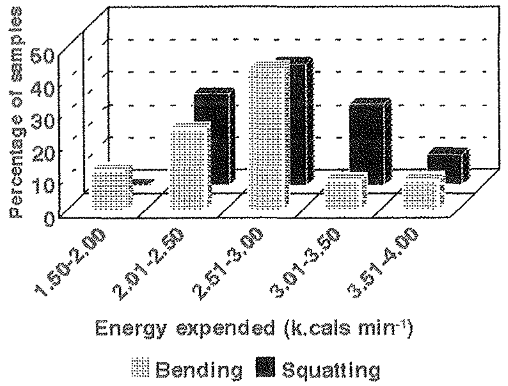
Table 35 : Relative aerobic strain (RAS)

RAS (%) (class mid value)	Posture							
	Bending				Squatting			
	% of sample	Mean	S.D	C.V %	% of sample	Mean	S.D	C.V %
16	9.4	26.86	6.06	22.55	3.1	28.25	5.33	18.87
21	21.9				12.5			
26	31.3				37.5			
31	18.7				25.0			
36	18.7				15.6			
41	-				6.3			

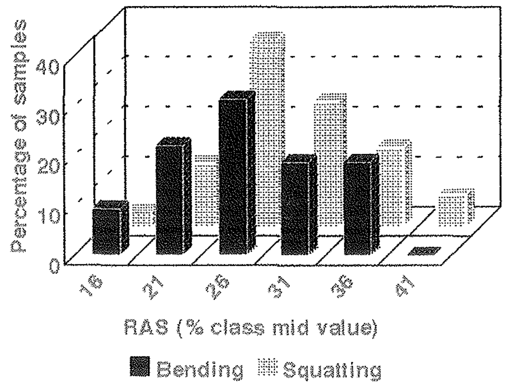
Petrofsky and Lind (1978) recommend 25 per cent $VO_{2(max)}$ as a more realistic guide to an upper limit for even an 8-hour work day. Since the



Actual incremental energy expenditure



Total energy expended



Relative Aerobic Strain

Fig.9.Calorie profile while mopping 9.2 sq.m

homemakers are on 'duty' for more than 8 hours a day this limit can be safely accepted. Unfortunately for approximately 48 per cent of the samples the RAS value lies somewhere between 29-43 per cent range in the squatting posture, when 37.4 per cent lie within this range in the bending posture. Even for industrial purposes an RAS above 33 1/3 per cent is found to be deleterious, and is avoided for all practical reasons (Astrand, 1967). But the study throws light on 21.9 and 18.7 per cent of the sample in the squatting and bending postures respectively to have crossed the line highlighting the strenuousness of the activity (especially in individuals with low physical fitness). This also proves the assumption that the endurance will be high if the RAS is low. According to the categorisation of work load or job heaviness (Sen, 1969 and Appendix X) for RAS between 25-37.5 per cent, the job has been classified as moderately heavy. Naturally the performance of the job in the squatting posture is definitely strenuous to doing the same activity in the bending posture, comparatively, based on RAS values and job classification. To establish if individual body weights have confounded these results, the following Table was drafted taking the ratio of RAS to individual body weights.

Table 36 : Body weight independent RAS (/kg)

RAS (/kg)	Percentage of sample Posture Bending	Squatting
1 - 15	3.1	-
16 - 20	9.4	3.1
21 - 25	37.5	34.4
26 - 30	21.9	31.3
31 - 35	15.6	12.5
36 - 40	12.5	15.6
Above 41	-	3.1

Approximately 22 and 32 per cent of the sample recorded between 26 to 30 per cent in the bending and squatting postures respectively. For 34.4 per cent it was nearly 25 per cent in the squatting posture. Such a classification denotes that the individual body weights have not affected the outcomes in any way.

2. Details on endurance

This part of the findings are discussed under :

- a. Operational criteria of physical actions
- b. Cardiovascular repercussions of endurance
- c. Discomfort or pain reported
- d. Caloric profile of endurance
- e. Morphological traits versus physiological parameters

a. Operational criteria of physical actions: This relates to performance of specific types of movements generally falling into groups like range of movement, endurance and speed to name a few (Mc Cormick, 1976). This aspect of the study discusses the following in detail and Figure 10 picturizes the concerned data.

- i. Endurance limit of mopping
- ii. Area mopped within endurance
- iii. Range of movement
- iv. Rate of work for endurance

i. Endurance limit of mopping: The maximum time for which the selected sample could work (endurance limit) is presented below.

Table 37 : Endurance limit of mopping

	Percentage of sample Endurance limit (s)									
Posture	1 - 60	61-120	121-180	181-240	241-300	301-360	361& above	Mean	Paired t value	'r'
Bending	3.1	50.0	18.7	12.5	3.1	6.3	6.3	160.09	3.09 (p<0.01)	.6147
Squatting	18.7	65.6	6.3	6.3	3.1	-	-	107 .09		

For a majority of 65.6 per cent the maximum endurance in the squatting posture was only below two minutes, while for 18.8 per cent it was less than one minute. For 13 per cent of the sample work could be prolonged even by above five minutes in the bending posture (Fig.10). Since it is already established that the RAS for bending is low for the selected sample naturally the endurance is longer. It is evident therefore that working in the squatting posture ($\overline{x}$ = 107.09) cannot be prolonged for long and if at all continued it may tax the physiology of the individual. Though paired <u>t</u> value highlighted considerable variation between the postures on this score, by and large analysis to infer possible association between postures proved significance.

ii. Area mopped within endurance: The details obtained for the performance characteristic in terms of work accomplished is given under Table 38.

Table 38 : Area mopped within endurance limit

Area mopped (sq.m)	Percentage of sample						
	Posture						'r'
	Bending	Mean	S.D	Squatting	Mean	S.D	
Below 10	-	39.37	23.24	12.5	20.69	14.47	.4219
11 - 25	25.0			68.8			(p<0.05)
26 - 40	43.7			12.5			
41 - 55	6.3			-			
56 - 70	15.6			3.1			
71 - 85	6.3			3.1			
Above 86	3.1			-			

Without rest pause or change in posture 68.8 per cent could mop an area between 11 to 25 sq.m in the squatting posture, while 12.5 per cent could clean only below 10 sq.m. Accomplishment was comparatively better in the bending posture since 43.7 per cent could mop between 26 to 40 sq.m. continuously. It was interesting to record that 25 per cent could mop even above 55 sq.m adopting the posture (Fig 10). It is evident therefore that performance is restricted in the squatting posture proving involvement of the 'static component'. Nevertheless they were more consistent in that posture. As the data pertains to the endurance limit of the samples and since the area mopped is in a way dependent upon endurance, the following Table was tabulated.

Table 39 : Endurance versus area mopped

				Percentage of sample Area mopped in (sq.m)					
Endurance (s)	Posture	Below 10	11-25	26-40	41-55	56-70	71-85	Above 86	'r' value
1 - 60	B	-	3.1	-	-	-	-	-	.6074
	S	9.4	9.4	-	-	-	-	-	.8226
61 -120	B	-	22.0	22.0	3.1	3.1	-	-	(p<0.01)
	S	3.1	56.4	6.2	-	-	-	-	
121-180	B	-	-	12.6	-	3.1	3.1	-	
	S	-	6.2	-	-	-	-	-	
181-240	B	-	-	3.1	3.1	6.2	-	-	
	S	-	-	3.1	-	3.1	-	-	
241-300	B	-	-	3.1	-	-	-	-	
	S	-	-	-	-	-	-	-	
301-360	B	-	-	3.1	-	-	-	3.1	
	S	-	-	-	-	-	-	-	
Above 361	B	-	-	-	-	3.1	3.1	-	
	S	-	-	-	-	-	3.1	-	

A majority of 56.4 per cent could mop an area between 11 to 25 sq.m. within 61 to 120 seconds in the squatting posture. On the other hand while 22 per cent could mop between 26 to 40 sq.m. within 61 to 120 seconds, an equal number could cover only between the range of 11 to 25 sq.m in that posture. Another feature was that in the bending posture the area mopped increased with endurance.

It has been shown that movement time is related to distance. This lack of linear relationship between distance and time probably can be attributed to the time required for acceleration to the maximum speed. Statistical analysis also revealed a high degree of positive correlation between the variables and was more so in the squatting posture.

iii. Range of movement : The range of movement made possible by the action of mopping in both the postures is depicted below.

Table 40 : Range of movement

Range of movement (sq.m)	Percentage of sample Posture			
	Bending	Mean	Squatting	Mean
1-10	34.4	0.17	37.4	0.25
11-20	40.6		34.4	
21-30	6.3		6.3	
31-40	9.3		3.1	
41-50	6.3		3.1	
Above 51	3.1		15.7	

The range of movement was comparatively higher in squatting than in bending posture. This justifies why the correlation between endurance and area mopped is high for the concerned posture. They followed a habitual cadence in mopping. With lesser movements the samples were able to accomplish more in the squatting posture. These facts kindled an interest to find out which one of the characteristic features of the physical stature influenced the range of movement more than the others.

Results are indicative of a comparatively related association between range of movement and trochanteric height, stature and arm reach in the bending posture. Positive correlation (.4114- significant at 5% level) exists between range of movement and the bending height. Regarding squatting posture, none of the variables with the concerned parameter exhibited remarkable association.

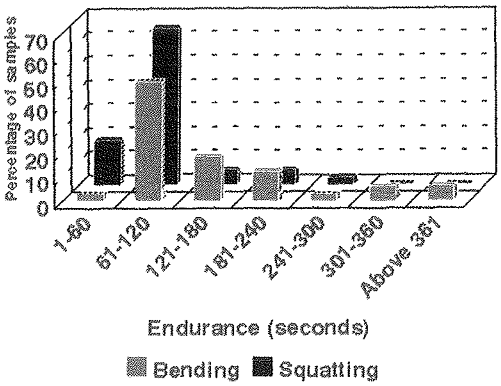
iv.Rate of work for endurance: The Table 41 and Figure 10 picture the rate of work accomplished adopting the two specified postures.

Table 41 : Rate of work for endurance

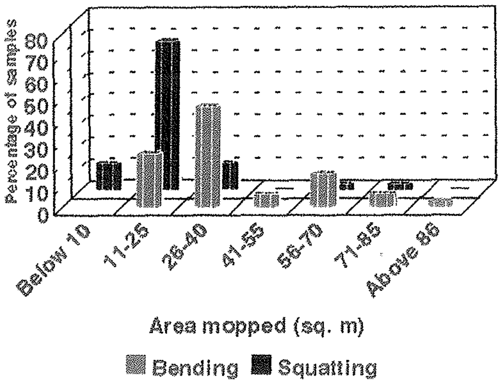
Rate of work (sq.m/min)	Percentage of sample Posture Bending	Mean	Squatting	Mean	'r'
5.6-10.5	18.8	17.2	43.8	12.8	.5299
10.6-15.5	31.2		31.2		(p<0.01)
15.6-20.5	21.9		12.5		
20.6-25.5	18.8		9.4		
25.6-30.5	-		3.1		
30.6-35.5	3.1		-		
35.6-40.5	3.1		-		
40.6-45.5	3.1		-		

The rate of work for a majority of 43.8 per cent of the sample in the squatting posture indicated poor performance (5.6 to 10.5 $sq.m.min^{-1}$). A uniform proportion (31.2 % each) recorded a performance between 10.6 to 15.5 $sq.m.min^{-1}$ in both the postures. Considering the minimum carpet area of rooms to be 9.2 sq.m (100 sq.ft) it is understandable that a maximum proportion (43.8%) could perform only that much of an area within a minute in the squatting posture, while a good proportion could endure longer in the bending posture. It also indicates that more than 75 per cent are slow in performance while adopting squatting posture showing only a rate of work upto 15.5 sq.m. min^{-1}. Therefore it is proved that the rate of work is less and the performance is slow in the squatting posture.

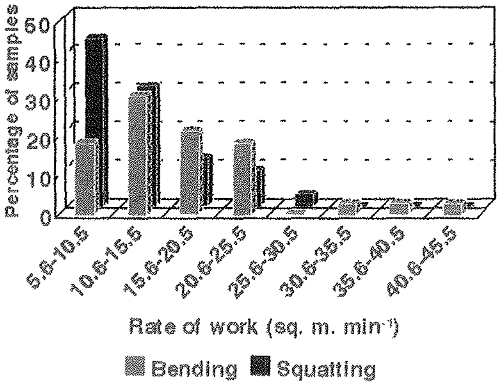
Correlation matrix showed the parameter with endurance in the bending posture alone (-.4203) to depict negative correlation ($p<0.05$). Evidently, the area mopped decides the rate of work than endurance which



Endurance Limit of Mopping



Area mopped within endurance limit



Rate of work for endurance

Fig.10. Operational criteria of physical actions

signifies performance in terms of time expended. Similarly the variable when correlated with physiological attributes showed non significance in both the postures.

b. Cardiovascular repercussions of endurance: In any executional work, either a performance produces enough sensory discomfort that the individual stops before he/she reaches what might be called the physiological limit, or the worker repeats heavy exertions before one becomes aware of the limit - endurance. Situations which typically produce muscle fatigue consists of those demands that pace or restrict a worker's performance. Another crucial feature is the length of activities. Muscle fatigue is a result of many interactions among task constraints such as the work posture and work period, and subject capabilities such as endurance, rate of work and physiological indices. The study was designed to solve some of the above listed problems by investigating identifiable variables and their interactive relationships to muscle fatigue.

The performance of the activity upto endurance limit and the work accomplished thereby would have influenced specific physiological changes within the individual leading to perceived fatigue by the samples. The constituents of the above are discussed in detail below. Figure 11 represents selected variables diagrammatically.

i. Cardiac cost of endurance
ii. Recovery cost
iii. Total cardiac cost of endurance
iv. Rate of recovery

i. Cardiac cost of endurance: The cardiac cost (for endurance) of the activity is therefore explained under:

Working pulse of endurance: The information recorded pertaining to the working pulse of the sample performing until endurance limit is presented under Table 42.

Table 42 : Working pulse of endurance

Working pulse (beats)	Percentage of sample Posture Bending	Mean	S.D	Squatting	Mean	S.D
Below 115	3.1	139.5	14.61	3.1	135.84	12.73
116 - 125	9.4			21.9		
126 - 135	37.5			25.0		
136 - 145	15.6			28.1		
146 - 155	15.6			15.6		
156 - 165	18.8			6.3		

The range of increase in HR varied from 110 to 165 beats. According to Astrand and Rodahl (1977) mopping activity raises the HR from 110 to 150 beats.

Performance of the activity in both the postures had tended to increase the HR considerably. For 50 per cent each of the sample the working pulse had increased upto 135 beats with 37.5 and 25 per cent exactly to have recorded between 126 to 135 beats in the bending and squatting postures respectively. The study also revealed that 34 per cent of the sample could continue working in the bending posture till their working pulse was raised from 146 to 165 beats, while only 22 per cent could endure till then in the squatting posture. Thus, the cardiovascular repercussions of the task varied widely. Mopping work involves a considerable amount of static muscular output while grasping the mopping cloth, and in the postural control of head and trunk when performing work in awkward postures. Work with high static component produces higher cardiac cost due to reduced intra muscular circulation. Such a spread of HR responses under similar pulmonary demands can be taken as a reflection of the range of the static component in such work opine, Lind et al., (1975) and Nag and Chatterjee, (1981).

Incremental work pulse (cardiac cost) of endurance: This aspect explains the exact increase in HR or in other words the cardiac cost of the activity above resting due to performance. It can be influenced both by the nature of work as well as the time expended for accomplishment. This is discussed as follows.

Incremental cardiac cost of endurance: The mean increase in HR (above resting) for performance of the activity in the selected postures is depicted in Table 43 and Figure 11.

Table 43 : Incremental cardiac cost of endurance

Incremental cardiac cost (beats)	Percentage of sample Posture								Paired t value
	Bending	Mean	S.D	C.V %	Squatting	Mean	S.D	C.V %	
31-40	3.1	63.19	14.18	22.4	3.1	59.75	12.28	20.5	2.12
41-50	18.8				31.2				($p<0.05$)
51-60	28.1				12.5				
61-70	15.6				28.1				
71-80	18.8				18.8				
81-90	15.6				6.3				

The cardiac cost recorded for the bending posture was found to be higher when compared to that of the squatting posture. Habituation in the latter may be a reason. While the correlation between postures was found to be non significant (.2708) the t value calculated was found to be significant. Since endurance is less for squatting, the cardiac cost is also less. In order to analyse whether any other attributes had effected this change the cardiac cost (incremental) was analysed in relation to the area mopped and the sample's endurance limit.

Incremental cardiac cost versus area mopped:Table 44 throws light on the concerned data.

Table 44: Incremental cardiac cost versus area mopped

Incremental cardiac cost (beats)	Posture	Percentage of sample Area mopped (sq.m) Below 10	11-25	26-40	41-55	56-70	71-85	Above 86
31-40	B	-	-	3.1	-	-	-	-
	S	-	3.1	-	-	-	-	-
41-50	B	-	6.3	9.4	-	3.1	-	-
	S	12.6	15.6	-	-	3.1	-	-
51-60	B	-	12.6	9.4	3.1	3.1	-	-
	S	-	6.3	3.1	-	-	3.1	-
61-70	B	-	3.1	-	3.1	3.1	3.1	3.1
	S	-	28.0	-	-	-	-	-
71-80	B	-	3.1	9.4	3.1	-	3.1	-
	S	-	9.4	9.4	-	-	-	-
81-90	B	-	-	12.6	-	3.1	-	-
	S	-	6.3	-	-	-	-	-

The cardiac cost (in the bending posture) was found to be increasing with the increase in the area mopped; but while performing in the squatting posture individual variations revealed that the maximum effort that could be put in was mopping between 11 to 25 sq.m for which the cardiac responses differed considerably. While for 28 per cent the incremental cardiac cost ranged between 61 to 70 beats, for 15.6 per cent it was between 41 to 50 beats. Incidentally 12.5 per cent could mop only below 10 sq.m., while their cardiac responses showed a rise between 41 to 50 beats. Anyway, remarkable significance could not be established between the two variables. Therefore it can be stated that cardiac cost is not dependent upon the area mopped.

Incremental cardiac cost versus endurance: The following Table(45) sketches details on the pertinent data.

Table 45 : Incremental cardiac cost versus endurance

Incremental cardiac cost (beats)	Posture	Percentage of sample Endurance (in s)						
		1-60	61-120	121-180	181-240	241-300	301-360	Above 361
31-40	B	-	3.1	-	-	-	-	-
	S	-	3.1	-	-	-	-	-
41-50	B	-	9.4	6.3	-	-	3.1	-
	S	12.5	15.6	-	3.1	-	-	-
51-60	B	3.1	12.5	6.3	3.1	-	-	3.1
	S	-	6.3	-	3.1	-	-	3.1
61-70	B	-	3.1	-	6.3	-	3.1	3.1
	S	3.1	22.0	3.1	-	-	-	-
71-80	B	-	15.7	3.1	-	-	-	-
	S	3.1	12.5	3.1	-	-	-	-
81-90	B	-	6.3	3.1	3.1	3.1	-	-
	S	-	6.3	-	-	-	-	-

It was deducible that 18.7 per cent of the sample could work only for less than a minute in the squatting posture. For this short period of endurance ($\bar{x}$ = 107.09s) 12.5 per cent showed an increase in work pulse between 41 to 50 beats and 3.1 per cent each recorded between 61 to 70 and 71 to 80 beats respectively.

Bending was the posture for which the endurance value differed considerably. Almost 15.5 per cent of the sample could work for more than four minutes adopting the posture. The maximum observed for squatting posture was below four minutes (96.9%). Rise in work pulse (with endurance between 61 to 120 seconds) for 40.8 per cent of the sample an increase between 61 to 90 beats was observed as against 25.1 per cent falling in this range in the bending posture. These indicators highlight squatting as a strenuous posture for the activity concerned. Cardiac cost in a way tended to show an inverse response to changes in endurance. Statistical analysis showed a very low degree of negative correlation. It is clear that neither the factors of area nor maximum work time influence cardiac cost and so, it is advisable to study recovery cost for possible associations.

Welford (1974) while presenting a historic view of fatigue research suggested that time required for recovery may be a useful method for quantifying the severity of fatigue. Therefore this part aims at explaining the :

Recovery time of endurance

Incremental recovery cost of endurance

Recovery time of endurance: Table 46 presents details on the recovery time of endurance. Figure 11 explains the same.

Table 46 : Recovery time for endurance test

Posture	Percentage of sample Recovery time (in min)							
	1-5	6-10	11-15	16-20	21-25	26-30	Mean	S.D
Bending	43.7	28.1	9.4	9.4	6.3	3.1	8.81	7.28
Squatting	43.7	25.0	6.3	12.5	3.1	9.4	10.00	6.89

Though the endurance in the squatting posture was comparatively low (between postures), the time taken to recover (by the samples) was found to be slightly high; this was more so with 9.4 per cent who recorded a recovery time between 26 to 30 min indicative of poor vascular dynamics in these subjects. Otherwise the distribution was almost uniform. The values being scattered it was not surprising that the paired t value also did not emerge significant (0.15). Therefore an analysis to relate the recovery time with endurance was done and is depicted in Table 47.

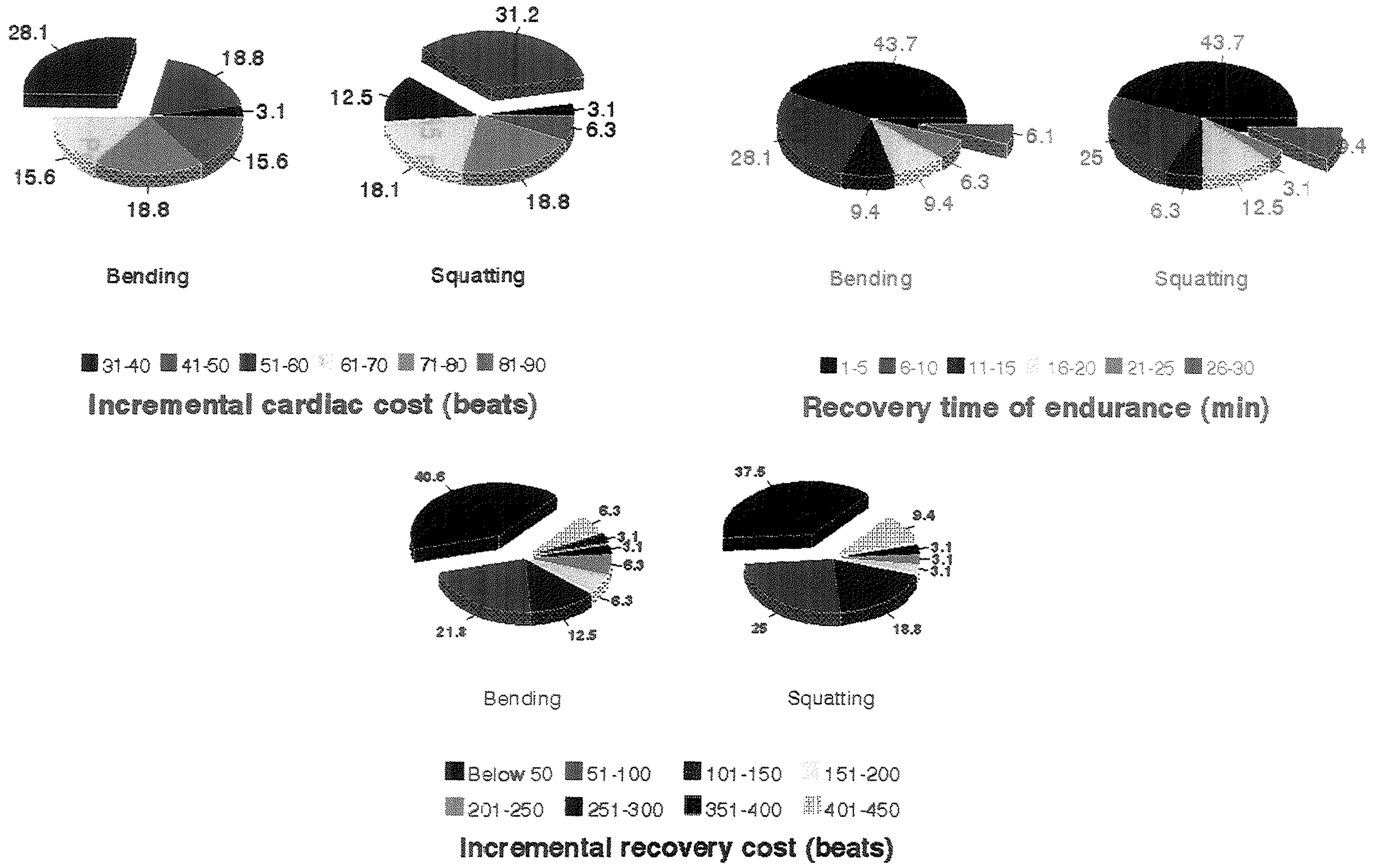


Fig. 11. Cardio vascular response to performance

Table 47 : Endurance versus recovery time

Endurance (in s)	Posture	Percentage of sample (Recovery time in min) 1-5	6-10	11-15	16-20	21-25	26-30	r
1- 60	B	-	-	3.1	-	-	-	.3151 NS
	S	12.6	6.3	-	-	-	-	.2353 NS
61-120	B	25.0	15.6	3.1	6.3	-	-	
	S	25.0	25.0	3.1	-	3.1	9.4	
121-180	B	9.4	6.3	-	-	-	3.1	
	S	3.1	3.1	-	-	-	-	
181-240	B	9.4	-	-	-	3.1	-	
	S	3.1	-	3.1	-	-	-	
241-300	B	-	-	-	-	3.1	-	
	S	-	-	-	-	-	-	
301-360	B	-	6.3	-	-	-	-	
	S	-	-	-	-	-	-	
Above 361	B	-	-	3.1	3.1	-	-	
	S	-	-	-	3.1	-	-	

Recovery time cost analysed based on endurance, while squatting proved 65 per cent of the sample to have worked only between 61 to 120 s for which their recovery time extended upto 30 min with 25 per cent each requiring between 1 to 5 and 6 to 10 min respectively; but for the same performance duration, 9.4 per cent required between 26 to 30 min. Around 19 per cent who could work only below 60 s also required approximately 10 min for recovery (Fig.12).

Performance in the bending posture showed a wide distribution both in terms of endurance as well as recovery time; yet, 40 per cent whose performance was only for two minutes required upto 10 min for recovery. The recovery time being so, the increment in cardiac cost during recovery needs to be attended to.

Incremental recovery cost of endurance: The term denotes the sum of heart beats (above resting) from the cessation of work until the pulse returns to its resting level and is an accepted method of measuring fatigue and recovery. Table 48 and Figure 11 describe the data.

Table 48 : Incremental recovery cost of endurance

Incremental recovery pulse (beats)	Percentage of sample posture Bending	Mean	Squatting	Mean
Below 50	40.6	112.62	37.5	111.25
51-100	21.8		25.0	
101-150	12.5		18.8	
151-200	6.3		3.1	
201-250	6.3		3.1	
251-300	3.1		3.1	
301-350	-		-	
351-400	3.1		-	
401-450	6.3		9.4	

Due to their rate of work being slow in the squatting posture, the samples tended to recover showing less increase in cardiac cost than with bending posture. The mean values for recovery cost was 112.62 (bending) and 111.25 beats (squatting), while their minimum and maximum values ranged from 3 to 416 beats for bending and 39 to 436 beats for squatting. Nevertheless, the variable was not at all associated with personal attributes in both the postures. Inter-individual variation, also was higher. Lack of time control, unaccustomed postures, lower physical fitness, less endurance and strenuousness of the work may be attributed as causal factors. Cardio-vascular flexibility also was beyond control. All these factors have confounded the results. So, the data was correlated with endurance, incremental cardiac cost and area mopped.

Endurance versus incremental recovery cost: Table 49 presents details on endurance versus incremental recovery cost.

Table 49 : Endurance versus incremental recovery cost

Endurance (s)	Posture	Percentage of sample Incremental recovery cost (beats) Below 50	51-100	101-150	151-200	201-250	251-300	301-350	351-400	401-450	r
1- 60	B	-	-	3.1	-	-	-	-	-	-	.3349 NS
	S	12.5	3.1	3.1	-	-	-	-	-	-	.2353 NS
61-120	B	21.9	15.6	3.1	3.1	6.3	-	-	-	-	
	S	18.8	21.9	12.5	3.1	-	-	-	-	9.5	
121-180	B	9.5	3.1	3.1	-	-	-	-	-	3.1	
	S	3.1	-	3.1	-	-	-	-	-	-	
181-240	B	9.5	-	-	-	-	-	-	3.1	-	
	S	3.1	-	-	-	-	3.1	-	-	-	
241-300	B	-	-	-	-	-	-	-	-	3.1	
	S	-	-	-	-	-	-	-	-	-	
301-360	B	-	3.1	-	3.1	-	-	-	-	-	
	S	-	-	-	-	-	-	-	-	-	
Above 361	B	-	-	3.1	-	-	3.1	-	-	-	
	S	-	-	-	-	3.1	-	-	-	-	

A majority of 21.9 per cent could endure between 61 to 210 s but required between 51 to 100 beats for recovery in the squatting posture; but an equivalent number required only below 50 beats for the same in the bending posture. A parallel increase in recovery cost was observed with increase in endurance level. It is clear that the work rate in the squatting posture has not increased with the endurance time indicating that the samples had not maintained the same rate of work throughout the work period. This can be attributed as a valid reason for these observations.

Area mopped versus incremental recovery cost: The details pertaining to this aspect is depicted through Table 50

Table 50 : Area mopped versus incremental recovery cost

		Percentage of sample Incremental recovery cost (beats)									
Area mopped (sq.m)	Posture	Below 50	51-100	101-150	151-200	201-250	251-300	301-350	351 400	401-450	r
Below 10	B	-	-	-	-	-	-	-	-	-	.1955 NS
	S	9.3	3.1	-	-	-	-	-	-	3.1	.2338 NS
11-25	B	15.6	-	6.3	-	3.1	-	-	-	-	
	S	25.0	18.8	18.0	3.1	-	-	-	-	3.1	
26-40	B	15.6	15.6	-	3.1	-	-	-	3.1	6.4	
	S	-	3.1	3.1	-	-	3.1	-	-	3.1	
41-55	B	3.1	3.1	-	-	-	-	-	-	-	
	S	-	-	-	-	-	-	-	-	-	
56-70	B	6.3	3.1	-	-	3.1	3.1	-	-	-	
	S	-	-	-	-	-	-	-	-	-	
71-85	B	-	-	6.3	-	-	-	-	-	-	
	S	-	-	-	-	3.1	-	-	-	-	
Above 86	B	-	-	-	3.1	-	-	-	-	-	
	S	-	-	-	-	-	-	-	-	-	

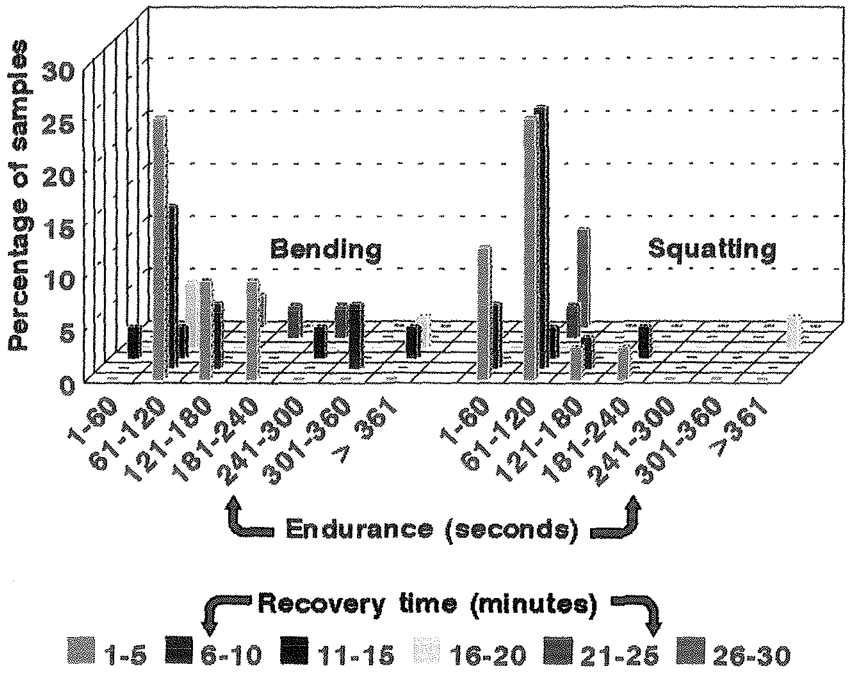
Majority of the sample showed that they could mop only in the 11 to 25 sq.m. range in the squatting posture, for which again they showed considerable increase in recovery cost. Mopping of a mere 11 to 25 sq.m. area evidently increased recovery HR by more than cent per cent (above resting) especially in the squatting posture.

Incremental cardiac cost versus incremental recovery cost: The association between the incremental cardiac cost and incremental recovery cost was analysed and the data is presented under Table 51 and Figure 12.

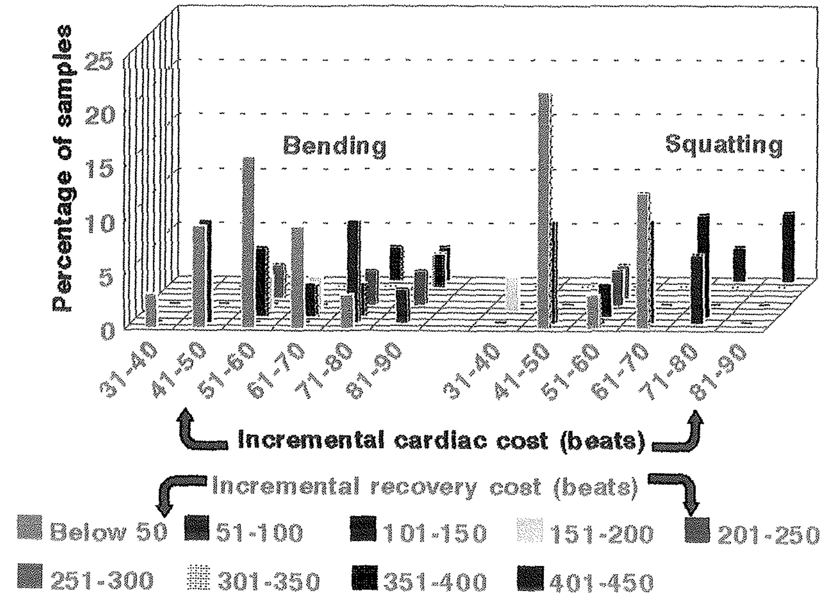
Table 51 : Incremental cardiac cost versus incremental recovery cost

Incremental cardiac cost (beats)	Posture	Percentage of sample Incremental recovery cost (beats)									Paired t value
		Below 50	51-100	101-150	151-200	201-250	251-300	301-350	351-400	401-450	
31-40	B	3.1	-	-	-	-	-	-	-	-	2.53
	S	-	-	-	3.1	-	-	-	-	-	$(p<0.05)$
41-50	B	9.4	9.4	-	-	-	-	-	-	-	
	S	21.8	9.4	-	-	-	-	-	-	-	2.55
51-60	B	15.8	-	6.3	3.1	-	3.1	-	-	-	$(p<0.05)$
	S	3.1	-	3.1	-	3.1	3.1	-	-	-	
61-70	B	9.4	-	3.1	3.1	-	-	-	-	-	
	S	12.8.	9.4	-	-	-	-	-	-	-	
71-80	B	3.1	9.4	6.3	-	6.3	-	-	-	3.1	
	S	-	6.3	9.4	-	-	-	-	-	3.1	
81-90	B	-	3.1	-	-	3.1	-	-	3.1	3.1	
	S	-	-	-	-	-	-	-	-	6.3	

When 21.8 per cent who recorded an incremental HR between 41 to 50 beats showed an increase below 50 beats in the squatting posture for recovery, 12.5 per cent who recorded between 61 to 70 beats for performance tended to require only below 50 beats for recovery. In squatting there is some postural blood trapping at the fold of the knee. All individuals, generally are not able to cope with this though they may return to normal during recovery. Maladjustment to postural trapping of blood may be a reason for this variation among the samples. Similar cases were observed in the bending posture too. But according to cardiovascular dynamics there is no blood trapping in the bending posture rendering management of the posture easier. Hence a suggestion may be made that when work can be done adopting a different posture, squatting posture should be avoided. It is worth admitting that the cases who recorded abnormal hike in recovery cost



Endurance Vs Recovery time



Incremental cardiac cost Vs incremental recovery cost

Fig. 12. Time and cardiac cost-performance and recovery

(i.e. above 400 beats) were suspected for physical inability. Their blood pressure was checked and the results pointed two cases as hypertensives and one as hypotensive. Though the two variables studied showed a high degree of correlation in both postures (.5583 and .5775 significant at 1% level in bending and squatting respectively) while analysed between postures they showed significant variation.

iii. Total cardiac cost of endurance: This is the sum of heart beats from the start of the work until resting level is restored - total of work pulse plus recovery pulse (Barnes, 1980). It reflects the impact of the performance on cardiac action. Table 52 pictures details on the variable.

Table 52 : Total cardiac cost of endurance

Total cardiac cost (beats)	Percentage of sample Posture Bending	Mean	Squatting	Mean	(r)
101-150	15.6	248.75	18.8	247.41	.6122
151-200	28.1		31.2		(p<0.01)
201-250	21.9		15.6		
251-300	12.5		15.6		
301-350	3.1		6.3		
351-400	3.1		3.1		
401-450	6.3		-		
451-500	-		-		
Above 501	9.4		9.4		

The mean values were found to be 248.75 beats for bending and 247.41 beats for squatting. Since this seems to be dependent upon the time cost of the activity, the total cardiac cost was tabulated with total time cost, to find out if there is any correlation between the two. Table 53 explains the data.

Table 53 : Total work pulse versus total time cost

Total work pulse (beats)	Posture	Percentage of sample Total time cost (min) 1-5	5-10	11-15	16-20	21-25	26-30	above 31	r
Below 500	B	18.8	21.9	-	-	-	-	-	.9185
	S	31.2	9.4	-	-	-	-	-	.9340
501-1000	B	-	18.8	6.3	-	-	-	-	(p<0.01)
	S	-	21.9	6.3	-	-	-	-	
1001-1500	B	-	-	12.5	3.1	3.1	-	-	
	S	-	-	12.5	-	-	3.1	-	
1501-2000	B	-	-	-	3.1	-	3.1	-	
	S	-	-	-	3.1	-	-	-	
2001-2500	B	-	-	-	-	-	3.1	-	
	S	-	-	-	-	3.1	-	-	
2501-3000	B	-	-	-	-	-	3.1	3.1	
	S	-	-	-	-	-	3.1	6.3	

The total work pulse and total time cost in both the postures taken individually showed a very high degree of correlation as shown in the Table. The total time cost incurred for activity (between postures) also showed significance (.5866 significant at 1%). This necessitated estimating the rate of recovery.

iv. Rate of recovery : Table 54 explains data on rate of recovery of the selected sample

Table 54 : Rate of recovery

Rate of recovery (min)	Percentage of sample Posture Bending	Mean	Squatting	Mean	Mean difference between postures
Below 1	6.3	4.08	-	5.93	.3525 NS
1.1- 4.0	53.1		40.6		
4.1- 8.0	28.0		34.3		
8.1-12.0	6.3		12.5		
12.1-16.0	6.3		6.3		
16.1-20.0	-		6.3		

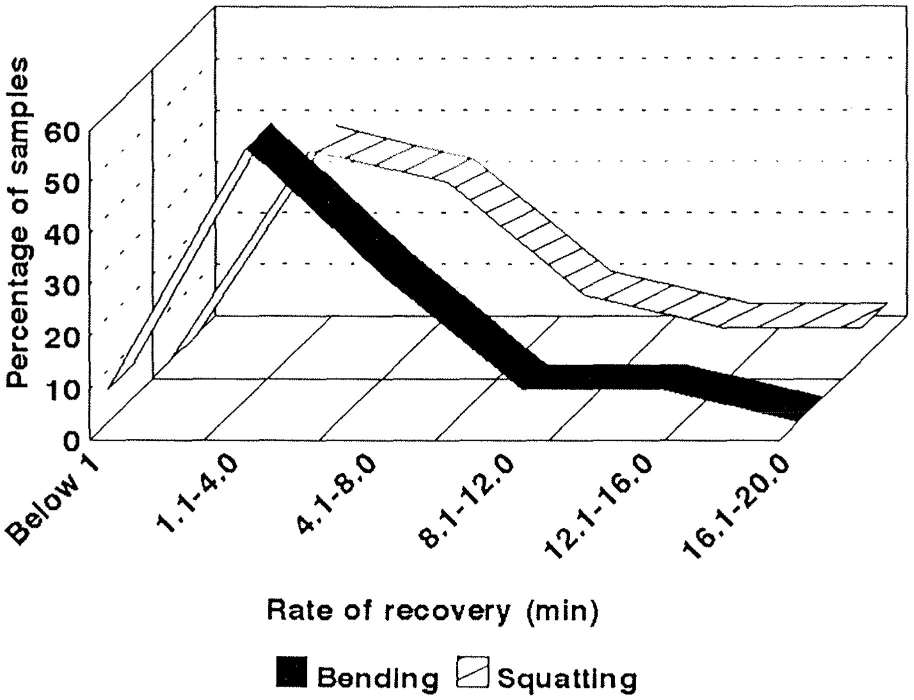
The rate of recovery tended to be on an increase in the squattin posture which reflects the strain on the cardiovascular system of th subjects in this posture. For a low endurance they required a high recover time (Fig.13). Naturally the samples would have felt the strain. The following session explains the same.

c. Discomfort or pain reported: Mopping till endurance heralded discomfort or induced pain. Table 55 explains the same.

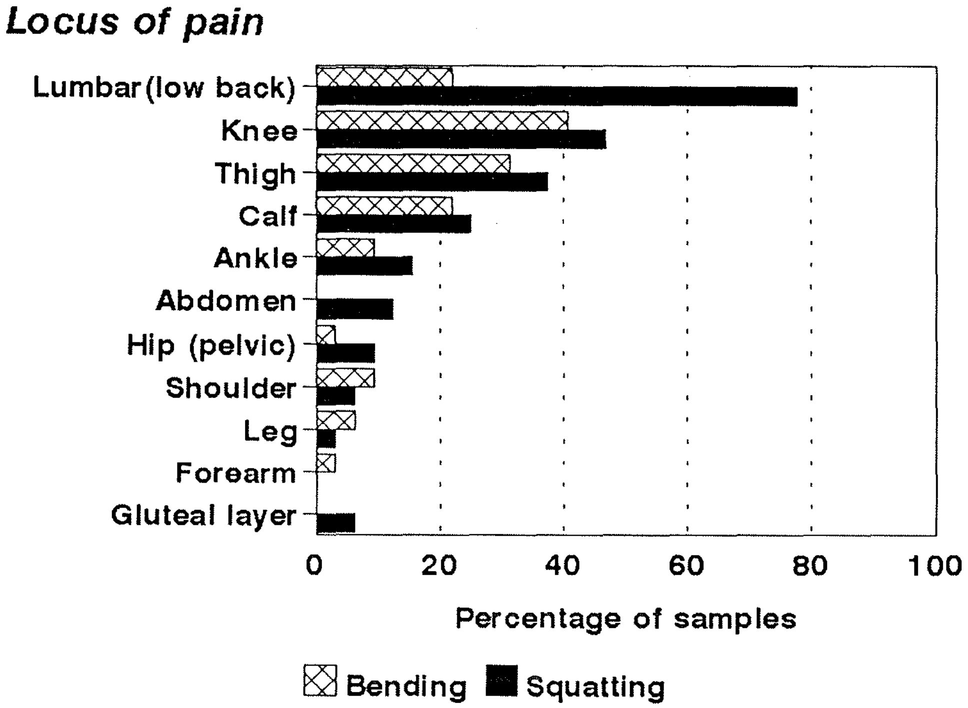
Table 55 : Discomfort/pain with mopping action

Locus of pain/discomfort	Percentage reporting Posture	
	Bending	Squatting
Lumbar (low back)	21.9	77.5
Knee	40.6	46.9
Thigh	31.3	37.5
Calf	21.9	25.0
Ankle	9.4	15.6
Abdomen (compression)	-	12.5
Hip (pelvic region)	3.1	9.4
Shoulder	9.4	6.3
Leg	6.3	3.1
Forearm	3.1	-
Gluteal layer	-	6.3

Pain in the lower back topped the list while mopping in the squatting posture (Fig.13). Akkerveekan, (1985) defines pain as an emotional response to afferent inputs, an abnormal emotional state aroused by unusual patterns of activity in specific afferent system; it is not a sensation. Snook (1985) defines low-back pain as lumbosacral pain as well as buttock and leg pain (either acute or chronic), lumbago and lumbar insufficiency. The findings also project the same. The samples also added gasping and



Rate of recovery



Discomfort or pain reported

Fig.13. Sequel to performance

dizziness to the list. It emphasizes that blood trapping is more in the squatting posture than in the bending posture. This calls for an explanatory study on causative factors (Table 56).

Table 56 : Attributes to discomfort/painful experience

Reasons	Percentage reporting Posture Bending	Squatting
Uncomfortable posture maintenance	52	100
Muscular pain	50	97
Flexion of the knee	-	96
Low back pain	26	94
Constrained breathing	22	93
Exhaustion/Dizziness	51	89
Forward bend of the trunk	31	74
Unstable position of feet	21	73
Lethargy	17	68
Cramps	48	64
Restricted movement	-	57
Tremor in the limbs	48	53
Problems of varicose veins	35	35
Visual difficulty	42	13

According to Senior (1975) situations where one is forced to work for a long period in an uncomfortable position and working at something one does not like produce fatigue. The findings of the study support this statement. Knowing that more than three fourths of the sample had reported of low back pain it is felt necessary to quote Mc Atamney and Corlett (1992). According to them factors known to increase the risk of low back injuries are among other factors, the load and the posture, that is, reduced lumbar lordosis, twist of the trunk, unstable position of feet, forward bend of the trunk, position of arms and legs along with inappropriate flooring conditions and time and social pressures.

Van Wely (1970) has related posture to reported pain thus :

Bad posture	Probable site of pain or other symptoms
* Standing (and particularly a pigeon-footed stance)	Feet, lumbar region
* Sitting without lumbar support	Lumbar region
* Sitting without support for the back	Erector spinae muscle
* Upper arm hanging unsupported out of vertical	Shoulder, upper arms
* Trunk bent forward : stooping position	Lumbar region and erector spinae muscle
* Maintenance of any joint in its extreme position	The joint involved

It goes without saying that mopping action definitely will have an impact on the performer's low back. Added to this Indian women suffer osteoporosis especially in the lumbo-sacral region as they age and they tend to feel imbalanced with the posture as they progress in the process of aging. When muscle groups are in a state of imbalance from faulty posture they tend to become habitual. As imbalance increases, excess work is required which results in fatigue states Mathur (1981).

d. Caloric profile of endurance

This part of the study explains the following:

i. Working oxygen consumption of endurance

ii. Oxygen debt

iii. Caloric cost of endurance

i.Working oxygen consumption of endurance: This part of the study includes details on:

Oxygen pulse and total oxygen consumption for endurance and incremental O_2 consumption for performance and recovery.

Oxygen pulse: Using the linear least square regression formula developed to find out the VO_2, the O_2 pulse was calculated and is presented under Table

Table 57 : Oxygen pulse during endurance

Oxygen pulse (ml. beat -1)	Percentage of sample Posture Bending	Mean	S.D	Squatting	Mean	S.D	Paired <u>t</u> value
4.26-4.50	6.2	4.97	0.30	9.3	4.90	0.28	2.402
4.51-4.75	25.0			21.9			(p<0.05)
4.76-5.00	25.0			25.0			
5.01-5.25	21.9			28.1			
5.26-5.50	21.9			15.7			

The samples when tabulated based on specific class intervals and as is evident from the paired <u>t</u> value did not show very great variation in their oxygen pulse status. The data was therefore correlated between the two postures which showed high association (.7804).

Total oxygen consumption for endurance: The total $\dot{V}O_2$ consumed for performing till endurance is presented under Table 58.

Table 58 : Total oxygen consumption for endurance

Oxygen consumption (l.min -1)	Percentage of samples Posture Bending	Mean	S.D	C.V	Squatting	Mean	S.D	C.V	Paired <u>t</u> value
0.90-1.00	18.7	1.10	0.11	10	28.1	1.07	0.10	9.3	3.00
1.01-1.10	37.5				28.1				(p<0.01)
1.11-1.20	21.9				28.1				
1.21-1.30	21.9				15.7				

Though the difference in mean values is very negligible the significant paired <u>t</u> value shows that the bending posture requires a greater $\dot{V}O_2$. This may be due to longer endurance in the posture. It is clear from the <u>t</u> value that the parameter showed significant variation between the selected postures. Nevertheless multiple regression analysis proved, non-significance between the postures and the samples' endurance and total $\dot{V}O_2$.

Incremental oxygen consumption for performance: The incremental oxygen consumption pattern of the selected sample is depicted through Table 59.

Table 59 : Incremental oxygen consumption for performance (Endurance)

Incremental VO_2 (1)	Percentage of sample Posture Bending	Mean	S.D	Squatting	Mean	S.D	Paired t value	'r'
0.31-0.40	25.0	0.50	0.09	34.4	0.47	0.07	3	.7733
0.41-0.50	31.2			31.2			($p<0.01$)	($p<0.001$)
0.51-0.60	18.8			18.8				
0.61-0.70	25.0			15.6				

Posturewise samples showed variation in terms of incremental VO_2. The value for the t test was found to be 3 ($p<0.01$). Co-efficient of correlation indicated high association between postures in this respect.

The energy expenditure in a particular sub-maximal activity is the same for everyone state Lange Andersen et al, (1978); but the stress in such work can be objectively described by measuring the O_2 consumption. This statement is obviously true, they say, for group data; there may exist greater difference between individuals if small groups are concerned.

ii. Oxygen debt or incremental oxygen consumption for recovery: The $\dot{V}O_2$ incurred for recovery after performance is otherwise the oxygen debt incurred consequent to performance. Table 60 and Fig.14 explain the same.

Table 60 : Oxygen debt or incremental oxygen consumption for recovery

Oxygen debt (l.min^{-1})	Posture Bending % of sample	Mean	Squatting % of sample	Mean	Paired t value
0.10-0.60	46.8	0.89	56.2	0.83	4.46
0.61-1.20	28.1		25.0		($p<0.01$)
1.21-1.80	9.4		6.3		
1.81-2.40	6.3		3.1		
2.41-3.00	3.1		-		
3.01-3.60	6.3		9.4		

The mean values for recovery indicated uniformity between postures, but the mean difference between postures (.6125) and the paired _t_ value (4.46) showed high significance ($p<0.01$). Subsequently the two variables were correlated individually for postures which showed association (.4871 and .5777) at the level of 5 per cent and 1 per cent for bending and squatting respectively depicting that the samples varied slightly in the bending posture. It was evident that for a very low endurance time the sample in squatting posture repaid more of O_2 as debt compared to the other posture. The energy requirement during this phase of O_2 debt is substituted by this oxygen though is 'alactacid'. The dependence of the variable was therefore found by regressing it with incremental VO_2.

Table 61 : Incremental oxygen consumption versus oxygen debt

Posture	Independent variable	Dependent variable	Constant	Parameter dependent variable	r^2	Paired _t_ value
Bending	Incremental VO_2 of endurance	Incremental VO_2 of recovery	-1.4361	4.6544	0.32 ($p<0.01$)	2.66 ($p<0.05$)
Squatting	Incremental VO_2 of endurance	Incremental VO_2 of recovery	-1.6665	5.2799	0.30 ($p<0.01$)	2.56 ($p<0.05$)

In this context too the samples showed great variation in the squatting posture as is evident from the Table. While the independent variable influenced the recovery VO_2 by 32 per cent in the bending posture, only 30 per cent could be attributed to it in the squatting posture. The variable was individually correlated with endurance time and area mopped which showed non significance.

iii. Caloric cost of endurance: The amount of energy expended is directly proportional to the intensity of muscular work performed (Bogert et al., 1973). Therefore the energy expenditure incurred during performance until endurance is studied and classified under working calorie and work calorie.

Table 62 : Caloric cost of endurance

Caloric cost	Posture								
	Bending				Squatting				Paired
	% of sample	Mean	S.D	C.V %	% of sample	Mean	S.D	C.V %	t value
Working calorie (K.cals. min^{-1})									
4.00-4.50	3.1	5.50	0.57	10.3	3.1	5.35	0.49	9.1	2.17
4.51-5.00	15.6				25.0				($p<0.05$)
5.01-5.50	37.5				31.3				
5.51-6.00	21.9				25.0				
6.01-6.50	21.9				15.6				
Work calorie (K.cals)									
1.60-1.97	21.8	2.49	0.56	22.5	34.4	2.36	0.49	20.8	0.40
1.98-2.35	28.1				12.5				(NS)
2.36-2.73	12.5				28.1				
2.74-3.11	18.8				18.8				
3.12-3.49	18.8				6.2				

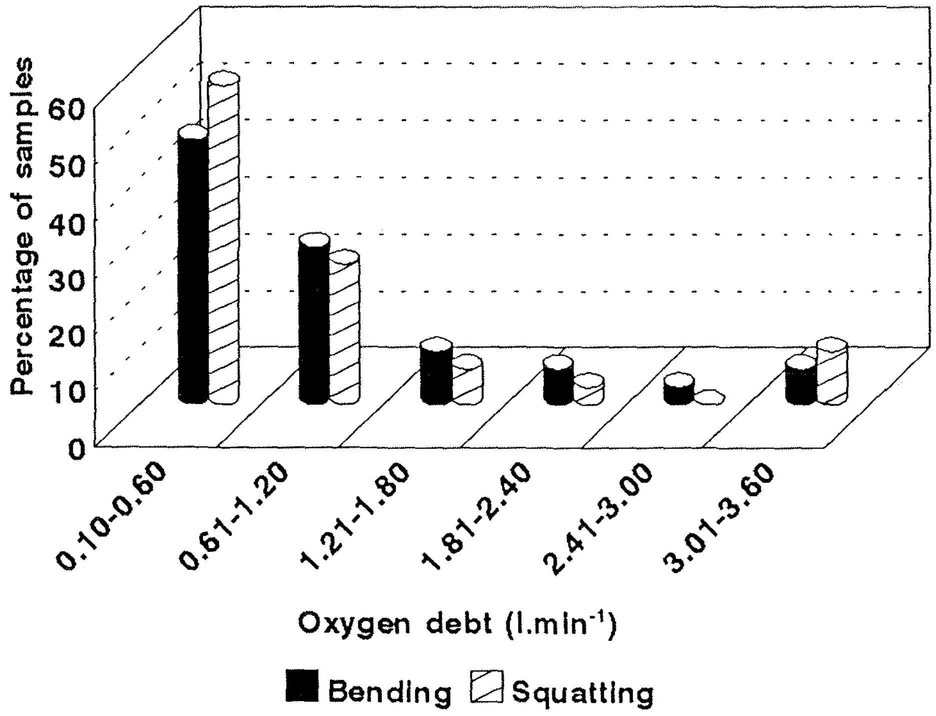
The posture of workers when performing some tasks is a decisive factor influencing energy expenditure. Vos (1973) reports that squatting for an activity itself requires an energy expenditure of approximately 2 K.cals min^{-1}. The subjects required 5.50 k.cals min^{-1} as metabolic cost in the bending posture while their requirement was 5.35 k.cals. min^{-1} for squatting. However, the samples required more than 2 k.cals as increment for performing (Fig.14) the activity in both the postures. When the former variable was correlated with endurance time it did not show association in both the postures, but showed movement in the opposite direction. The latter variable showed high association on comparison between postures (.7562).The paired t value did not show variation in this respect.

Recovery calorie: Table 63 shows data on recovery calorie.

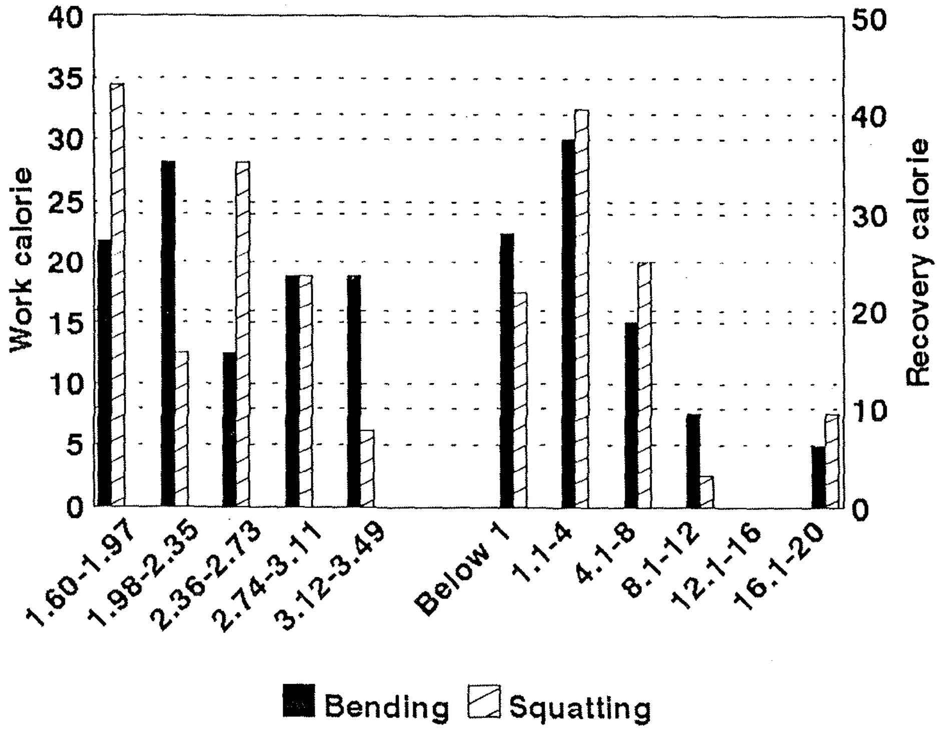
Table 63 : Recovery calorie

Calorie cost of incremental recovery pulse (K.cals.)	Posture				r
	Bending		Squatting		
	% of sample	Mean	% of sample	Mean	
Below 1	28.1	4.04	21.9	4.39	.6265
1.1 - 4	37.5		40.6		(p<0.01)
4.1 - 8	18.8		25.0		
8.1 - 12	9.4		3.1		
12.1 - 16	-		-		
16.1 - 20	6.2		9.4		

Inspite of all discrepancies that existed with physiological parameters between the postures, it was interesting to note that the incremental energy cost for recovery was more or less uniform though the mean values differed. The difference calculated using paired t test which indicated nonsignificance between the postures helped to reinforce the fact. The data also indicated that for the concerned activity the samples required almost double the calorie cost of activity as recovery calories highlighting that the job is really a strenuous one (Fig.14), but association between the variables considered with area mopped showed nonsignificance. Linear regression analysis was performed to establish a relationship and study the influence of energy cost of activity on the calorie cost of recovery (Fig.14) since the two variables on correlation showed a high degree of association (.6004 and .6372 with bending and squatting postures respectively) at 1 per cent level. Table 64 pictures the relevant data.



Oxygen debt (l.min^{-1})



Work calorie Vs recovery calorie

Fig.14.Calorie cost of endurance

Table 64: Work calorie versus recovery calorie

Posture	Independent variable	Dependent variable	Constant	Parameter dependent variable	r^2	Significance
Bending	Work calorie	Recovery calorie	-5.2232	3.7233	0.23	($p<0.05$)
Squatting	Work calorie	Recovery calorie	-8.9534	5.6557	0.34	($p<0.001$)

In the squatting posture the variables concerned showed remarkable association while it was only at 5 per cent level in the bending posture. The independent variable influenced the dependent variable to the tune of 23 per cent in the bending posture and 34 per cent in the squatting posture. It is assumed that the other attributes like area mopped, endurance and individual anthropometry account for the rest.

e. Morphological traits versus performance parameters: The major morphological traits were correlated with the sample's physiological parameters and the results are tabulated under Table 65.

Table 65: Morphological traits versus performance parameters

	Morphological traits											
Performance parameters	Age		Stature		Body size		Body fat(%)		LBM		BMI	
	Bending	Squatting	B	S	B	S	B	S	B	S	B	S
Endurance	-.0178	.0868	-.3071	-.2567	-.1189	-.4878*	.0635	- 2810	-.2413	-.4194*	-.0221	-.4443*
Area mopped	-.2419	.0674	-.1397	-.1199	.0153	-.4307*	-.0074	-.4053	-.0622	-.2089	.0652	-.4230*
Incremental cardiac cost	-.0188	.1959	.1247	.0411	.1289	-.0613	-.0754	-.3621	.2424	-.3073	.1021	-.0323
Incremental VO_2	-.0171	.0877	.1210	.0417	.1250	-.0268	-.0851	-.0962	.2465	.1286	.0993	.0113
Incremental energy expenditure	-.0171	.0877	.1210	.0417	.1250	-.0268	-.0851	-.0962	.2465	.1286	.0993	.0113
Recovery time	-.0332	.0723	-.2216	.0154	-.2113	-.2817	-.1345	-.1161	-.0943	.0997	.1132	-.0171
Incremental recovery cost	.1401	.2516	-.1906	.0267	-.0864	-.0281	-.0768	-.1506	-.0334	.1096	-.0311	-.0411
Incremental recovery VO_2	.2748	.3087	-.1902	.0261	-.1368	-.0283	-.0766	-.1506	-.0337	.1096	-.0314	-.0411
Incremental recovery calories	.2762	.2509	-.2402	.0248	-.0964	-.0287	-.0329	-.1510	-.0893	.1093	-.0289	-.0412
Oxygen pulse	-.0983	.0138	-.0296	-.1369	.1910	.3297	.0815	.1224	.2407	.1155	.2470	.1943

*Significant at 5% level

Endurance showed association with body size, LBM and BMI in the squatting posture alone indicating that these morphological factors influence endurance of the performer. Evidently significance was in the expected direction. When these physical attributes increased, endurance decreased (except LBM). Similarly body size and BMI decided the area of space mopped as they also show association in the squatting posture again in the negative. In this posture it can be inferred that physiological cost increases because of cardiovascular dynamics.

Energy expenditure did not show variation with any of the morphological attributes. Explanations ascribe to body fat; otherwise all are of the same body weight and muscle mass. Therefore energy expenditure does not vary. None of the other parameters showed variation or association with the morphological traits studied.

These facts in a way prove mopping is arduous and the thrall of posture influences the cardiovascular dynamics. The ensuing sections analyse the factors responsible for the demand.

E. Posture targetting - Angles of body bend

For the elimination of bad postures and to ensure correct and efficient working posture, postural analysis is of paramount importance. The angles of body bend recorded are explained under:

1. Anatomical movements at the extremities while mopping
2. Posture targetting
3. Shift in angles Vs heart rate

1. Anatomical movement at the extremities while mopping: The movement of a micromotion nature that frequently takesplace at the extremity joints about three imaginary axes while doing activities are transverse (flexion and extension), anterio-posterior or sagittal (adduction and abduction) vertical (rotation) and circumduction (Ganguli, 1982). The ensuing Tables and

Figure 15 present the data on the various movements, their biomechanical definitions, and their influence on the heart rate of the selected sample.

a. Flexion of the trunk : By flexion, is meant bending, or decreasing the angle between the parts of the body as in forward bending of the trunk when the hip joints are involved. Table 66 exhibits the change in HR due to flexion in the two concerned postures.

Table 66 : Flexion of the trunk while mopping

HR particulars	Percent of resting	Percentage of sample Posture				Paired t value
		Bending	Mean	Squatting	Mean	
Increment in HR	3-10	25.0	-.097	40.6	9.46	5.99
	11-18	6.2		31.3		(p<0.01)
	10-26	3.1		9.4		
	27-34	-		3.1		
	35-42	-		3.1		
Decrement in HR	3-10	56.4		12.5		
	11-18	6.2		-		
	19-26	3.1		-		

While flexion of the trunk influenced a percent increment in HR considerably in the squatting posture, the same movement tended to cause a decrement (per cent below resting) in the bending posture indicating that squatting posture involves more of a static component. As is evident approximately 68 per cent of the samples recorded only decrement in HR while flexing for bending. The results obtained in the bending posture, to a certain extent support De and Bhasins' (1991) view point that peak HR has no relation with posture adopted.

b. Shoulder adduction: Adduction indicates movement toward the midline of the body. Table 67 gives the relevant data.

Table 67 : Shoulder adduction while mopping

HR particulars	Percent of resting	Percentage of sample Posture Bending	Mean	Squatting	Mean	Paired t value
Increment in HR	below 9	43.8	8.66	21.9	18.56	5.27
	10-18	34.4		31.3		(p<0.01)
	19-27	6.2		25.0		
	28-36	3.1		15.6		
	37-45	-		3.1		
	46-54	-		3.1		
Decrement in HR	1-9	12.5		-		

Here again the adduction of the shoulder joint could induce increment in HR remarkably well in the squatting posture. Though 21.9 per cent recorded only below 9 per cent increase above resting values (in squatting posture) an equivalent proportion showed an increase spread over a wide range between 28-54 per cent above resting. On the other hand three-fourths of the sample tended to show an increase below 18 per cent above resting in the bending posture. It is therefore clear that samples tended to show variation in their cardiovascular response to shoulder adduction while squatting and bending for mopping (Glencross, 1973).

c. Shoulder abduction: Abduction indicates moving away from the midline of the body. Table 68 presents the data.

Table 68 : Shoulder abduction while mopping

HR particulars	Percent of resting	Percentage of sample Posture Bending	Mean	Squatting	Mean	Paired t value
Increment in HR	1- 7	18.8	11.63	18.8	15.56	3.10
	8-14	40.6		28.0		(p<0.01)
	15-21	31.3		31.3		
	22-28	-		9.4		
	29-35	3.1		9.4		
	Above 36	-		3.1		
Decrement in HR	1-7	6.2		-		

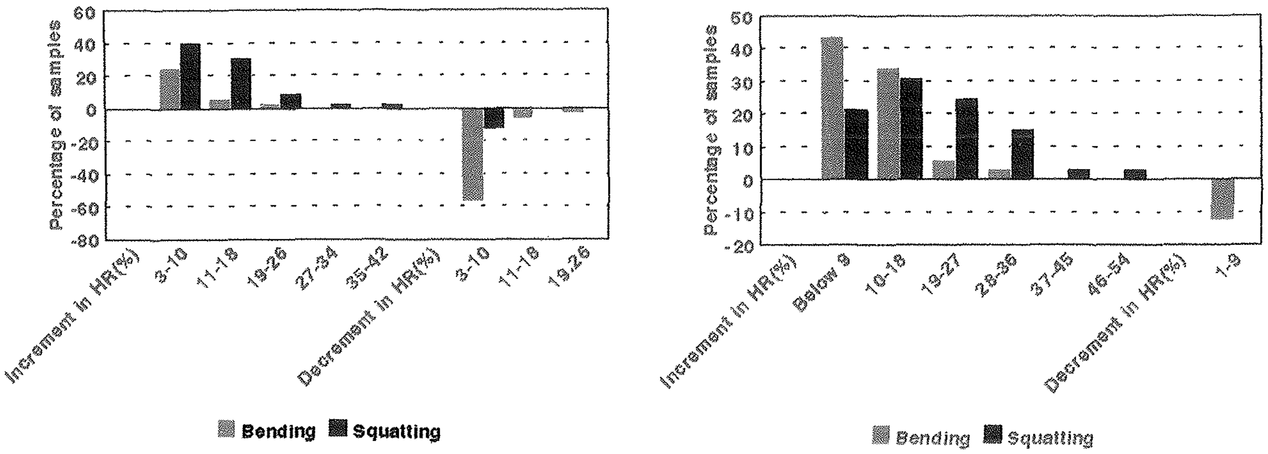
Comparatively shoulder abduction too activated the cardiovascular system more in the squatting posture than in the bending posture, though there was no obvious difference between the postures.

d.Extension of the trunk: By the term it is meant straightening, or increasing the angle between the parts of the body essential for the functioning of the muscles.

Table 69 : Extension of the trunk

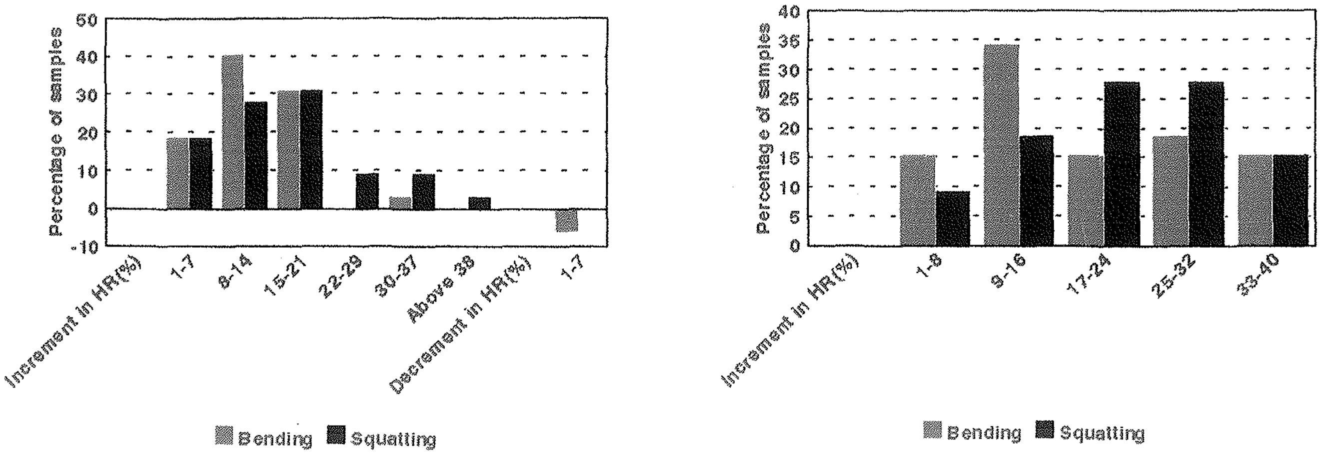
HR particulars (Percentage above resting)	Percentage of sample Posture Bending	Mean	Squatting	Mean	Paired t value
1- 8	15.6	20.22	9.4	22.69	1.44 (NS)
9-16	34.4		18.8		
17-24	15.6		28.1		
25-32	18.8		28.1		
33-40	15.6		15.6		

While more than 60 per cent of the sample exhibited a percentage increase in HR between 1-24 in the bending posture almost the same proportion recorded between 17-24 when squatting for the activity.



Flexion of the trunk

Shoulder adduction



Shoulder abduction

Extension of the trunk

Fig.15. Anatomical movements - Influence on heart rate

It is therefore evident that even a small movement involves various joints and the action in turn activates the cardiac system. More than in bending, the system seems to be affected more in the squatting posture.

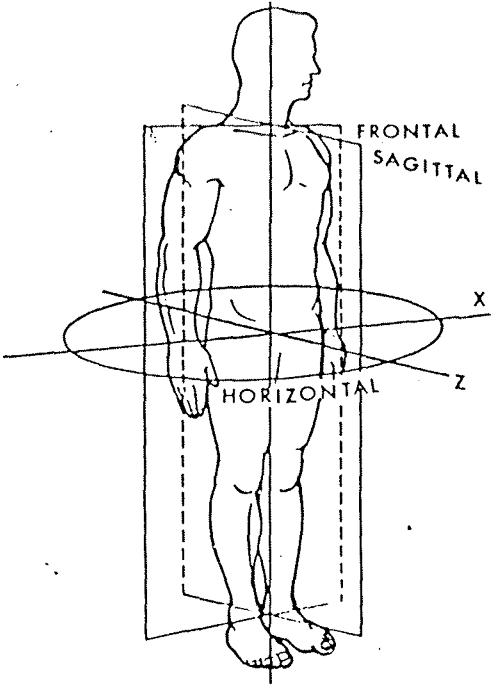
2. Posture targetting: Posture involves the mechanical coordination of the various systems of the body with reference to skeletal muscular systems and their neurological associations. Pain and discomfort may result from increased strain upon parts of the body, especially when weakened from physical inactivity. Backaches, headaches, foot pains, and neck discomfort may be traced to faulty body mechanism, when the flexibility of the joint concerned - the range of possible movement about a joint or a sequence of joints - is measured.

As explained under methodology (P 62) still photographs of subjects while performing the activity were also taken. The angles of body bend was also measured from the photographs. Markings facilitated defining and measuring angles of body position. The details on the angles of body bend are presented under Table 70 and Figure 16. A model of the posturogram made indicating the shift in angle of each body member while performing the activity in the selected postures is also presented as Figure 17.

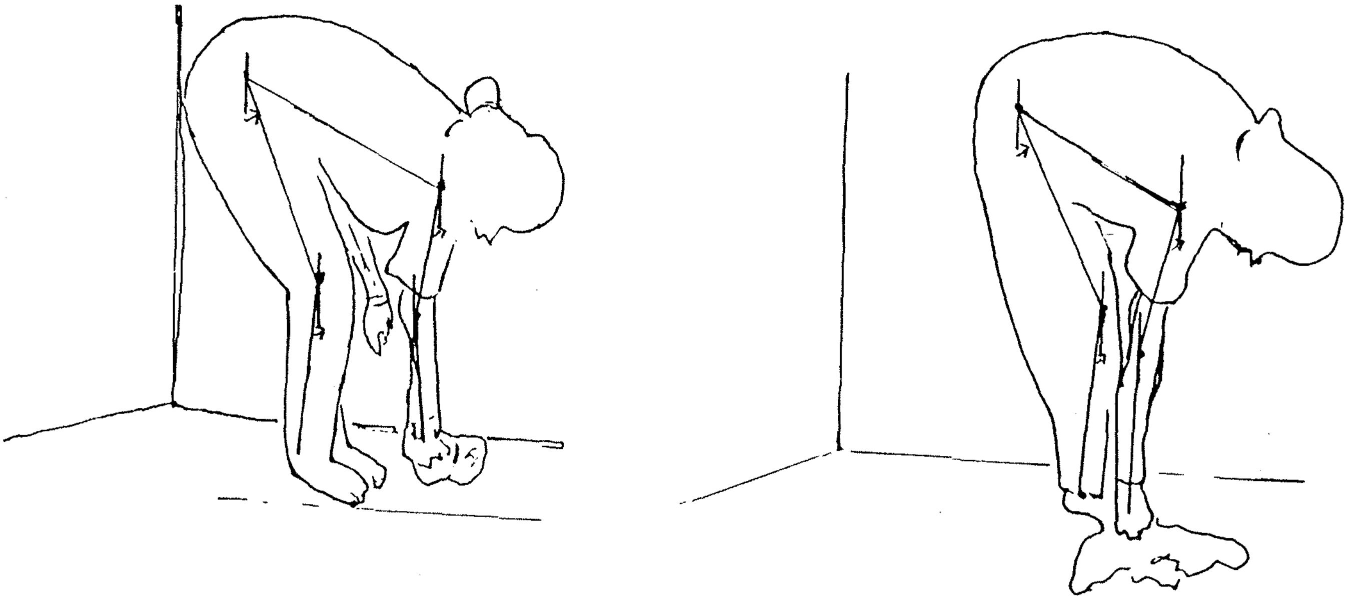
3. Shift in angles versus heart rate: Table 70 presents relevant data.

Table 70 : Angles of body bend

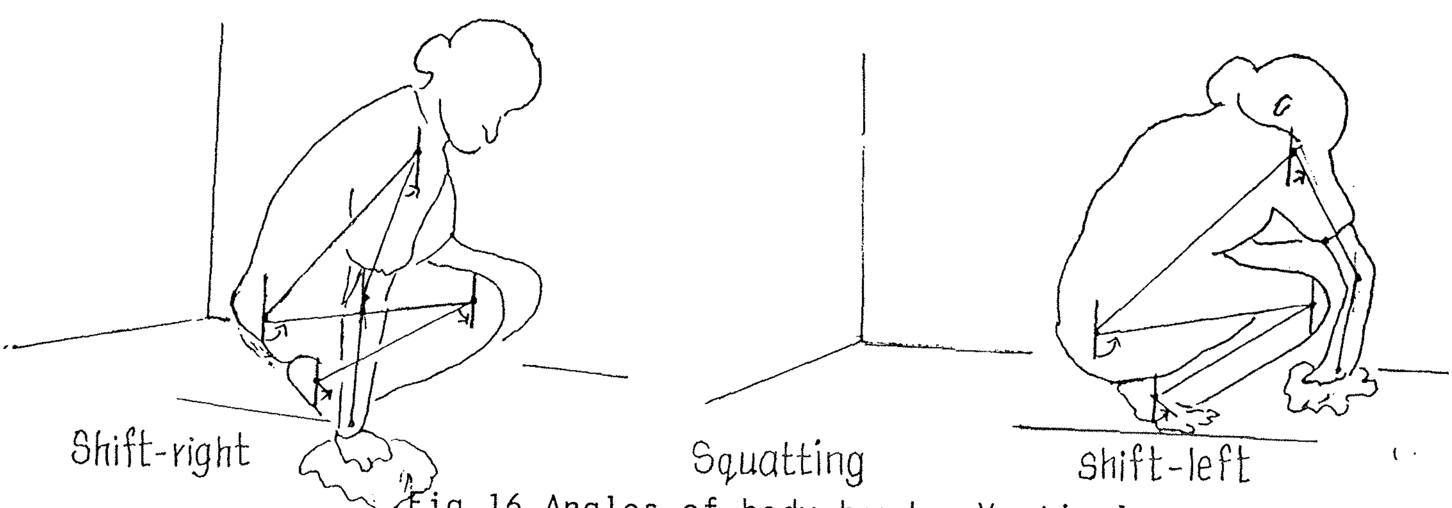
Anatomical movements	Joint concerned from vertical	Mean angles formed (°) from vertical Posture	
		Bending	Squatting
Flexion	Trunk (hip)	110	55
Adduction	Right shoulder	16	25
	Right elbow	2	28
Abduction	Right shoulder	10	15
	Right elbow	8	20
Adduction and abduction	Right upper leg	18	90
	Right lower leg	15	78
	Right heel	0	30



System of coordinates related to the body; The origin is at the body's center of gravity, anterior to the second sacral vertebra.

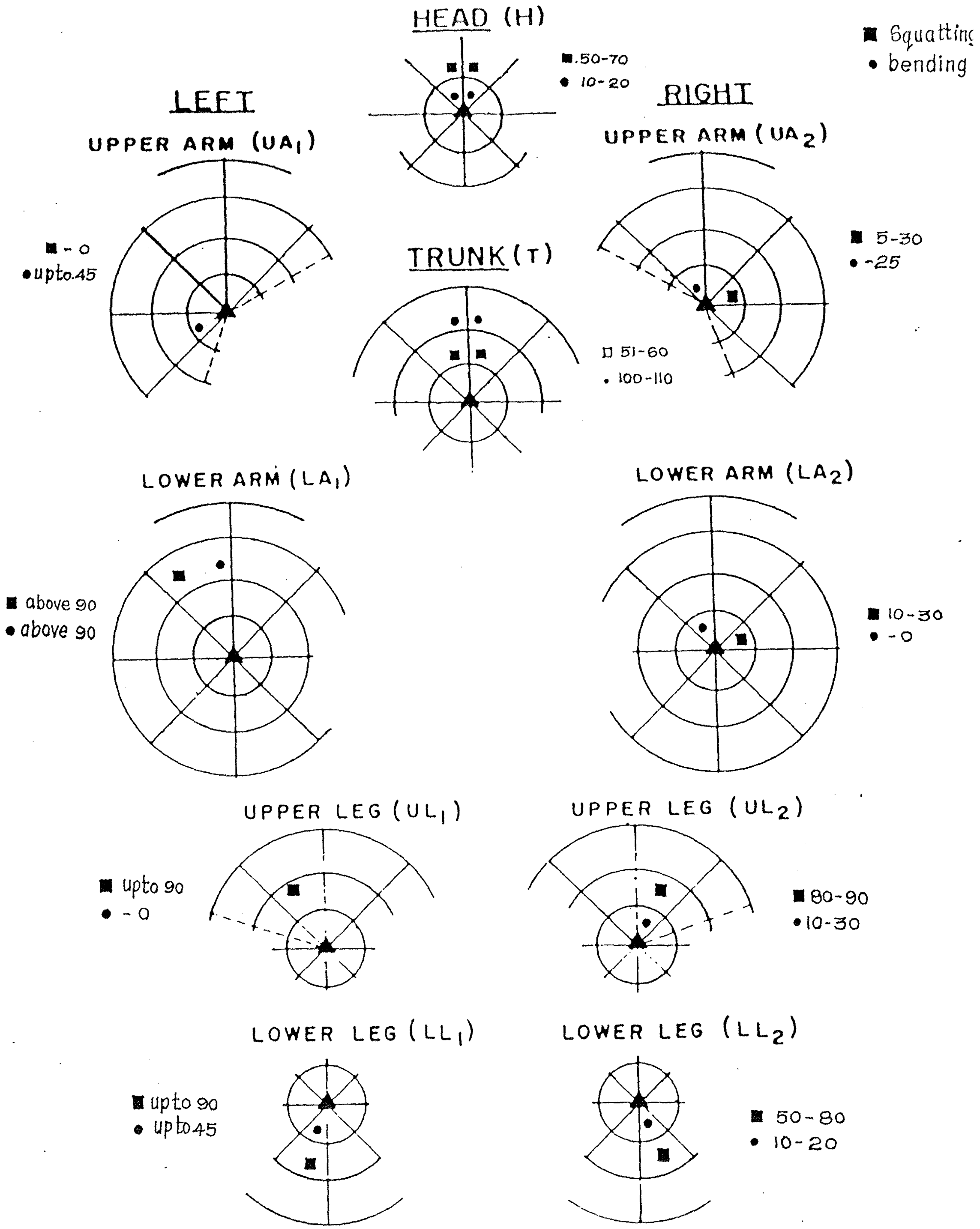


Shift-left Bending Shift-right



Shift-right Squatting shift-left

Fig. 16 Angles of body bend - Vertical



MODEL POSTUREGRAM

Figure. 17

Between the two postures, in the squatting posture the samples recorded deviation from original angles in all the joints concerned. Angle of trunk flexion alone was high in the bending posture. Naturally these shifts in body angles would have influenced function of cardiac muscle. Therefore the incremental heart rate influenced by the shift in angles in both the postures was correlated.

The major observation was that heel angle versus HR in the bending posture especially towards right (abduction) was statistically significant (-.9401). A very obvious factor was that when in three situations the elbow angle versus HR and knee angle Vs HR showed a low degree of negative correlation, shift towards left in the bending posture and shift towards right in the squatting posture alone respectively showed a slightly higher degree of positive correlation. The difference though not statistically significant, was in the expected direction. No doubt that small variation within a posture affects the HR in a predictable manner. Therefore the quality of movement as determined by principles of body mechanics is logically combined with subjective reports of discomfort and strain and is presented in the ensuing section.

F. Fatigue/drudgery index of mopping

The data collected (using the rating scale) in terms of rating corresponding to strongly agree, agree and disagree were then translated to scores. The total scores ranged between 30 and 187, with the mean scores of 103±32 for bending and 130±16 for squatting. Table 71 presents the classification of scores according to fatigue and drudgery index feature.

Table 71 : Mean scores awarded to fatigue/drudgery index

Fatigue/drudgery index feature classified under factors of	Percentage of response Posture	
	Bending	Squatting
Boredom	34.4	15.6
Psychological instincts	21.8	18.8
Fatigue-physical strain	25.0	50.0
Frustration	18.8	15.6

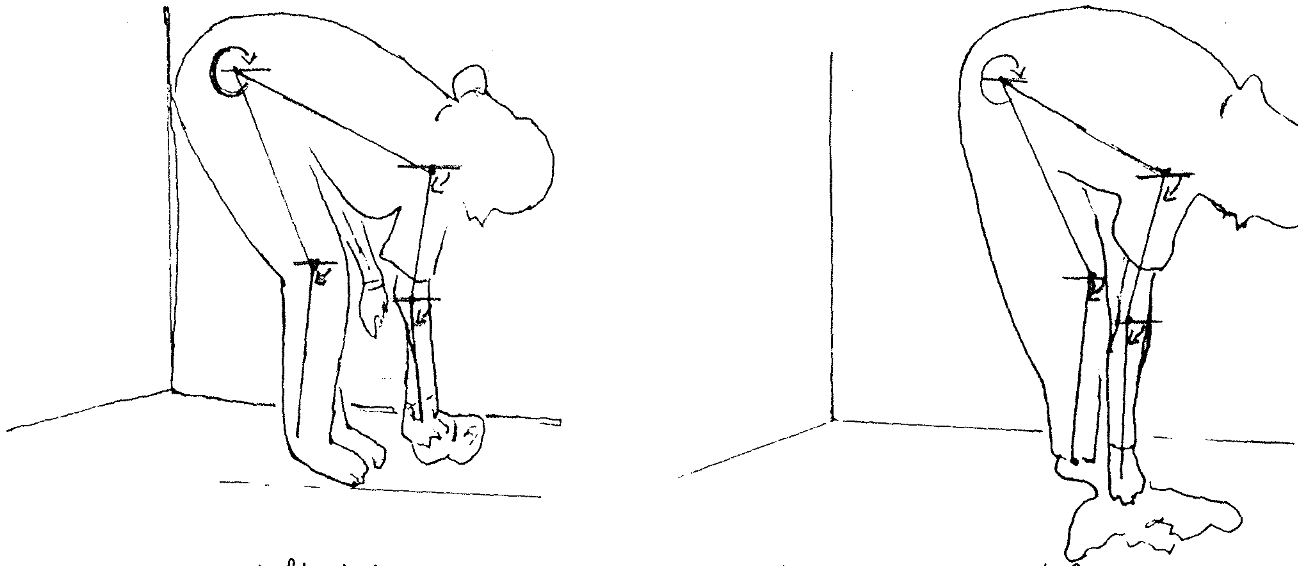
The responses focussed on factors related to boredom fatigue as of significance to the subjects mopping in the bending posture while the same activity reflected physical strain in the squatting posture. Fifty per cent also has agreed upon their psychological affections while performing the job.

Since the results pointed so, the details were tested using ANOVA to find out whether the means of specified classification differ significantly. Evidently type of family and age of homemakers showed significance with the scores awarded for the fatigue/drudgery index (at 1% level).

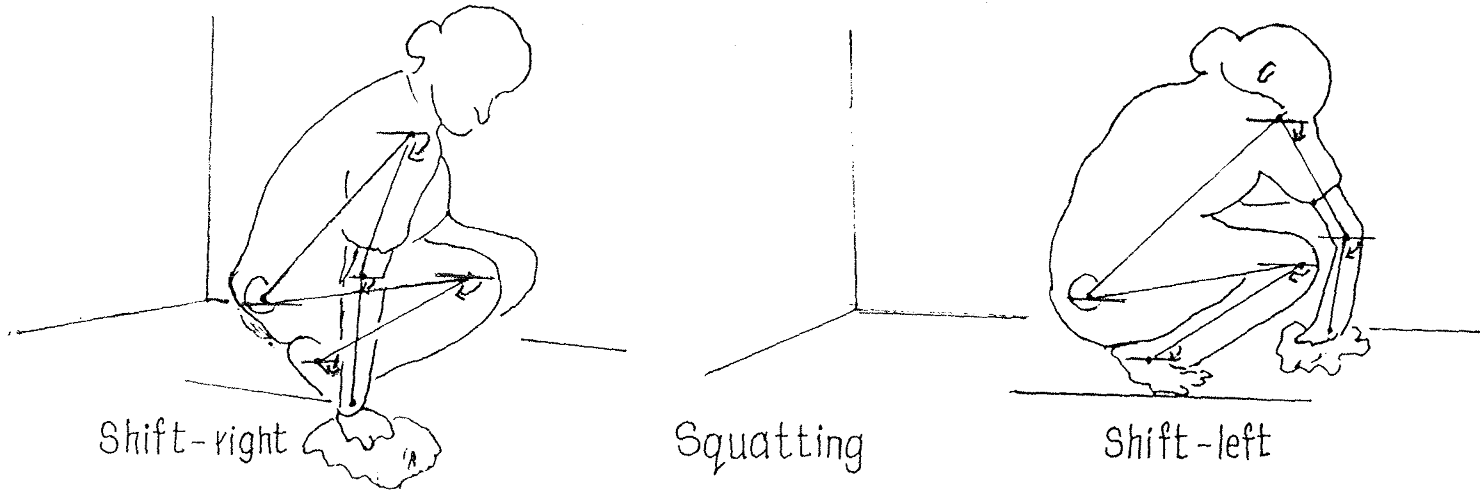
Table 72 : Assessment of fatigue/drudgery index

Basis of classification	Response to index	Range of scores	Percentage of homemakers Posture adopted Bending	Squatting	SE of the difference between sample mean
Mean± 2SE	Strongly agree	above 114.3	31.2	56.3	7.29
	Agree	91.7 to 114.3	34.4	31.2	(p<0.01)
	Disagree	below 91.7	34.4	12.5	
Number of options	High drudgery	121 - 200	18.7	78.1	
times	Neutral	120	18.7	9.4	
number of items	Low drudgery	0 - 119	62.6	12.5	

Based on both classifications mopping in the squatting posture was adjudged as highly fatiguing and drudgery provoking by all the samples. For an equivalent proportion whatever way one classifies, mopping is not fatigue causing or a drudge. Comparatively the activity performed in the bending posture was not much of a fatigue triggerer for many of the subjects. Since the difference was more than 2.58 SE (significant at 1% level) it can be concluded that the perception of fatigue/drudgery with regard to mopping activity is not equal between the concerned postures.



Shift-left Bending Shift-right



Shift-right Squatting Shift-left

Fig.18 Angles of body bend - Horizontal

angle of flexion.

In symmetric loading the stresses are equalized bilaterally on the musculo-skeletal system allowing a person to utilize his/her muscle strengths most effectively. Considering load distribution as a factor, mopping is asymmetrical. This causes not only a lateral bending movement on the lumbar column but, because of lordodic curvature of the column, produces a rotation of each vertebra on its adjacent vertebra. Eventually as Chaffin and Park, (1983) opine disc degeneration most often involving the annulus fibrosus occurs.

2. Shift in angle versus heart rate: Table 74 presents increment in HR effected with shift in angles.

Table 74 : Incremental HR due to shift in angles of body bend

Posture	Situation	Mean increment in HR (Percentage)
Bending	Shift towards left	24
	Shift towards right	27
Squatting	Shift towards left	23
	Shift towards right	25

Observations pointed to an effective increase in HR with shift in position (involving all the five joints) in both the postures. In the bending posture the knee and ankle (heel) angles are the ones more subject to shift from basic position. Evidently the change in their positions would have influenced increase in heart beats more than the others. The results agree with the findings of Dhesi and Firebaugh (1973) which state that these two angles were significant sources of heart rate elevation.

The hike in HR can also be attributed to the positioning of the various angles concerned with the posture. The reason put forth is that the flexion of the leg (while squatting) decreased the knee bend, thereby exerting pressure on blood vessels and nerves in the posterior part of the leg (Natarajan, et al, 1974). The increase in pressure on the posterior side of the leg, state Dhesi and Firebaugh (1973), restricts the blood vessels, impairs nerve efficiency, and increases the heart rate. The explanation agrees well with the present findings too.

3. Postural stress or the lumbar stress profile: The details on angles formed due to performance in the selected postures were used to evolve a 'static co-planar multi link modelling system' by finding out the corresponding force and load moments of the joints concerned. These data picture the anti-clockwise moment at L5/S1 junction. They are indicative of the stress to the back muscles (erector spinae in particular) in maintaining that particular posture. Table 75 presents the data.

Table 75 : Biomechanical data obtained from static modelling system

Situation	Joints involved	Biomechanical parameters Angle formed (in degrees)	Force (Newtons)	Load moment (Newton meters)
Bending Shift towards left	Elbow	86	+ 13	+ 0
	Shoulder	103	+ 28	- 1
	Hip (L5/S1)	67	+ 396	+ 98
	Knee	110	+ 442	+ 45
	Heel	0	+ 464	+ 166
Shift towards right	Elbow	100	+ 13	- 1
	Shoulder	106	+ 28	- 3
	Hip (L5/S1)	65	+ 396	+ 105
	Knee	94	+ 442	+ 94
	Heel	0	+ 464	+ 215
Squatting Shift towards left	Elbow	78	+ 13	+ 1
	Shoulder	82	+ 28	+ 2
	Hip (L5/S1)	1	+ 396	+ 259
	Knee	150	+ 442	+ 129
	Heel	39	+ 464	+ 223
Shift towards right	Elbow	98	+ 13	- 1
	Shoulder	98	+ 28	- 2
	Hip (L5/S1)	104	+ 396	+ 254
	Knee	151	+ 442	+ 123
	Heel	32	+ 464	+ 226

Lumbar stress or force indicates the reactive force at the joint, while load moment refers to the force which has to be developed by the lower back muscles (erector spinae) to maintain the posture and is measured as a load moment developed around the L5/S1 fulcrum. So here the distance of individual body parts from L5/S1 becomes a factor depending upon the posture adopted. The static component in any activity considers the beginning of the movement ('start' position), while dynamic forces change with time or acceleration. This is a co-planar model, that is,it is assumed that all the forces are co-planar (acting in the sagittal plane); so this is called the static co-planar multilink modelling system. A dynamic non-co-planar modelling would have given more accurate analysis; but it requires video recording of action. Considering the remote possibility of video recording static co-planar modelling was recorted to.

The forces and the load moments developed at the proximal joints are presented. According to Karvonen (1985) the needed force is produced by muscles. The bones, joints and connective tissues together with muscles form a complex leverage system to bring the force into action. Incidentally load moment developed was highest at the hip joint in the squatting posture in both the left and right shifts to the tune of + 259 Nm and + 254 Nm respectively, followed by heel (+ 223 Nm and + 226 Nm respectively). In the bending posture apparently, it was just the reverse. The load moment developed was higher at the heel joint (left shift : + 166 and right shift : 215 Nm) and comparatively lower at the hip joint (+ 98 Nm and + 105 Nm respectively).

A further limitation with squatting for the activity is that the arms must be extended farther in the forward horizontal direction than in the stooped or bending posture. Naturally, such a position of the arms means that a high torque will be produced at the shoulders. As a result, the person will normally lean forward more to lessen the load moment arm about the shoulder, and in so doing will cause greater stresses on the low-back both by effects of gravity acting on the torso mass and by hyperflexing the lumbar column. Such hyperflexion places a greater stress on the posterior positions of the annulus of the disc, thus distributing the compressive loads unevenly within the disc.

As Grieve (1974) and Schultz et al., (1982) state studies indicate that spine loads are directly related to trunk movements. They put forth that this idea has been further explored with biomechanical models, which show that prediction of trunk muscle forces and spine compression are quite well correlated to 'in-vivo' measurement of disc pressures. Since pressures within the trunk have also been found to increase as a function of trunk flexion (Andersson, 1985) the effective force incident on the erector spinae was calculated.

4. Posture versus effective musculo-skeletal stress: Table 76 presents the force effective on the erector spinae due to performance in the two postures. Erector spinae is a deep muscle of the back (Gray, 1992).

Table 76 : Effective force on erector spinae

Posture	Situation	Effective force (N)	Mean Erector spinae force(N)
Bending	Shift towards left	2144	2218
	Shift towards right	2292	
Squatting	Shift towards left	7456	5505
	Shift towards right	3554	

The effective force is the force generated. It is the force exerted by erector spinae to counteract gravitational attraction for each operation. Therefore it is highlighted that in the squatting posture in both shifts the effective force was higher (7456 N for left shift and 3554 N for right shift) and proves that this posture especially in the particular left shift is not tolerable in the long run.

The mean erector spinae force calculated indicate the extent of change that is necessary to offset the change in centre of gravity due to the changed posture. No doubt one needs to develop considerable incremental force in the squatting posture to counteract centre of gravity over and above that in the bending posture. Therefore the compressive force developed between the L5/S1 vertebrae was quantified.

5. Posture and compressive force on L5/S1 disc: The compressive force indicates the force exerted on the lumbar spine, that is, between the L5/S1 vertebrae, due to shift in angles of body bend. It depends upon the pelvic angle and the weight above the L5/S1 junction. It varies with the posture and the weight of the individual. Table 77 presents the related data.

Table 77 : Compressive force on L5/S1 disc

Posture	Situation	Compressive force (N)
Bending	Shift towards left	2228
	Shift towards right	2369
Squatting	Shift towards left	8121
	Shift towards right	2861

The study revealed that the shift towards the left especially exerted a remarkable force on the L5/S1 disc. It is clear that this much of force on the lumbar spine is not a favourable concept in the long run (Fig.19).

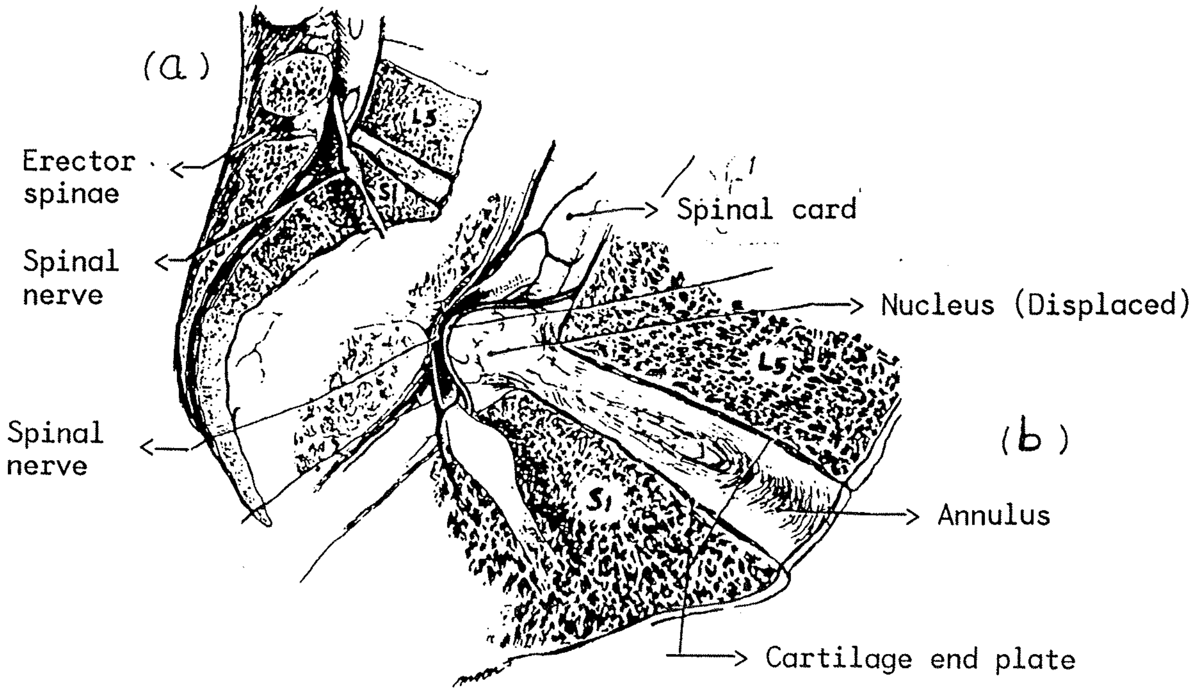


Fig.19 Displaced degenerated disc exerting pressure on spinal nerves

If the load moment is too much, the muscles and tendons of the erector spinae get sprained (see 'a' of Fig.) and may even lead to a muscle tear. Similarly, if the compressive force is as high as this, the subjects may end up with a nerve problem (see 'b' of Fig.). It may be so severe that it may lead to fracture of the bones itself. Andersson (1985) emphatically states that the compressive strength of vertebral motion segments to indicate that failure occurs at loads ranging from 5000-8000 N. He further adds that the compressive strength of the vertebral body is greater in males than in females and decreases with increasing age (osteoporosis). This factor may be more appropriate with Indian homemakers.

6. Probability of low back pain due to postural stress while mopping

Table 78 presents a comparison of the relative postural stress imposed by the two postures. Since the force exerted is for just a single action, it is understandable how many times the action will be repeated to mop a specific area. The cumulative force can be easily calculated and one can decide how strenuous and taxing the action can be on the performer. Therefore the probability of low back pain as a sequel to postural stress during mopping in both the postures was calculated from the data obtained from compressive force using the method suggested by Chaffin et al, (1977).

Table 78: Probability of low back pain due to postural stress while mopping

Posture	Situation	Compressive force (kg)	Probability of low back pain (in frequency rate)
Bending	Shift towards left	227	2
	Shift towards right	242	2
Squatting	Shift towards left	829	19
	Shift towards right	292	9

The probability of low back pain is 19 out of every 20,000 hours for the extreme case in the squatting posture as against 2 out of 20,000 hours in the bending posture. On an average the selected sample mopped one stroke (from left to right) within a second. The mean work time recorded for mopping a specific area of 9.2 sq.m was 52 seconds in the squatting posture. Naturally for mopping this minimum area they would have repeated the action 50 times. It is needless to say that to mop the whole house every day the samples would repeat the action as many as 200-300 times at least. Hence the probability of the samples to encounter low back pain is very obvious. Moreover, degenerative changes in discs may result as one ages; even minor sprain may cause internal and external derangements in the discs leading to muscle spasm, lumbago or sciatica- all involving the lumbo-sacral joint states Gray (1992). This is all the more pronounced with Indian women since they , gain weight (body weight) considerably well after their first confinement. As an added factor the stature of Indian women is also low. Such ethnic or conventional reasons can also contribute to their vulnerability to low back pain by adoption of the posture.

Another significant feature was that even according to the classification put forth by Chaffin and Park (1973) the frequency rate of 19 is assigned to compressive force (kg) equivalent to 650 +. As such the compressive force in the present context is 829 kg for shift towards left in the squatting posture and hence the frequency 19 may be an underestimate. The avoidance of static work for any part of the body is an important target for work improvement.

In the present context, not much is known about what stress - strain parameters are important in inflicting damage to the lumbar spine. Peak stress, duration stress, strain rate, intermittent repeated stress, and the like are all important, but to what degree and at what level should be analysed.

The reason for creating awareness among homemakers is probably explained by these factors. Such an awareness building is necessary to curtail the perceived effort enforced through performance. It may also help to reduce the number of painful episodes triggered by the job. Insofar as these have deleterious effects on efficiency and health it is important to attempt prevention and alteration.

7. Endeavours on ergonomic intervention

Indian homemakers put premium on clinging to conventional work methods. It is time they developed scientific temper and rational outlook in conformity with the acceptance of inevitable and resolving changes. Before subjecting the samples to an experimental study on use of manual moppers, an insight into the outcomes of the studies conducted with them were explained (Plate 7). The attempt actually made them witness in person in empirical terms the consequence of their action to their own physiology. Awareness of their miserable condition which they themselves had felt, experienced and expressed is a 'Sine qua non' for their liberation. Though anybody can comprehend that changing gears mid-stream is a most difficult task, the concept of knowing what to do and not caring for it has cast a shadow on women's endeavours.

To make at least the concerned sample realise that abandoning the postures and switching over to comfortable stances may help reduce the strain, they were subjected to a performance test using manual moppers. The findings are discussed in the next section.

H.Feasibility of using manual moppers

The findings are discussed under :

1.Description of the available manual moppers:

Table 79 portrays details on the features of the available manual moppers.

Explaining the findings of the task analysis

Trial of two models of moppers

Plate .7. AWARENESS BUILDING

Table 79 : Description of the available manual moppers

Criteria	Type Model A (Cotton thread)	Model B (Sponge)	Model C (Hosiery waste)	Model D (Natural-cum-synthetic fibr
<u>Construction features</u>				
Shape of the swab	circular	square	circular	Oval
Use of swab	wet mop	wet mop	wet mop	wet mop and dry
Weight of the mopper (gms) - dry	2200	950	750	1500
Handle	wood	metal/PVC	metal	metal
Swab fixer	tin/plastic	plastic	PVC cup	metal
Assembly materials	rivets	rivets	rivets	swivel head in plastic
Wringer/squeezer	nil	spring	lever	nil
Nature of handle	fixed	fixed	adjustable	adjustable
Nature of swab	fixed	fixed	fixed	removable
Component parts	assembled	assembled	assembled	modular (disassembling type)
Motion effected	vertical/ horizontal	vertical or horizontal	curved strokes	's' shaped curves
Nature of motion	rhythmic	nonrhythmic	rhythmic	rhythmic
<u>Dimensions</u>				
Length of handle (cm)	125	95	104	98
Length of handle with swab	149.5	103-135	124.5	106
Swab (base) fixer (cm)	12 (dia)	12.5 x 50	12.25	40 x 11
Swab (cm)	30 (length)	15.0 x 5.0	14 (dia)	60 x 27
Handle diameter (cm)	8	7.5	10	8.5
<u>Cost</u> (Rs)	25-60	60-100	150	650

None of the models was identical in their features with the other model. Model 'A' emerged as the most inexpensive one. Among the types model 'D' had the unique feature of having a very broad swab (60 x 27 cm). The base promised necessary stiffness both by virtue of the base head and the swab, tailored to a durable and straight piece of rexin backing. It could cover a large area than the other models.

Mode of operation: In model 'A', the swab is dipped in a bucket of water, squeezed manually and used for mopping from left to right in the horizontal plane. Within the handle of model 'B' a lever is provided connecting the swab assembly. By an essential contraction and extension action of the lever, the swab gets dispensed of excess water and is then used to mop floors by a back and forth action in the vertical plane. In the third model a rotary wringer attachment helps to pull up the hosiery for wringing water. With this process the swab (hosiery waste) bellows down and does the mopping. The operation is similar to that in model 'A'. In the fourth model, the swab (insert) is inserted over the swab base after rinsing and wringing off the water. Using a natural 'swerve', the swab is made to make a curved action of mopping. The swivel attachment allows mopping of space under furniture and skirting of walls too which none of the other models affords.

2. Potential user appeal: The cumulative opinion of the samples while evaluating the moppers was summarised and is presented in Table 80.

Table 80: Evaluation of the selected moppers

		Types		
Criteria		Percentage of respondents		
	Model A	Model B	Model C	Model D
Physical features				
Good shape	100	100	100	100
Portable	100	100	100	100
Easy to store	100	100	100	100
Good appearance	50	80	100	100
Feasibility for regular use				
Satisfactory swab	100	-	-	100
Easy to operate	80	40	-	100
Satisfied with the quality of work	80	20	-	100
More area can be covered	100	-	-	100
Affordable	100	67	-	-
Easy manoeuvrability	73	-	-	100
Easy to maintain	20	-	-	100
Light in weight	10	100	100	-
Helps to achieve a rhythm in action	100	-	-	100
Does not induce physical stress/fatigue	-	-	27	100
Require special skill to operate	-	-	20	100
Allows for direction change	-	-	18	100
Broad swab helps to apply local pressure	-	-	-	78
Swab dries quickly	-	21	2	54
Wet swab smells bad	100	28	41	17
Durable swab	50	20	24	75
Ergonomic considerations				
Holding handle is a strain on hands and elbow	100	100	100	100
Weight increases when the swab is wet	100	100	100	52
Need to apply force (shoulder and wrist) while mopping	100	80	80	-
Squeezing out water from swab is cumbersome	100	100	100	20
Swab wears out easily	100	100	not known	not known
Handle grip is inconvenient	100	100	100	100

From what has emerged it is inferred that Models 'A' and 'D' score better with respect to feasibility, operation and maintenance. Between the two models, the panel judged Model 'D' as the best, provided its cost is slashed down and a few modifications are effected. So this enabled the selection of the two models (A & D) for the performance study.

3. Performance impact of the manual moppers on end-users: The parameters considered for testing the models were endurance, area mopped, work pulse and recovery time. Necessary instructions were given to assure reliability of required data. For analysis the data recorded while squatting for mopping was compared with the parameters displayed while using manual moppers. The findings indicated the following :

a. Area mopped within a specified time: The performance in terms of productivity of the selected sample based on each minute recording is presented under Table 81. As stated under methodology, the samples were requested to mop in the squatting posture too while they mopped for continuous three minutes. The area mopped within one minute for three consecutive minutes is presented below.

Table 81 : Area mopped within specified time

Mopping technique	Posture adopted	Time (s) Area moped (sq.m) 0-60		61-120		121-180	
		Mean	S.D	Mean	S.D	Mean	S.D
Conventional	Squatting	10.6	2.96	9.97	3.37	9.76	3.38
Using model 'A'	Standing	12.3	2.21	13.1	2.88	13.6	3.61
Using model 'D'	Standing	13.2	0.08	14.8	1.92	16.0	1.71

In the conventional method the data showed decline in the sample's productivity with the lapse of each consecutive minute, while the parameter tended to improve when they used manual moppers. It is inferred that the first minute of mopping using manual moppers is basically a warming-up period, above which performance could be satisfactorily improved. The study also highlighted enhanced efficiency and productivity while using Model 'D'.

b. Outcomes of the performance test using selected models: Table 82 presents information on the comparative study of the samples performing in two different methods of mopping.

Table 82 : Comparative table of two techniques of mopping

		Technique adopted Mean value			
Variables	Conventional method	Model 'A'	Model 'D'	'F' value	Significance
Endurance (s)	107.9	157.41	358.73	157.01	$(p<0.01)$
Area mopped(sq.m)	20.69	31.01	44.83	13.8	$(p<0.01)$
Incremental work pulse (beats)	59.75	36	15	8.92	$(p<0.01)$
Percentage increase above resting base	70	48	20	23.7	$(p<0.01)$
Work calorie (K.cals/min)	2.36	1.42	0.79	17.8	$(p<0.01)$
Recovery time (s)	604	205	41	184.3	$(p<0.01)$

Body size and work time (endurance) showed high correlation with th data recorded for performance using the manual moppers. It is assumable tha use of a manual mopper could definitely enhance one's endurance limit an productivity (area mopped) compared to adoption of the conventional posture, a the same time reducing the physical strain on the worker as is evident by lesser increment in heart rate value above resting. F test proved significan variation mainly with recovery time. Since recovery time is a physiologica indication of stress, it is proved beyond doubt that mopping in the conventiona posture imposes great strain on the performer. This all the more amplifies th need to evolve and assess the performance of designs of available manual moppers

4. Suggestions for improving user acceptance: Improvements in the existin design of the two selected manual moppers (Models 'A' and 'D') were mad

based on the evaluation and reasons cited by the subjects.

- The handle does not offer good grip
- The handle slips, so needs to exert great force - especially in wrist, elbow and shoulder for manoeuvring the swab.
- The swab stains the wall surface above the skirting

According to Mc Cormick (1976) the three stage definition of huma factors states that it should : (a) consider human beings in the design of man-made objects (b) enhance functional effectiveness and maintain desirable huma values in the process (health, safety and satisfaction) and (c) approac with a systemic application of relevant information about huma characteristics and behaviours to the design of man-made objects. Thi observation adds added impetus for effecting improvement in the selected models.

a. Hand-object contact: Grieve and Pheasant (1982) described the hand position and function according to the degree of object contact and the extent to whic the hand is used on a closed or open-chain configuration. Considering this smooth handle which offers control of speed cycle (if possible) should b included in the handle component of the mopper.

b. Sturdy hand-grip: The handle attached to the mopper which also serve as a rotary device and enables change in direction where and wheneve necessary should be provided for improved productivity.

c. Hand - Handle interface : To ensure comfort in mopping, softe materials such as felt padding or sponge rubber which offer better equalizatio of pressure over the contact area and also protect the skin over bony prominence is suggested. A thermoset plastic handle with grooves for firm grip can also b tried.

d. The swab: The swab while mopping the skirting of walls touches the wal surface and smears it with dirty water. A lever system like in a daizywhee can be introduced within the mop base so that the fibrous layer can be pulled o a little leaving a 5 cm fibrous layer in the exterior to do the mopping of th skirting walls.

These modifications can be successfully effected in model A. Model D has to be seen from another dimension too, since consideration of appropriate and affordable technology attracts attention of consumers. Model 'D' alone was unanimously categorised as highly expensive (Rs.650/-). The insert (wet and dry) costs Rs.165/-. It is clear therefore that the handle with the mopbase costs Rs.485/-. In this model they had used powder coated aluminium, both for handle and mopbase. The suggestion put forth is that the handle and mopbase can be dye cast (plastic) which may cost less on mass production. Similarly chemically treated hosiery waste available at affordable price (from Tirupur) can be introduced instead of the natural-cum-synthetic fibres.

Incorporation of these suggestions would eventually improve the quality of the existing models and enhance the productivity of the end-user.

As household work is unmonetized and unmarketed, improved home technology is not considered important. Despite economic developmment the level of technology in the household arena is very meagre. Tiwari's (1994) viewpoint that technological advancement demands leadership and innovativeness definitely holds good here. Naturally technology innovation to improve the lot of women receive priority. If the gain from such innovations of appropriate technology were large and obvious, enough people would adopt them without needing any external motivation. Prospective entrepreneurs should oblige by accepting this as a challenge and produce designs which will mean a real service to the womenfolk of the society who struggle hard to manage with their limited human energy potential.

Summary & Conclusion

V SUMMARY AND CONCLUSION

The role of home management is to appraise the resources available, to judge their use in keeping with the goal or event demands and to develop plans to be implemented for effective conservation. Despite the importance, planning for housework in a specific manner is not in practice. For modern women, combining household work responsibilities and paid work creates demands that may produce role conflict. Naturally, satisfaction with household work is one output, while on the resource side fatigue and stress may result. This is more pronounced with the activities disliked by them - especially mopping of floors. Yet, homemakers are unaware of possible psychological and physiological consequences when they are involved in such specific activities like mopping. An analytical method for appraising household work - especially mopping - in terms of caloric demands and fatigue was therefore undertaken. The study entitled "Postural Ergonomic Analysis of mopping activity" was thus streamlined to address the following objectives:

A. Analyse activity patterns of selected homemakers

B. Identify the most difficult household task

C. Estimate caloric cost of activity in the two selected postures of bending and squatting -

D. Find out shift in angles of body bend through still film analysis and posture targetting

E. Calculate the stress - strain concept on the musculo-skeletal system by determining the compressive force on the L5/S1 disc.

G. Examine the feasibility of using manual moppers for energy conservation

The agenda drafted for the study included the following strategies:

1. A household survey was conducted involving 500 samples (homemakers) selected through convenience sampling to analyse their individual household activity patterns. A structured interview schedule was used for the purpose.

2. The caloric cost of six major household activities was done by subjecting ten selected samples to a test involving ergometry and telemetry. From individual HR recording the VO_2 and caloric cost for each activity was found out. From the analysis, mopping emerged as the most difficult activity demanding more of the homemakers energy.

3. Using the above test (which involved use of published data) as a guideline, eight samples were purposively selected and their maximal aerobic power was found using the telemeter-ergometer - gas analyser monitor system. From the values obtained (68 observations) for HR and VO_2 a regression equation was evolved. This was used for calculating the VO_2 and energy cost of 32 samples while they mopped in two different postures.

4. The angles of body bend while engaging in mopping in two postures were found using still film analysis and posture targetting.

5. Subjective feelings of the samples relating to mopping were found using a rating scale.

6. The stress-strain concept on the musculo-skeletal system was determined by developing a static co-planar multi-link modelling system.

7. A comparative study of the impact of mopping on the cardiovascular system was analysed by subjecting the samples to a test where they mopped both in the conventional squatting posture and in the standing posture using two upright models of manual moppers. The procedure again involved recording of HR while they performed the activity.

The findings of the study are summarised under:

Findings of the household survey

1. The socio-economic profile revealed that majority of the respondents were Hindus (67 per cent). Nuclear families ranked high (90 per cent). The age range between 38-42 years was the most represented (74 per cent). Though 90 per cent of the homemakers were educated, only 50 per cent of them were gainfully employed. Being employed naturally heralded a few problems related to their personal and managerial attributes. Albeit taking up outside career being difficult, it helped augment their economic status as is evident from the 55 per cent who belonged to the higher income strata (> Rs.4,451/- per month).

2. The homemakers disliked the activities of sweeping, ironing and mopping the most (83, 85 and 90 % respectively), by virtue of their strenuous nature and the enforced posture. To reduce the strains and to cope up with the requirements, 80 per cent of the homemakers resorted to engaging domestic help and entrusted the most strenuous activities to them, among which mopping received priority. However, all of them felt the need for an effective mopper to reduce the strain of mopping.

3. Almost one half of the sample (48 per cent) were living in BHEL quarters and others in their own houses or in rented houses. Wherever they lived the findings revealed that the livability and ergonomic aspects of the house gratified only two-thirds of the sample. But they were cautious in their use of their time and energy as is evident from a high proportion possessing many labour saving devices to help in activities of cooking, laundry and maintenance.

4. With respect to posture adopted while performing activities standing was the most preferred, while mopping, washing clothes and ironing warranted squatting also (71, 47 and 33 per cent respectively). For mopping alone bending was resorted to by 29 per cent.

5. An enquiry into triggering factors of fatigue as related to mopping revealed the enforced posture, physical pain, muscular effort involved and dislike for the task as significant ones. Nevertheless the homemakers with due respect to their educational status were knowledgeable enough not only to identify the most fatiguing activities but also practice few measures to alleviate fatigue through substitution of machinery (98 per cent), effecting changes in the task (73 per cent) and creating interest in the work itself (71 per cent).

Situation analysis

1. The first six activities (except child care) ranked as highly fatiguing by the homemakers were selected for further analytical purposes. The activities were mopping, washing and ironing clothes, sweeping (cent per cent each respectively), grinding (88 per cent) and rolling chappati (79 per cent).

2. The method adopted involved remote transmission of HR and skin temperature to a telemeter. As a prelude the subjects were calibrated on an ergometer while their cardiac potentials were recorded for varied loads in ergometry - namely 20, 30 and 40 watts. Their HR profile while they performed the six activities were interpolated on a regression line already fitted for their resting base (HR) versus responses to ergometry (for varied loads). This index helped to estimate the Vo_2 status of the samples for all the activities from which the calorie cost incurred for all the six activities was calculated. Ironing and sweeping alone showed variation (at 1 % level)

between postures regarding increment in HR. The arterial BP of the sample after completion of activity was also found. The paired t test (difference test) proved ironing, washing clothes and mopping to show significant variation (1 % level) between postures. Variation was not evident with skin temperature for the activities studied.

3. The mean caloric cost projected mopping followed by grinding and sweeping (3.99, 3.21 and 3.14 K.cals min^{-1} respectively) as strenuous in the standing posture, while the records made clear mopping, washing clothes and sweeping as highly strenuous (4.69, 3.84 and 3.43 K.cals.min^{-1} respectively) in the squatting posture. Since in both the postures mopping ranked first in caloric cost, this activity was adjudged as the most strenuous among the six highlighted for situation analysis and hence mopping was identified for further investigation.

Task analysis

1. A regression equation to be used for calculation of the Vo_2 of selected sample while mopping in two postures was arrived at based on the situation analysis. The data revealed that their work accomplishment (in watts and KPM) increased with endurance. The range extended only between 30-60 watts and their effective tolerance in terms of time was only between 3-6 minutes. It was therefore evident that the physical fitness of the sample was comparatively low.

2. From the HR data and $\dot{V}o_2$ incurred for various submaximal loads, two regression equations (one on LOTUS 1-2-3 and another in BASIC) were derived. Between the two, linear least square regression in Basic was found to be more reliable and hence was preferred to be used for the calculation of the energy cost of all 32 subjects selected for the task analysis while mopping in two different postures of squatting and bending.

3. The task analysis decided was scheduled to be conducted involving two phases. In the first phase, the subjects mopped a specific area of 9.2 sq.m and in the second phase, they mopped until endurance limit.

4. The parameters recorded in both the cases were HR along with area mopped or time taken as the case may be. In addition recovery time and recovery cost (HR) were also recorded during the second phase,namely, mopping till endurance.

Data recorded for mopping 9.2 sq.m.

1. The mean time recorded was 45 and 52 seconds in the bending and squatting postures respectively.

2. The mean working pulse documented for mopping the specific area was 118.6 and 122.2 beats while bending and squatting respectively. The samples were more consistent in the squatting posture (C.V = 8.9 %) The mean incremental work pulse calculated also proved squatting to be more demanding (46.1 beats) than bending (42.5 beats) for mopping. Naturally squatting posture produced 62.9 per cent mean increase in HR (above resting base), while bending influenced 56.47 per cent.

3. Analysis using paired t test proved that there existed a variation ($p<0.05$) between postures for parameters like work time, incremental work pulse and percent increase in HR above resting base. But incremental HR did not show correlation with age, stature or body size. Since 'time' has not been controlled, it is inferred that the factors of 'posture' and 'time' could have contributed to these findings.

4. Estimates on $\dot{V}o_2$ showed that the samples required a mean value of 0.53 $l.min^{-1}$ (34.3 $ml. kg^{-2/3} min^{-1}$) while bending for the activity as against 0.56 $l. min^{-1}$ (36.1 $ml. kg^{-2/3} min^{-1}$) for squatting.

5. Rate of work calculated highlighted that the subjects were slow in performance in the squatting posture (mean = 11.76 $sq.m. min^{-1}$). This proves that it involves static component. Greater the proportion of mechanical energy to go into static effort, lower the efficiency. In the other posture their performance was better ($\bar{x}$=14.66 $sq.m.min^{-1}$). Paired t value was found to be 3.72 ($p<0.01$). This parameter, therefore when correlated with work time proved high degree of negative significance in both the postures.

6. Actual Vo_2 and caloric cost (for the actual time of activity) incurred for mopping the specified area once again revealed squatting as more demanding between the two (0.32 l and 1.63 K.cals respectively).

7. With both the above said parameters rate of work depicted high negative correlation while work time showed high degree of positive correlation. The former also emphasizes the lesser physical fitness of the samples. The maximal aerobic power of the subjects ($Vo_{2(max)}$) ranged between 1.3 and 2.7 $l.min^{-1}$. Thus the activity in the squatting posture must be classified as moderately heavy work.

8. The total energy expended amounted to 2.67 $K.cals\ min^{-1}$ for bending and 2.81 $K.cals.\ min^{-1}$ for squatting. None of the individual attributes (age, stature, body size etc) were correlated to this parameter.

9. These findings focus upon two significant assumptions :

   While increase in body size, body fat and BMI cause less physical fitness and more energy expenditure, increase in LBM indicates more muscle, more fitness and less energy expenditure.

10. Similarly the mean values for Relative Aerobic Strain (RAS) calculated projected a value of 26.86 per cent for bending and 28.25 per cent for squatting. Actually 22 and 19 per cent of the samples in the squatting and bending postures respectively had crossed the safety margin of 33 1/3 per cent. This aspect clearly states that performing in these postures is ultimately deleterious as far as the samples are concerned because of their low physical fitness. Individual body weights were not found to influence RAS.

11. The categorisation of work load/job heaviness also proved that the job is moderately heavy (for RAS range between 25-37.5 per cent).

Details recorded for mopping till endurance

1. The endurance limit of the sample while performing in the bending posture was found to be higher ($\overline{x}$ = 160.9 seconds) as against 107.09s in the squatting posture. Since the RAS for bending was low the endurance was longer. The distribution of subjects for the parameter on area mopped as expected extended from a very low value of 10 sq.m to more than 86 sq.m stressing again that their performance capacity differed. Subjects in their squatting posture were found to be more consistent. The mean areas mopped were 39.37 and 20.69 sq.m for bending and squatting respectively.

2. The distribution also focussed that performance is restricted in the squatting posture proving involvement of the 'static component'.

3. The factors of endurance and area mopped were found to show high level of association. Endurance in the squatting posture alone showed negative significance with body size and BMI ($p < 0.05$) and positive relationship with LBM ($p < 0.05$). Similarly area mopped in the squatting posture alone showed negative correlation ($p < 0.05$) with body size and BMI.

4. The range of movement for a single stroke was found to be 0.25 sq.m while squatting and 0.17 sq.m. while bending for the activity. This factor justifies why the parameters of endurance and area mopped showed high correlation in squatting posture. Bending height alone showed association with the concerned parameter.

5. The rate of work calculated for endurance also projected that the samples' performance was slow in the squatting posture. The variable with endurance in the bending posture alone showed correlation (at 5% level) proving that area mopped decided the rate of work in the study.

6. The mean working pulse (beats min^{-1}) of endurance ranged from 115 to 165 beats with one half of the sample distribution concentrating more on the 126-145 range. The mean values recorded were 139.5 for bending and 135.84 beats for squatting.

7. The mean incremental work pulse recorded was 63.19 beats for bending and 59.75 for squatting. The parameter did not show correlation with endurance or area mopped. It is inferred that the parameter is not dependent on the two variables.

8. The samples did not differ much in neither the time taken for recovery nor their incremental recovery cost (HR) between postures. But, for a slower rate of work the recovery cost was considerable. The variable was not associated with endurance, or area mopped, but showed significance with incremental cardiac cost of endurance ($p < 0.05$) in both the postures. Since the rate of work (squatting) had not increased with endurance it indicates that the samples had not maintained a steady rate of work throughout the study. Nevertheless, the samples displayed uniformity in their total cardiac cost status. Irrespective of the above factor the rate of recovery was found to be higher with squatting posture (5.93 Vs 4.08 for bending). For a low endurance they required a high recovery time. This factor highlights that the activity in the squatting posture is strenuous, involves static component and hence is not tolerable in the long run.

9. An enquiry into feelings of discomfort/pain felt after mopping revealed a majority to report lower back pain followed by pain in the knee in the squatting posture, while bending caused pain in the knee and thighs. Uncomfortable posture maintenance and muscular pain ranked high as attributes to pain.

10. Oxygen pulse calculated was evidently 4.97 and 4.90 $ml. beat^{-1}$ for bending and squatting respectively.

11. With respect to the work time, the samples required more oxygen (though only negligibly) in the squatting posture (1.07 $1.min^{-1}$ for mean work time of 107.09 seconds) compared to the other one. Multiple regression analysis was not found to show notable significance between the postures with regard to total $\dot{V}O_2$ and samples' endurance.

12. Though the samples showed variation in terms of posture with their incremental VO_2 requirement ($p<0.01$), the parameter studied between postures showed high correlation. The mean requirement was 0.50 1. and 0.47 l while bending and squatting for mopping respectively. The same analysis involving incremental work pulse versus incremental VO_2 indicated high correlation in both the postures.

13. While the other factors did not show much variation between postures the 0_2 debt incurred - which is a true indicator of the stress on the cardiovascular system due to muscular effort, projected that the sample differed considerably well with a paired t value of 4.46 ($p<0.01$). Though there was not much difference in the mean values (0.89 for bending and 0.83 $1. min^{-1}$ for squatting) individual observations differed. Acutally, when compared in terms of a low endurance, samples in the squatting posture incurred more 0_2 debt than in the other posture.

14. Multiple regression analysis pointed to significance between incremental performance $\dot{V}O_2$ and incremental recovery $\dot{V}O_2$ in both the postures. Comparison of the two parameters in both the postures showed significance at 5 per cent level.

15. The caloric cost of endurance and work calories naturally were more for bending posture than for squatting posture (5.50 and 2.49 K.cals.min^{-1} for bending and 5.35 and 2.36 K.cals. min^{-1} for squatting respectively). Correlation analysis to establish association between the work calorie and endurance/area mopped showed non significance in both the postures.

16. Despite all other factors the samples in the squatting posture required more calories for recovery ($\overline{x}$ = 4.39 K.cals .min^{-1} as against 4.04 K.cals .min^{-1} in the bending posture). Considering that the mean value for endurance is only 107 seconds, it points out clearly that the activity in this posture is definitely tiresome. Linear regression involving working energy expenditure and recovery calories showed high significance ($p<0.001$) in the squatting posture and ($p<0.05$) in the bending posture).

Details on angles of body bend

A recapitulation of the findings on this aspect as percent above resting base is presented below:

1. While flexing the trunk during performance, the subjects tended to show decrement in HR (65.7 %) in the bending posture. Contrarily HR increased with flexion of trunk in the squatting posture.

2. Though in both the postures, with shoulder adduction and abduction, the samples showed increment in HR, the distribution was found over a wide range (upto 54 and 36 per cent of resting respectively) in the squatting posture. Difference test proved that the parameter studied (flexion, adduction and abduction) to show marked variation between postures. Similarly extension of the trunk while squatting, exhibited variation in distribution though not significant statistically.

Details on posture targetting

With trunk flexion the hip angle from vertical was found to be 110° in bending, while it was reduced to 55° in squatting. For all anatomical movements, the joints concerned from vertical (in squatting) showed visible variation in terms of angles of bend - the conspicuous ones being the joints of the right upper leg (90°), right lower leg (78°) and right heel (30°).

Outcomes of the rating scale

The total scores ranged between 30 and 187 with the mean scores of 103±32 (mean + 1.96 S.D) for bending and 130 ± 16 for squatting. Eventually the index factor of 'boredom' emerged from 34.4 per cent of the samples as perception for mopping for bending posture as against 50 per cent who categorised them under fatigue - physical strain - while performing in the squatting posture. Ultimately when assessing the fatigue/drudgery index, it was evident that 78.1 per cent perceived the activity performed in the squatting posture as of high drudgery while 62.6 per cent considered the same as of low drudgery in the bending posture.

Static co-planar multilink modelling system

1. The angles of body bend from horizontal in the sagittal plane was considered for determining the stress on the lumbo-sacral region. In both the postures the five joints involved showed remarkable shift in angles.

2. All the joints involved were shifted more from original in the squatting posture compared to the other posture.

3. One significant feature was that in the shift towards left in the squatting posture the hip angle (L5/S1) underwent such a rotation that the angle formed was reduced to 1° which evidently was responsible for the compressive force on the L5/S1 disc. Irrespective of the direction of shift (left or right) in both the postures, the HR tended to show apparently a minimum of 25 per cent increase.

4. The load moment or the force which has to be developed by the lower back muscles (erector spinae) to maintain the posture was calculated. Here the load moment was highest at the hip in the squatting posture in both the right and left shifts to the tune of +254 Nm and +259 Nm respectively, followed by heel (+226 Nm and +223 Nm respectively). In the bending posture the force was apparently higher at the heel joint (left shift : +166 and right shift : +215 Nm).

5. The mean erector spinae force evident due to shift in angles because of the posture was 2218 N for bending and 5505 N for squatting. To be specific, for the shift towards left alone in the squatting posture the effective force was 7456 N.

6. Compressive force estimations pointed to 8121 N for the shift towards left in the squatting posture. For the other three situations it was below 3000 N.

7. Probability of low back ache project a frequency rate of 19 for the shift towards left in the squatting posture (for a single operation). Since homemakers repeat the action many times during mopping of even a minimum area, the tolerability of the posture in the long run is questioned.

Evaluation of the manual moppers for social acceptance

1. The market survey focussed attention to the availability of four types of moppers differing by virtue of the mopping component - cotton thread, sponge, hosiery waste and natural cum synthetic fibre - identified as Models A, B, C and D respectively. Among the models, Model A turned out to be the least expensive, and Model D appeared to be more durable. These two models again were the ones which required manual wringing out of water from the 'swab'.

2 When analysed based on potential user appeal to the two models, D and A scored the first two ranks respectively. So these two models were chosen for comparative study.

Response to the use of manual moppers

The samples (32) performed the activity adopting three different techniques - conventional mopping (squatting), using model A and using model D (standing for both). When analysed based on work accomplished with the passage of each minute revealed that the area mopped decreased with time in the conventional method (squatting) but increased with every minute when they used a mopper. Between the two models, the samples performed better with Model D. Naturally endurance was longer while using moppers. Cardiac responses indicated that with the use of a mopper, the activity was made less strenuous - as indicated by an incremental work pulse of 15 and 36 beats with model D and Model A respectively. Evidently the percent increase above resting was also reasonable. More than all other factors the recovery time recorded was minimum for model D (41 seconds), preceded by model A (205 seconds) and conventional method (604 seconds).

Table 83 presents a comprehensive sketch of the salient findings.

Table 83: Comprehensive summary of the findings

S.No.	Parameters recorded	Mopping 9.2 sq.m Posture		Mopping till endurance Posture		Trial with moppers Posture		
		Bending	squatting	Bending	Squatting	Squatting	Model A	Model A Standing
1.	Work time (s)	45	52.2	160.09	107.09	107.09	157.4	358.7
2.	Area mopped within endurance (sq.m)	-	-	39.37	20.69	20.69	31.01	44.8
3.	Area mopped within one minute (sq.m)	-	-	-	-	9.76	13.6	16.0
4.	Incremental work pulse beats	42.5	46.1	63.19	59.75	59.75	36	15
5.	Percent increase in work pulse	56.48	62.9	-	-	70	48	20
6.	Actual incremental VO_2 (l)	0.26	0.32	-	-	-	-	
7.	Incremental $\dot{V}O_2$ (l.min)	-	-	0.50	0.47	0.47	0.28	0.16
8.	Actual energy expended (K.cals)	1.32	1.63	-	-	-	-	-
9.	Work calorie (K.cals.min^{-1})	-	-	2.49	2.36	2.36	1.42	0.79
10.	Total calorie cost (K.cals.min^{-1})	2.67	2.81	5.50	5.35	-	-	-
11.	Percentage incremental calorie cost	26.9	28.9	-	-	-	-	-
12.	Relative Aerobic Strain(%)	26.86	28.25	-	-	-	-	-
13.	Range of movement (sq.m)	-	-	0.17	0.25	-	-	-
14.	Rate of work (sq.m.min $^{-1}$)	14.66	11.76	17.2	12.8	-	-	-
15.	Recovery time (min)	-	-	8.81	10.0	10.0	3.4	0.7
16.	Total cardiac cost (beats)	-	-	248.75	247.41	-	-	-
17.	Incremental recovery cost (beats)	-	-	112.62	111.25	-	-	-
18.	Rate of recovery	-	-	4.08	5.93	-	-	-
19.	Oxygen pulse (ml.beat^{-1})	-	-	4.97	4.90	-	-	-
20.	Total $\dot{V}O_2$ (l.min^{-1})	-	-	1.10	1.07	-	-	-
21.	Oxygen debt (l.min^{-1})	-	-	0.89	0.83	-	-	-
22.	Recovery calorie (K.cals.min^{-1})	-	-	4.04	4.39	-	-	-
23.	Effective force (N) left	-	-	2144	7456	-	-	-
	right	-	-	2292	3554	-	-	-
24.	Compressive force Newton left			2228	8121			
	right			2369	2861			
	kg. left			227	829			
	right			242	292			
25.	Probability of low back pain left			2	19			
	right			2	2			

All these data prove that the activity could be performed efficiently by use of a mopper.

At times there is a need for change in work methods and the change should be diverted toward improvement. With this in mind a few suggestions are being put forth to effect improvements in the models evaluated. The suggestions apply to modifications to be effected with the hand object contact, sturdy hand grip, hand handle interface and swab. These are not enough. Inorder to make it viable for purchase, innovative ventures involving indigenous materials and technology should be introduced. This will definitely take care of the social - cost - benefit aspect of the products.

Recommendations

The study has established conventional mopping in the squatting posture as the most strenuous one. This research experience has thrown light on the possibilities for further research on the following lines which would go a long way to guide both the homemakers and the manufacturers of household equipment.

Research thrust :

1. Norms should be set for women of different stature based on anthropometric studies.

2. Human energy expenditure computations for different household tasks in varying posture should be attempted.

3. Tools should be designed such as a large scale goniometer for determining angles of body bend.

4. Simple techniques to assess the impact of postural variations on the performance of different household tasks should be developed.

5. Assessment of the tolerability levels with biomechanical and EMG studies in the field should be encouraged.

Extension strategies:

1. Motivate homemakers to accept changes in work habits and become more prudent in conserving personal energy in household tasks, through educating them scientifically on the correct postures to be followed.

   Women's organisations attempting to channelise women power for societal responsibilities may take the lead in such educational endeavours.

2. Encourage entrepreneurs, particularly women entrepreneurs to design, fabricate, produce and commercialise moppers with indigenous materials and technology, keeping in mind economic viability and technical feasibility(Fig.20)

3. Television with its mass appeal and which telecasts a variety of programmes on health care may be resorted to, to educate women on correct postures for different household activities.

4. The funding agencies may be persuaded to include in their list of eligible enterprises for loan/subsidy assistance for production of moppers.

MANAGEMENT

OF

PERSONAL

PHYSICAL

ENERGY

RESOURCE

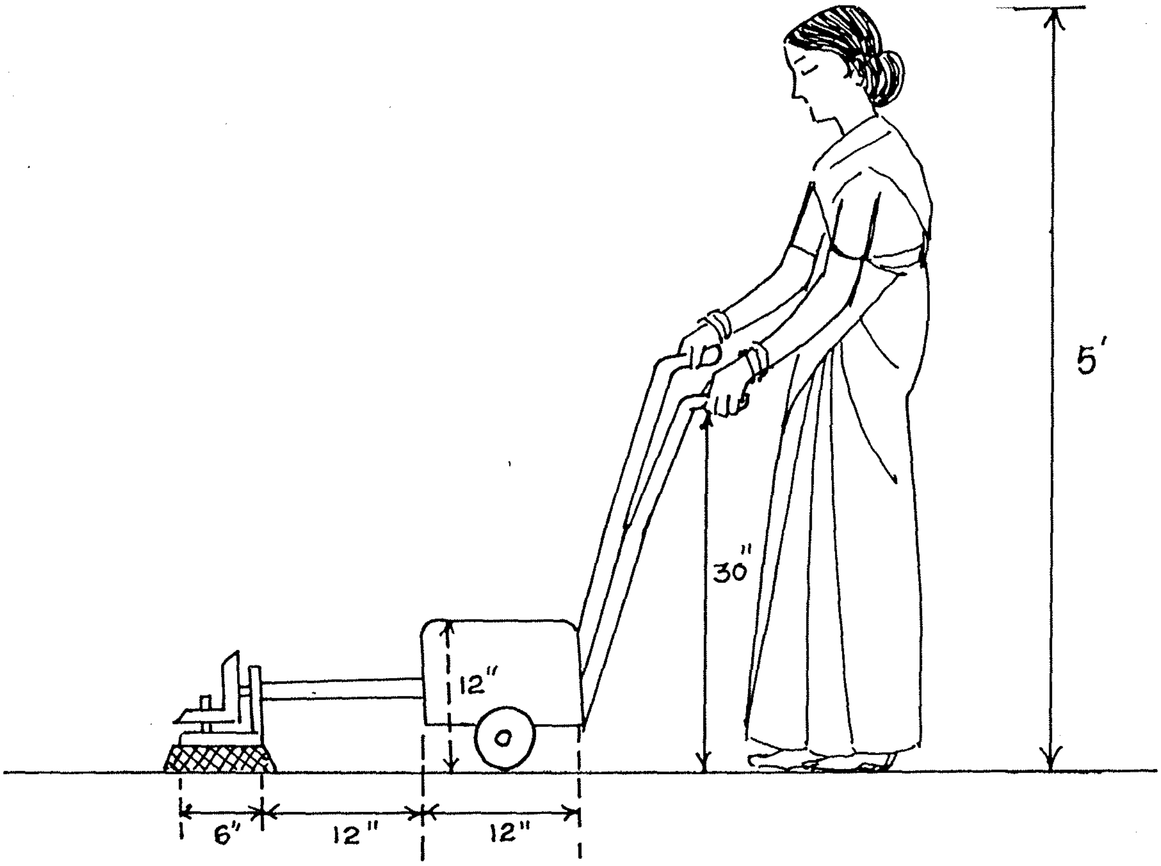


Figure - 20

A SUGGESTED DESIGN FOR A MOPPER BASED ON ERGONOMIC PRINCIPLES

References

REFERENCES

Acheson, K.J., Campbell, I.T., Edholm, O.G., Miller, D.S and Stock, M.J.(1980). The measurement of daily energy expenditure : An evaluation of some techniques. Am.J.clin.Nutr: 33, Pp.1155-1164.

Adams, M.A and Hutton, W.C. (1986). Has the lumbar spine a margin of safety in forward bending? Clinical Biomechanics:1, Pp.3-6.

Adiseshiah, W.T.V. (1989). Tools for collecting data : Observation. A handbook of methodology of research. Coimbatore: Sri Ramakrishna Mission Vidyalaya press, P.93.

Agan, T. (1979). The house - Its plan and Use, New Delhi : Oxford and IBH, Pp.317-318

Agan, T., Kona, S and Tormey, L. (1972). Extra heart beats as a measurement of work cost. Home Economics Research Journal : 1, Pp.28-33.

Agarwal, A.K and Natu, M.V. (1994). Doping - An undesirable desire. Everyman's Science : 29:2, P.45.

Agarwal, C. (1989). Status of Women. Vol: II. Jaipur: Printwell Publishers, P.2.

Agarwal, G.C and Gottlieb, G.L. (1970). A model of muscle force and EMG. Proceedings of the 23rd ACEMB-Washington D.C, P.139.

Aggarwal, J.C.(1975). Educational research - An introduction. New Delhi : Arya book depot, P.178.

Akkerveeken, V.P.F. (1985). Teaching Aspects. Ergonomics :23,Pp.371-377.

Allander, E. (1974). Prevalence, incidence and remission rates of some common rheumatic diseases or syndromes. Scandinavian Journal of Rheumatology : 3, Pp.145-153.

Anand, B.K. (1976). Textbook of physiology-I. New Delhi : Tata McGraw-Hill, Pp.185-190.

Andersson, G.B.J. (1981). Epidemiologic aspects on low-back pain in industry. Spine : 6, Pp.53-60.

Andersson, G.B.J. (1985). Posture and compressive spine loading : Intradiscal pressures, trunk myoelectric activities, intra-abdominal pressures and biochemical analysis. Ergonomics :28, Pp.91-93.

Andersson, G.B.J. (1985). Permissible Loads : Biomechanical considerations. Ergonomics : 28 :1, Pp.323-326.

Andersson, G.B.J and Ortengren, R. (1984). Assessment of backload in assembly line work using EMG. Ergonomics : 27, Pp.1157-1168.

Andersson, G.B.J., Ortengren, R and Nachemson, A. (1977). Intradiscal pressure, intra-abdominal pressure and myoelectric back muscle activity related to posture and loading. Clinical orthopaedics : 129, Pp.156-164.

Anton, T.J. (1979). Occupational safety and health management. New York : Mc Graw-Hill, Pp.38-49.

Arcan, M., Brull, M.A., Scholten, R and Rhorle, H. (1977). A new method for determining the active force system in lower limbs during human locomotion. Proceedings of international conference of bio-engineering. Kapstadt, Pp.1-5.

Arieli, A., Anderson, K.M and Paedro, C. (1985). Effect of training, fat or carbohydrate ingestion of exercise - induced changes in glucose and triglyceride blood levels. Advances in diet and nutrition. London : John Libbey, P.65.

Ashizawa, K., Okada, A., Kouchi, M., Horino, S and Kikuchi, Y. (1994). Anthropometrical data of middle-aged Japanese women for industrial design applications. J. Human. Ergol : 23, Pp.73-80.

Asmussen, E. (1968). The neuromuscular system and exercise. In : H.B. Falls. (Ed). Exercise physiology. New York: Academic, Pp.3-41.

Astrand, I. (1967). Degree of strain during building work related to individual work capacity. Ergonomics : 10, Pp.293-303.

Astrand, P.O and Rodahl, K. (1977). Text book of work physiology. Tokyo : Mc Graw-Hill, Kogakusha, Pp.1-96, 154-178, 237-315, 431-450.

Avery, D. (1987). Home versus job. Social welfare : 34: 7, P.33.

Avons, P., Garthwaite, P., Davies, H.L., Murgatroyd, P.R and James. W.P.T. (1988). Approaches to estimating physical activity in the community; Calorimetric validation of actometers and heart rate recording. Eur.J.Clin.Nutr:42, Pp.185-196.

Ayoub, M.M. and Mital, A (1989). Manual materials handling. London : Taylor and Francis, P.10.

Babsky, E., Khodorov, B., Kositsky, G and Zubkov, A. (1970) Human physiology. Moscow : MIR publishers, Pp.31-44, 321.

Babsky, E and Zubkov, A. (1970). Human Physiology. Moscow : MIR publishers, Pp.116-209.

Bandini, L.G., Schoeller, D.A and Dietz, W.H. (1990). Energy expenditure in obese and nonobese adolescents. Pediatr. Res., 27, Pp.198-203.

Banerjee, S., Rohatgi, K.S., Mukerjee, M and Sen, R.N. (1958). Measurement of body surface area of adult females. Indian Journal of Medical Research : 46:5, Pp.69-73.

Banister, E.W., Allen, M., Fadl, S., Bhakthan, G and Howard, D. (1988). Contemporary health issues. Boston : Jones and Bartlett, Pp.1-13.

Barnes, R.M. (1980) Motion and time study. Design and measurement of work. New York : John Wiley, P.441-465.

Basar, E. (1976). Biophysical and physiological systems analysis. Masachusetts. USA: Addison - Wesley, Pp.17, 18, 131-132.

Becker, F.D. (1974). Design for living : The resident's view of multi-family living. Centre for urban development research. Cornell University. New York : Ithaca. P.16.

Bell, G.H., Davidson, N.J and Scarborough, H (1970). Text book of physiology and biochemistry. Edinburgh : The English language book society and E and S Livingstone, Pp.219-323, 924, 934.

Belli, A., Rey, S., Bonnefoy, R., Lacour, J.R. (1992). A simple device for kinematic measurements of human movement. Ergonomics, 35: 2, Pp.177-186.

Benesh, R and Mc Guiness, J. (1974). Benesh movement notation and medicine. Physiotherapy : 60, Pp.176-178.

Benzley, J.J.(1990). Household tasks : An equity issue for home economics. Journal of Home Economics. 82 : 4, P.25.

Berg,K.(1971). Heart-rate telemetry for evaluation of the energy expenditure of children with cerebral palsy. Am.J. Clin. Nutr., 24 ,Pp.1438-1445.

Berme, N. (1980). Control and movement of lower limbs. In : A. Morecki, (Ed), Biomechanics of motion. New York : Springer - Verlag Wien, P.200

Berndsen, M.B., Dul, J and Hildebrandt, V.H. (1991). Priority assessment of ergonomic interventions : Order out of chaos. In : Y. Queinnec and F.Danicllou (Eds). Designing for everyone : Proceedings of the XI congress of the international ergonomics association. Vol.II. London : Taylor and Francis, Pp.1276-1278.

Best, J.W. and Khan. J.V. (1987). Research in Education. New Delhi : Prentice Hall of India, Pp.11, 210.

Bharathi, V.V. and Jacintha, M. (1994). Family resource management (New concepts and theory). New Delhi : Discovery publishing house, Pp.74-81.

Bhasin, H.V., Amitabha De and Kothiyal, K.P. (1989). Work place design for assembly jobs. In : K.B. Sahay and R.K. Saxena, (Eds). Biomechanics. New Delhi: Wiley Eastern, P.271.

Bhatnagar, O.P and Babbar, R. (1982). Muscular training and physiological adjustments. Swasth Hind, October, Pp.229-230.

Bhoosnurmath, R.S. (1994). Ergonomics - the science of human factors engineering. Invention Intelligence. January. Pp.17-20.

Bhushan, V and Sachdeva, D.R. (1994). An introduction to sociology. Allahabad : Kitab mahal publications, P.105.

Bigland - Ritchie, B., Donovan, E.F and Roussos, C.S. (1981). Conduction velocity and EMG power spectrum changes in fatigue of sustained maximal efforts. J. Appl. Physiol:51, Pp.1300-1305.

Bigland - Ritchie, B.R., Jones, D.A., Hosking, G.P., and Edwards, R.H.T. (1978). Central and peripheral fatigue in sustained maximum voluntary contractions of human quadriceps muscle. Clin. Sci. Mol. Med: 54; Pp.609-614.

Bigos, S.J., Spengler, D.M., Martin, N.A., Zeh, J., Fisher, L and Nachemson, A. (1986). Back injuries in industry : A retrospective study, III. Employee-related factors. Spine: II, Pp.252-256.

Bigos, S.J., Spengler, D.M., Martin, N.A., Zeh, J., Fisher, L., Nachemson, A and Wang, M.H. (1986). Back injuries in industry : A retrospective study II. Injury factors. Spine: II, Pp.246-251.

Bjelle, A., Hagberg, M. and Michaelsson, G. (1979). Clinical and ergonomic factors in prolonged shoulder pain among industrial workers. Scandinavian Journal of work environment and health: 5, Pp.205-210.

Black, J.A and Champion, D.J. (1976). Methods and issues in social research. New York : John Wiley, Pp.187-246.

Bobbert, M.F., Mackay, M., Schinkelshock, D., Huijing, P.A and Van Ingen Schenall, G.H. (1986). Biomechanical analysis of drop and counter movement jumps. Euro.Jour. of Appl.Physiol: 54, Pp.566-573.

Bogert, E. (1982). House Craft - Principles and practices. London:Isaac Pitman, Pp.57-58.

Bogert, J.L., Briggs, G.M and Calloway, D.H. (1973). Nutrition and Physical fitness. London : W.B. Saunders Pp.33-39.

Borg, W.R. and Gall, M.D. (1983). Educational research - An introduction. New York : Longman, P.281.

Borrini, G and Margen, S. (1990). 'Human energetics' in human energy. A.V. Desai (Ed). International development research centre. Ottawa, P.84.

Bradfield, R.B. (1971). Assessment of typical daily energy expenditure. Reprint. Am.J.Clin.Nutr: 24, Pp.1-6.

Bradfield, R.B. (1971). A technique for determination of usual daily energy expenditure in the field. Am.J.Clin. Nutr: 24, Pp.1148-1154.

Bryant, W.K. (1988). Durables and wives' employment yet again. Journal of consumer research: 15:1, Pp.37-47.

Burke, R.E anmd Edgerton, V.R. (1975). Motor unit properties and selective involvement in movement. In : J.H. Wilmore and J.F. Keogh (Eds). Exercise and sports sciences reviews : 3, Pp.31-81.

Buskirk, E.R., Harris, D., Mendez, J and Skinner, J. (1971). Assessment of typical daily energy expenditure. Reprint. Am.J.Clin. Nutr: 24,Pp.1119.

Carroll, C and Miller, D. (1986). Health : The science of human adaptation. Dubuque, Iowa: W.M.C. Brown, Pp.5-10.

Cavagna, A.G. (1975). Force platforms as ergometers. J. Appl. Physiol:39, Pp.174-179.

Ceesay, S.M., Prentice, A.M., Day, K.C., Murgatroyd, P.R., Goldberg, G.R., Scott,W and Spurr,G.B. (1989). The use of heart rate monitoring in the estimation of energy expenditure, a validation study using indirect whole-body calorimetry. Br.J.Nutr:61, Pp.175-186.

Chaffin, D.B. and Andersson, G.B.J. (1984). Occupational biomechanics. New York: John Wiley, Pp.35-59.

Chaffin, D.B., Herrin, G.D., Keyserling, W.M and Garg, A. (1977). A method for evaluating the biomechanical stresses resulting from manual materials handling jobs. Am.Ind. Hyg. Assoc.J :38, Pp.662-675.

Chaffin, D.B and Park, K.S. (1973). A longitudinal study of low back pain as associated with occupational lifting factors. Am.Ind.Hyg. Assoc.J :34, Pp.513-525.

Chaffin, D.B and Park, K.S. (1983). Work practices guide for manual lifting. Publication ~~of the American Industrial Hygiene Association~~ of the American Industrial Hygiene Association. Akron. Ohio, Pp.13-18, 37-38.

Chahal, H.K. (1972). Relationship of heart rate and angles of body bend during chappati making at standing level kitchen. Masters thesis, Punjab agricultural university, Ludiana.

Chakravarthy, C. (1991). Girl child : A critical factor in India's development planning and reassessment of strategies. ICCW news bulletin : 39:1, Pp.4-7.

Chandra, A.M., Mahanta, S and Sadhu, N. (1994). Physical efficiency of Bengal farmers in response to change in environmental factors. J. Human.Ergol : 23, Pp.1-2.

Chaney. M.J. and Ross, M.L. (1971). Nutrition. Boston : Houghton Mifflin, P.34.

Charaka-Samhita : Sutra (1992). R.K.Sharma and B.Dash (Eds). Varanasi : Chowkhamba Sanskrit series : I to III, P.9:9.

Chatterjee, C.C. (1981). Human physiology-I. Calcutta : Medical allied agency, Pp.265-300.

Chaudhari, T.P.S. (1989). Tools for collecting data : Schedules and questionnaires. A handbook of methodology of research. Coimbatore : Sri Ramakrishna Mission Vidyalaya Press, P.111.

Chavalitsakulchai, P. and Shahnavaz, A. (1991). Musculo-skeletal discomforts and feelings of fatigue among female professional workers : The need for ergonomics consideration. J.Human. Ergol : 20, Pp.257-264.

Christensen, C.G., Frey, H.M., Foenstelien, E., Aadland, E and Refsum, H.E. (1983). A critical evaluation of energy expenditure estimates based on individual O_2 consumption/heart rate curves and average daily heart rate. Am.J.Clin. Nutr:37, Pp.468-472.

Clamann, H.P and Broecker, K.T. (1979). Relation between force and fatigability of red and pale skeletal muscles in man. American journal of physical medicine: 5, Pp.70-85.

Colombini, D., Occhipinti, E., Molteni, G., Grieco, A., Pedotti, A., Boccardi, S., Frigo, C and Menoni, O. (1985). Posture analysis. Ergonomics : 28:1, Pp.275-284.

Corlett, E.N., Eklund, J.A.E., Reilly, T and Troup, J.D.G. (1987). Assessment of workload from measurements of stature. Applied ergonomics :18, Pp.65-71.

Corlett, E.N., Madeley, S.J and. Manenica, I. (1979). Posture Targetting : A technique for recording working postures. Ergonomics : 22:3, Pp.357-366.

Corlett, E.N and Mahadeva, K. (1970). A relationship between a freely chosen working pace and energy consumption curves. Ergonomics : 13 : 4, Pp.517-524.

Coward, W.A., Prentice, A.M and Murgatroyd, P.R (1984). Measurement of CO_2 and water production rates in man using ^{2}H ^{18}O - labelled H_2O - comparisons between calorimeter and isotope values. In : Human energy metabolism, physical activity and energy expenditure measurements in epidemiological research based upon direct and indirect calorimetry. Euronut report :5, Pp.126-128.

Cromwell, L., Weibell, F.J and Pfeiffer, E.A. (1991). Biomedical instrumentation and measurements. New Delhi : Prentice-Hall, Pp.1-66,301-465.

Dandare, M.P and Ahankari, S.V. (1983). Involving community leaders in the family welfare programme : An experience. The Journal of Family Welfare : 30:2, P.61.

Datta, S.R. and Ramanathan, N.L. (1971). Ergonomics comparison of seven modes of carrying loads on the horizontal plane. Ergonomics : 14:2, Pp.269-278.

Dauncey, M.J and James, W.P.T. (1979). Assessment of the heartrate method for determining energy expenditure in man using a whole body calorimeter, Br.J.Nutr: 42, Pp.1-13.

Davis, P.R. and Stubbs, D.A. (1977). Safe levels of manual forces for young males. Applied Ergonomics :8 :1, Pp.219-228.

Davson, H. (1970). A textbook of general physiology. London : J and A. Churchill, P.1347.

Deacon, R.E and Firebaugh, F.M. (1981). Home management, context and concepts. Boston : Houghton Mifflin, Pp.295, 302, 343.

Deacon, R.E and Firebaugh, F.M. (1988). Family resource management, principles and application. Boston : Allyn and Bacon, Pp.5-165.

De, A. and Bhasin, H.V. (1991). A comparative investigation into forward bending posture under static load. International symposium on ergonomics, occupational health, safety and environment. IIT. Bombay, Pp.12-2.

De Cenzo, D.A and Robbins, S.P. (1993). Personal/human resource management. New Delhi : Prentice Hall, Pp.357-365.

Deol, M and Dhesi, J.K. (1976). Characteristics of the most and least liked household tasks of rural housewives. Journal of Research : XVI :2, P.231.

Devadas, R.P. (1983). Better homes. Delhi : Oxford university press, Pp.6-20,70, 273-275.

Devadas, R.P. (1983). Textbook on child development. II. Delhi : Macmillan, Pp.1-4.

Devadas, R.P. (1987). Work ethics. In : R.P. Devadas and M.Chandramani (Eds). Ethical values in a changing world. Coimbatore : Ramakrishna Vidyalaya press, P.21.

Devadas, R.P. and Patwardhan, A. (1976). Comparative study of three different types of mixers and grinders with regard to time, motion, energy and cost. In:R.P.Devadas (Guide). A compilation of the synopses of Ph.D. theses. Coimbatore: Saradalaya press, Pp.25-31.

Devi, I. (1987). Changing status of women. New Delhi : Sterling, P.01.

Dhesi, J.K. (1973). The effects of stages of chapati-making and angles of body position on heart rate. Ergonomics :16, Pp.811-815.

Dhesi, J.K and Chahal, H.K. (1975). The effects of stages of chapati-making and angles of body bend on heart rate during sitting and standing postures. The Indian Journal of Home Science :9:1, Pp.7-13.

Dhesi, J.K and Firebaugh, F.M. (1973). The effects of stages of chapati making and angles of body position on heartrate. Ergonomics :16:6, Pp.811-815.

Dhesi, J.K., Kaul, R.N and Jain, S. (1975) Energy expenditure while sweeping with different types of brooms held in different postures. The Indian Journal of Home Science : 9:2, Pp.35-46.

Di Prampero. (1986). An analysis of the factors limiting the maximal O_2 consumption in humans. In : M. Meyer and N.Heisler (Eds). Topics in respiratory and comparative physiology. Stuttgart, New York: Gustav Fischer Verlag, P.77.

Donovan, C.M and Brooks, G.A. (1977). Muscular efficiency during steady rate exercise. II. Effects of walking speed and work rate. J. Appl. Physiol:43, Pp.431-439.

Doyal, L. (1995). What makes women sick? Gender and the political economy of health. London : Macmillan, P.28.

Duchateau, J and Hainaut, K. (1985). Electrical and mechanical failures during sustained and intermittent contractions in humans. J. Appl.Physiol :58:3, Pp.942-947.

Dunn, B. (1983). Fundamentals of nutrition. Boston : CBI publishing, Pp.85-90.

Durnin, J.V.G.A. (1989). Methods to assess physical activity and the energy expended for it by infants and children. In : Activity, energy expenditure and energy requirements of infants and children. Proceedings of an I/D/E/C/G workshop. Masachusetts, Pp.49-53.

Fellman, N., Bedu, M., Spielvogel, H., Falgairette, G., Van Praagh, E and Coudert, J. (1986). Oxygen debt in submaximal and supramaximal exercise in children at high and low altitude. Jour. Appl. Physiol : 60:1, Pp.209-215.

Ferguson, D. (1972). Ergonomics and the quality of living. Applied Ergonomics : 3 :2, Pp.70-74.

Ferguson, S.A., Marras, W.S and Waters, T.R. (1992). Quantification of back motion during asymmetric lifting. Ergonomics :35, Pp.845-859.

Frankenhaeuser, M., Nordheden, B., Myrsten, A.L. and Post, B. (1971). Psychophysiological reactions to understimulation and overstimulation. Acta. Psychologica : 35, Pp.298-308.

French, W.L. (1990). Human resource management. Boston : Houghton Mifflin, P.202.

Frievalds, A., Chaffin, D.B., Garg, A and Lee, K.S. (1984). A dynamic biomechanical evaluation of lifting maximum acceptable loads. Journal of Biomechanics :17, Pp.251-262.

Frymoyer, J.W., Pope, M.H and Costanza, M.C. (1980). Epidemiologic studies of low back pain. Spine : 5, Pp.419-423.

Fukashiro, S., Iimoto, Y., Kobayashi, H and Miyashita, M. (1981). A biomechanical study of the triple jump. Medicine and science in sports and exercise : 13, Pp.233-237.

Fukashiro, S and Komi, P.V. (1987). Joint moment and mechanical power flow of the lower limb during vertical jump. International Jour.of Sports Medicine:8 (suppl), Pp.15-21.

Gabor, D., Colombo, U., King, A and Galli, R. (1978). Beyond the age of waste. England : Pergamon, P.6.

Gaesser, G.A and Brooks, G.A. (1975). Muscular efficiency during steady - rate exercise : Effects of speed and workrate. J. Appl. Physiol : 38, Pp.1132-1149.

Gandra, Y.R and Bradfield, R.B. (1971). Energy expenditure and oxygen handling efficiency of anaemic school children. Am.J.Clin. Nutr:24, Pp.1451-1456.

Ganguli, S. (1982). Performance evaluation of man-machine systems - A scientific analysis of the lower extremity amputee - Appliance system's efficiency. New Delhi : Affiliated East-West press, Pp.1, 3, 10-16.

Gauger, W.H and Walker, K.E. (1980). "The dollar value of household work". Information bulletin : 60 (revised). Ithaca. New York State college of human ecology : Cornell university press, Pp.1-5.

Ghista, D.N. (1974). Engineering in medical practice and delivery. In : D.N. Ghista and R. Patil (Eds) Biomechanical research proceedings : Monograph : Pp.171-173.

Ghosh, B.N. (1985). Scientific methods and social research. New Delhi : Sterling, P.136.

Gita, D. (1989). Energy use in rural households of semi-arid regions of Andhra Pradesh. (An ICAR co-ordinated research Project report : 1981-89), APAU, Hyderabad, Pp.8-10.

Glencross, D.J. (1973). Temporal organization in a repetitive speed skill, Ergonomics : 16 : 6, Pp.765-776.

Goel, M. (1974). Space requirement for some selected activities carried out in the kitchen in sitting position. Master's thesis. Punjab agricultural university,Ludhiana, P.82.

Gould, J.D and Lewis, C. (1985). Design for usability : Key principles and what designers think. Communication of the ACM. Vol:28, Pp.300-311.

Grandjean, E. (1985). Fitting the task to the man. An ergonomic approach. London: Taylor and Francis, Pp.1-190.

Grandjean, E and Hunting, W. (1977). Ergonomics of posture; review of various problems of standing and sitting posture. Applied Ergonomics : 8, Pp.135-140.

Granstsrom, B., Kvarnstrom, S and Tiefenbacher, F. (1985). EMG as an aid in the prevention of excessive shoulder strain. Applied Ergonomics : 16, Pp.49-54.

Gray,(1992). Anatomy. (37th Ed). P.L.Williams and M.Dyson (Eds). Avon: Churchill Livingstone. Longman, P.490.

Green, J.H. (1972). An introduction to human physiology. London : Oxford, Pp.28-138.

Grieve, D.W. (1974). Dynamic characteristics of man during crouch and stoop lifting. In : R.C. Nelson and C.A. Morehouse (Eds). Biomechanics. Vol.IV. University Park press, Pp.19-29.

Grieve, D.W. (1979). The postural stability diagrams (PSD) : Personal constraints on the static exertion of force. Ergonomics : 22, Pp.1155-1164.

Grieve, D.W. (1984). The influence of posture on power output generated in single pulling movements. Applied Ergonomics : 15, Pp.115-117.

Grieve, D.W. and Pheasant, S.T. (1982). Biomechanics. In : W.T. Singleton (Ed). The body at work : Biological ergonomics. Cambridge : Cambridge University press, Pp.187-191.

Grollman, S. (1974). The measurement of hypertension. The human body - its structure and physiology. New York : Macmillan, Pp.249-254.

Gross, I.H.,Crandall, E.W and Knoll, M.M. (1980) Management for modern families. New Jersey : Prentice, Pp.5,6,75-88, 250-292, 426-430.

Gudinchet, F., Schutz, Y., Michelin, J.L., Stettler, E and Jequier,E. (1982). Metabolic cost of growth in very low birthweight infants. Pediatr. Res:16, Pp.1025-1030.

Gupta, N. (1990). Energy management practices of selected homemakers in Bihar. Unpublished Masters thesis, Avinashilingam Deemed University. Coimbatore, Pp.79,90.

Gupta, S.P. (1991). Statistical methods. New Delhi : Sultan Chand, Pp.E.3 .1-4.27.

Hagberg, M. (1982). Local shoulder muscular strain - symptoms and disorders. J.Human. Ergol: 11, Pp.99-108.

Hansson, T., Roos, B and Nachemson, A. (1980). The bone mineral content and ultimate compressive strength. Spine :5, Pp.46-55.

Hanson, J.A and Jones, F.P. (1970). Heart rate and small postural changes in man. Ergonomics : 13:4, Pp.483-487.

Hardinge, M.G. (1973). Why exercise? Herald of health :50 :9, Pp.23,24.

Haridasan, G., Sanghvi, S.H., Joshi, V.M and Pandya, S.S. (1978). A study of electromyographic activity in abductor digiti minimi of healthy and neuropathic subjects. In : S.K.Guha (Ed). Proceedings of the International symposium/work-shop on trends in biomedical engineering. New Delhi : CBME publication,Pp.273-274.

Harrell, T.W. (1964). Industrial psychology. New Delhi : Oxford and IBH, Pp.46-347.

Hartmann, P., Patil, B.R and Dighe, A. (1989). The mass media and village life - An Indian study. New Delhi : Saga, P.58.

Haslegrave, C.M., Tracy, M., Corlett, E.N. (1988). Influence of working posture on strength capability. In : E.D. Megaw (Ed). Contemporary ergonomics' 88. London : Taylor and Francis, Pp.20-169.

Hemalatha, G. (1988). Time utilization pattern of selected employed homemakers. Unpublished Master's Thesis. Bharathiar University, Coimbatoro, Pp.31-48.

Hert, P. (1980). Gender and class consciousness. New York : Macmillan, P.182.

Hertzberg, H.T.E. (1972). Engineering anthropology. In : H.P. Van Cott and R.G.Kinkade (Eds). Human engineering guide to equipment design. Washington, DC : U.S. Government printing office. Chapter, 11.

Hesser,C.M and Lind, F. (1984). Role of airway resistance on the control of ventilation during exercise. Acta. Physiol. Scandinavia : 120, Pp.557-565.

Hettinger, T. (1985). Occupational hazards associated with diseases of the skeletal system. Ergonomics : 28, Pp.69-75.

Heywood, P.F and Latham, M.C. (1971). Use of the SAMI heart rate integrator in malnourished children, Am.J.Clin. Nutr:24, Pp.1446-1450.

Hildebrandt, V. (1987). A review of epidemiological research on risk factors of lowback pain. In: P.Buckle (Ed). Musculo-skeletal disorders at work. London : Taylor and Francis, Pp.9-16.

Hildes, J.A. (1970). Ecologic and ethnic adaptations. In : D.H.K.Lee and D.Minard (Eds). Physiology, environment and man - based on a symposium conducted by the National academy of sciences - National research council. New York : Academic press, P.153.

Hoeger, W.W.K. (1989). Lifetime physical fitness and wellness; A personalized program. Englewood. Colorado : Morton publishing, Pp.23-115.

Hutton, W.C and Adams, M.A. (1982). Can the lumbar spine be crushed in heavy lifting? Spine : 7, Pp.586-590.

Ikai, M and Steinhaus, A.H. (1961). Some factors modifying the expression of human strength. J. Appl. Physiol : 16, P.157.

Inglis, J.K. (1972). A text book of human biology. New York : Pergamon, Pp.36-45.

Jager, M and Luttman, A. (1992). The load on the lumbar spine during asymmetrical bi-manual materials handling. Ergonomics :35 (7/8), Pp.783-806.

Jain S.P. (1973). Human energy expenditure while brooming with brooms of dfferent kinds and lengths. Published Masters thesis. Punjab agricultural university, Ludhiana. P.74

Jain, V.K and Dasgupta, U. (1976). Bio feedback training apparatus aid transcedental meditation and body relaxation. Proceedings of the VI All India symposium on bio medical engineering. Bangalore, Pp.65,66.

Jain, V.K and Nair, C.G.M. (1976). EMG processor, proceedings of the VI all India symposium on biomedical engineering. Bangalore P.93.

James, W.P.T and Schofield, E.C. (1990). Human energy requirements. A manual for planners and nutritionists. New York : Oxford medical publication, P.53.

Jones, J.C. (1967). The designing of man - machine systems. Ergonomics : 10 :2, Pp.101-111.

Jorgensen, K. (1985). Permissible loads based on energy expenditure measurements. Ergonomics :28:1, Pp.365-369.

Kaijser, L. (1970). Limiting factors for aerobic muscle performance. Acta. Physiol. Scand. Suppl :34, Pp.1-96.

Kalbagh, C. (1992). Women in agriculture and rural development. New Delhi : Discovery, Pp.84-89.

Kandarian, S.C., Peters,D.G., Taylor, J.A and Williams, J.H. (1994). Skeletal muscle overload upregulates the sarco-plasmic reticulum slow calcium pump gene. Am.Jour. Physiol:266, P.c. 1190.

Karhu, O., Kansi, P and Kuorinka , I. (1977). Correcting working postures in industry : A practical method for analysis. Applied Ergonomics :8, Pp.199-201.

Karvonen, M.J. (1985). Effect of temporal patterns of work as lifting and handling capacities. Ergonomics :28:1, P.177.

Kashiwazaki, H., Inaoka, T., Suzuki, T and Kondo, Y. (1986). Correlations of pedometer readings with energy expenditure in workers during free-living daily activities. Eur. J. Appl. Physiol:54, Pp.585-590.

Kashiwazaki, H., Watanabe, M and Suzuki, T. (1991). Differences in habitual physical activities within household and population in an area of fruit culture. Eur.J.Appl.Physiol:54, P.412.

Katch, F.I and Mc Ardle, W.D. (1983). Nutrition - Weight control and exercise. Philadelphia : Lea and Febiger, Pp.45-98.

Kaur, S.(1987). Women in rural development. New Delhi : Mittal, P.25.

Kaur, M and Sharma, R.C. (1987). Health and physical education. Ludhiana : Tandon, Pp.82, 132.

Keiser, M.B and Weaver, E.K. (1962). Body movements related to energy used. Journal of Home Economics: 59, Pp.479-482.

Kelsey, J.L and White, A.A. (1980). Epidemiology and impact of low back pain. Spine :5, Pp.133-142.

Khalil, T.M. (1973). An electromyographic methodology for the evaluation of industrial design. Human factors : 15:3, Pp.257-264.

Klein, P.D., James, W.P.T and Wong, W.W. (1984). Calorimetric validation of the Doubly labeled water method for determination of energy expenditure in man. Hum.Nutr.Clin.Nutr:38c, Pp.95-106.

Kogi, K. (1991). Research facilitating participatory action for improvements. J.Human. Ergol:20, Pp.168-170.

Komi, P.V. and Tesch, P. (1979). EMG frequency spectrum, muscle structure and fatigue during dynamic contractions in man. Eur. J.Appl. Physiol. Occup. Physiol :42, Pp.41-50.

Kothari, C.R. (1995). Research Methodology - methods and techniques. New Delhi : Wiley Eastern, Pp.25-117.

Kram, R and Powell, A.J. (1989). A treadmill - mounted force platform. J. Appl. Physiol: 67, Pp.1692-1698.

Kroemer, K.H.E. (1992). Personnel training for safer material handling. Ergonomics : 35: 9, P.1119.

Krupa Shankar, M.S., Prasad, K.C.S., Mohan, C and Bhaskara, B.S. (1993). Microprocessor based floor maintenance system.Invention Intelligence: December, P.270.

Kumar, S. (1987). Arm lift strength variation due to task parameters. In: P.Buckle (Ed). Musculo skeletal disorders at work. London : Taylor and Francis, Pp.37-42.

Kumar, S. (1984). The physiological cost of three different methods of lifting in sagittal and lateral planes. Ergonomics : 27, Pp.425-433.

Kumar, S and Davis, P.R. (1983). Spinal loading in static and dynamic postures : EMG and intra abdominal pressure study. Ergonomics : 26, Pp.913-922.

Kumar, S and Garand, D. (1991). Static and dynamic lifting strength at different reach distances in symmetrical and asymmetrical planes. Ergonomics : 35, Pp.863-882.

Kumar, S and Mital, A. (1992). Margin of safety for the human back : A probable consensus based on published studies. Ergonomics : 35 (7/8), Pp.769-781.

Kuorinka, I and Viikari - Juntara, E. (1982). Prevalence of neck and upper limb disorders and work load in different occupational groups. Problems in classification and diagnosis. J. Human. Ergo:11, Pp.65-72.

Kvarnstrom, S. (1983). Occurrence of musculoskeletal disorders in a manufacturing industry with special attention to occupational shoulder disorders. Scandinavian Journal of Rehabilitation Medicine :8, Pp.1-114.

Kwanty, et al (1970). An application of signal processing techniques to the study of myoelectric signal. IEE trans on BME 17(4), Pp.303-313.

Lange Andersen, K., Masironi, R., Rutenfranz, J., Seliger, V.,Degre, S., Trygg, K and Orgim, M. (1978). Habitual physical activity and health. WHO European series : 6, Copenhagen, P.10.

La Porte, R.E., Kuller, L.H., Kupfer, D.J., Mc Partland, R.G., Matthews, G and Caspersen, C. (1979). An objective measure of physical activity for epidemiological research. Am. J. Epidemiol: 109, Pp.158-168.

Lee. J. (1996) Roots of fatigue. The Hindu. February. 8, P.26.

Lee, M.W. (1992). A stochastic model of muscle fatigue in frequent strenuous work cycles. Michigan : University Microfilms International, Pp.184-186.

Leino, P and Hasan, J. (1987). Physical work load and musculo skeletal disorders in the engineering industry. In : P.Buckle (Ed). Musculo skeletal disorders at work. London : Taylor and Francis, Pp.23-24.

Leskinen, R.P.J. (1988). Comparison of static and dynamic biomechanical Models. Ergonomics : 28, Pp.285-291.

Levy, M.R., Dignan, M and Shireffs, J.H. (1988). Essentials of life and health. New York : Random house INC., Pp.57, 346, 361-362.

Liles, D.H. (1986). The application of the job severity index to job design for the control of manual materials - handling injury. Ergonomics : 29, Pp.65-76.

Lind, A.R. Rochelle, R.H., Petrofsky, J.S., Rinchart, J.S and Burse, R.L. (1975). The influence of dynamic exercise on fatiguing isometric exercise and the assessment of changing levels of isometric component. Washington, DC : NIOSH technical information no. 75-177, P.53.

Lind, F and Hesser, C.M. (1984). Breathing pattern and occlusion pressure during moderate and heavy exercise. Acta. Physiol. Scand : 122, Pp.61-69.

Lucas, A. (1989). Energy requirements in normal infants and children. In: B.Schurch and N.S. Scrimshaw (Eds). Activity, energy expenditure and energy requirements of infants and children. Proceedings of an I/D/E/C/G workshop. Masachusetts, P.5.

Luhtanen, P and Komi, P.V. (1980). Force-power- and electricity - velocity relationships in walking, running and jumping. Euro. Jour. Appl. Physiol:44, Pp.279-289.

Maeda, K. (1977). Occupational cervicobrachial disorder and its causative factors. Journal of Human Ergology :6, Pp.193-202.

Manohar, M.K and Shobha. V. (1983). 'Maid servants'. In : M.K. Mohan (Ed). Socio-economic status of Indian women. Delhi : Seema publication, Pp.31-46.

Marras, W.S and Mirka, G.A. (1989). Trunk strength during asymmetric trunk motion. Human Factors : 31, Pp.667-677.

Marras, W.S and Mirka, G.A. (1992). A comprehensive evaluation of trunk response to asymmetric trunk motion. Spine; I, Pp.151-153.

Maslow, A.H. (1970). Motivation and personality. New York : Harper and Row, Pp.1-92.

Mathiassen, S.E and Winkel, J. (1992). Can occupational guidelines for work - rest schedules be based on endurance time data? Ergonomics :35 : 3, P.257.

Mathur,B.P.(1989). Health and low-cost housing. Swasth Hind:36:6,Pp.144-146.

Mathur, D. (1988). Women, family and work. Jaipur : Rawat, Pp.01, 08.

Mathur, P.R. (1981) Points for proper posture. Home science: 19:2, P.81.

Mc Atamney, L and Corlett, E.N. (1992). Ergonomic workplace assessment in a health care context. Ergonomics : 35:9, Pp.965-978.

Mc Cormick, E.J. (1974). A human factors dilemma : Specialized or enlarged jobs? Invited address : Human factors society annual meeting. Huntsville, Ala., Pp.1-15.

Mc Cormick, E.J. (1976). Human factors in engineering and design. New Delhi : Tata Mc Graw - Hill, Pp.1-15, 161-176, 465.

Mc Cormick, E.J and Tiffin, J. (1979). Industrial psychology. New Delhi : Prentice Hall, P.277.

Mclean, D and Tobin, R. (1988). Proceedings of national research council. Washington DC : National academy press, P.141.

Meister, D. (1971). Human factors : Theory and practice. New York : John wiley Inc., P.273.

Menon, M.P.B. (1979). Application of engineering technology in rehabilitation medicine. Proceedings of the summer school in biomedical engineering. Trivandrum, Pp.18-26.

Merh. S. (1984). Inter-relationship between population education and family life education. The Journal of Family Welfare : XXX: 3, Pp.10,11.

Mero, A and Komi, P.V. (1986). Force-EMG - and elasticity - velocity relationships at submaximal, maximal and supramaximal running speeds in sprinters. Euro. Jour. Appl. Physiol:55, Pp.553-561.

Minard, D. (1970). Physiological characterization of health hazards on man's environment. In: D.H.K.Lee and D. Minard. (Eds). Physiology, environment and man. Based on a symposium conducted by the national academy of sciences - National research council. New York : Academic press, P.1.

Mital, A. (1984). Maximum weights of lifts acceptable to male and female industrial workers for extended workshifts. Ergonomics : 27, Pp.1115-1126.

Mital, A. (1985). A comparison between psychophysical and physiological approaches across low and high frequency range. J. Human. Ergol:14, Pp.59-64.

Mital, A. (1987). Patterns of differences between the maximum weights of lifts acceptable to experienced and unexperienced material handlers. Ergonomics :30, Pp.1137-1147.

Mital, A and Faard, H.F. (1986). Psychophysical and physiological responses to lifting symmetrical and asymmetrical loads symmetrically and asymmetrically. Ergonomics :29, Pp.1263-1272.

Monod, H. (1985). Contractility of muscle during prolonged static and repetitive dynamic activity. Ergonomics : 28:1, Pp.81-89.

Montoye, H.J. (1971). Estimation of habitual physical activity by questionnaire and interview. Am. J. Clin. Nutr: 24 (Reprint), P.21.

Montoye, H.J. (1982). Age and oxygen utilization during submaximal treadmill exercise in males. J. of Gerentology : 37, Pp.396-402.

Moorthy, M.V. (1982). Principles of labour welfare. New Delhi : Oxford and IBH, P.28.

Moritani, T., Gaffney, F.A., Carmichael, T and Hargis, J. (1985). Interrelationships among muscle fibre types, EMG and BP during fatiguing isometric contraction. In : D.A. Winter et al (Ed). Biomechanics IX-A. Human kinetics. Illinois, Pp.287-292.

Moritani, T., Nagata, A and Muro, M. (1981). Electromyographic manifestations of neuromuscular fatigue of different muscle groups during exercise and arterial occlusion. Jpn. J.Phys. Fitness Sport. Med : 30, Pp.183-192.

Moritani, T., Nagata, A and Muro, M. (1982). Electromyographic manifestations of muscular fatigue. Med. Science. Sports Exercise : 14, Pp.198-202.

Mrunalini, A. (1992). Quality of work life of women in home and farm. Unpublished Master of philosophy thesis : Avinashilingam Deemed University, Coimbatore, P.169.

Mullick, P. (1981). Elements of homescience. Ludhiana,Kalyani publishers, P.71/A.

Murali, M.N. (1982). Biomedical instrumentation and hospital systems. Vol. I: Monograph, Pp.281-296.

Murrell, K.F.H. (1979). Ergonomics : Man in his working environment. London: Taylor and Francis, P.10.

Nachemson, A. (1981). Disc pressure measurements. Spine : 6, Pp.93-97.

Nag, P.K and Chatterjee, S.K. (1981). Physiological reactions of female workers in Indian agricultural work. Human Factors : 23 : 5, Pp.607-614.

Nair, A. (1979). Medical physics. Proceedings of the summer school in biomedical engineering. Trivandrum, Pp.3-4.

Nair, G.K. (1979). Human engineering or ergonomics. Proceedings of the summer school in biomedical engineering. Trivandrum, Pp.14-20.

Narayana, N and Ramanjaneyulu, M. (1989). Rural housing in India. Yojana : 33:23, P.17.

Natarajan, M., Shanmugam, I.S and Balakrishnan, A. (1974). Function of tibialis anterior in squatting with feet flat on the ground - An electromyographic study. In : D.N. Ghista and M.K. Patil (Eds). Biomechanical research proceedings - I. Monograph, Pp.89-93.

Nayar, U. (1976). Textbook of physiology-I. New Delhi : Tata Mc Graw-Hill, Pp.55-81.

Nickell, P and Dorsey, J.M. (1991). Management in family living. New Delhi : Wiley Eastern, Pp.200-246.

Noble, B.J. (1986). Physiology of exercise and sport. St. Louis : Time mirror/ Mosby college publishing, P.69.

Noder, W. (1983). Speaking of : Fitness over 40. Translated by Susan Ray. New Delhi : Sterling, Pp.15-116.

Noone, G and Mazumdar, J. (1992). Lifting low-lying loads in the sagittal plane. Ergonomics : 35 :1, Pp.65-92.

Noro, K and Imada, A. (1991). Participatory ergonomics. London : Taylor and Francis, P.1123.

Oberoi, K., Dhillon, M.K and Miglani, S.S. (1983). A study of energy expenditure during manual and machine washing of clothes in India. Ergonomics : 26, Pp.375-377.

Oberoi, K and Miglani, M. (1984) Pulse pressure and average mean pressure responses during manual and machine washing of clothes : Indian Journal of Home Science : 11 : 2, Pp.8-15.

Oberoi, K., Puri, S and Sandhu, P. (1996). Muscular stresses of grinding wet masala in different postures. Proceedings of the eighty third session of the Indian science congress, Patiala, P.180.

Ohsawa, S and Sagawa, T. (1992). Statistical survey of sitting postures of Ramaken fresco in old Thailand. J. Human. Ergol: 21, P.94.

Omino, K and Hayashi, Y. (1992). Preparation of dynamic posture and occurrence of low back pain. Ergonomics : 35: (5/6), P.693.

Ong, C.N. (1991). Ergonomics and health concerns of using VDU. J. Human. Ergol : 20, P.167.

Ortengren, R., Andersson, G.B.J and Nachemson, A. (1978). Lumbar backloads in fixed spinal postures during flexion and rotation. In : E. Asmussen and K.Jorgensen. (Eds). Biomechanics VI. Baltimore : University park press, Pp.159-166.

Ortiz, J.A and Morrison, B.M. (1983). Energy and home economics - An 80 year history. Home Economics : 75 : 3, P.42.

Pandey, M. (1989). Overcoming rural housing shortage. Kurukshetra : 38: 12, P.17.

Paventhar Bharathidasan (1993). Kudumbavilakku (revised edition). Madras: Manivasakar Press, Pp.1-2.

Patrick, J.M. Bassey,E.J and Fentem, P.H. (1983). The rising ventilatory cost of bicycle exercise in the VII decade : A longitudinal study of nine healthy men. Clin. Sci: 65, Pp.521-526.

Peruvaayin Mulliyar. (1981). Asarakovai. (II Ed). Madras : New Century, Songs : 43 & 46.

Perzeszty, A. (1984). Economics, home economics and the 'New' home economics.In : P.J. Thompson (Ed). Home economics teacher education year book : Knowledge, technology and family change. Bloomington III : Bennet and Mc Knight.

Petrofsky, J.S and Lind, A.R. (1978). Metabolic, cardiovascular and respiratory factors in the development of fatigue in lifting tasks. J. Appl. Physiol : Respiration, environmental and exercise physiology : 45, Pp.64-68.

Petrofsky, J.S. and Phillips, C.A. (1984). Discharge characteristics of motor units and the surface EMG during fatiguing isometric contractions at submaximal tensions. Aviat. Space. Environ. Med : 56, Pp.581-586.

Phadnis, V and Malani, I. (1978). Women of the world. Illusion and reality. New Delhi: Vikas publishing, Pp.18-30.

Pimental, N.A., Sawka, M.N., Billings, D.S and Trad, L.A. (1984). Physiological responses to prolonged upper-body exercise. Med.Sci.Sports.Exercise :16, Pp.360-365.

Pizatella, T.J., Putz-Anderson, V.,Bobick, T.G., Mc Glothlin, J.D and Waters,T.R. (1992). Understanding and evaluating manual handling injuries : NIOSH research studies. Ergonomics : 35: 9, Pp.945-951.

Podlesak, K. (1992). The use of work physiology in ergonomics. Manual for physiology. Occupational health service, BHEL, Trichy, Pp.47-49.

Pollitt, E and Gorman, K. (1989). Long-term developmental implications of motor maturation and physical activity in infancy in a nutritionally at risk population. In : B.Schurch and N.S. Scrimshaw (Eds). Activity, energy expenditure and energy requirements of infants and children. Proceedings of an I/D/E/C/G workshop. USA, Pp.279-294.

Porter, R.W. (1987). Risk factors and back pain. In : P. Buckle (Ed). Musculo skeletal disorders at work. London : Taylor and Francis, Pp.75-81.

Powers, S.K., Beadle, R.E and Mangum, M. (1984). Exercise efficiency during arm ergometry : Effects of speed and work rate. J. Appl. Physiol :56, Pp.495-499.

Prasad, L and Bannerjee, A.M. (1985). Management of human resources. New Delhi: Sterling, Pp.161, 172-173.

Priel, V.A., (1974). A numerical definition of posture. Human factors:16, Pp.576-584.

Puttet, G., Senterre, J., Rigo, M and Salle, B. (1984). Nutrient balance, energy utilization and composition of weight gain in very-low birth weight infants fed pooled human milk or a protein formula. J. Pediatr: 105, Pp.79-85.

Radhakrishnan, S. (1979). Bio-mechanics. Proceedings of the summer school in biomedical engineering. Trivandrum, P.4.

Radhakrishnan, S and Naga Ravindra, M. (1989). Biomechanical assessment of hand strength. In : K.B. Sahay and R.K. Saxena. (Eds) Biomechanics. New Delhi : Wiley Eastern, P.182.

Raja, S., Unnikrishnan, E., Jayasankar, V and Ramani,S. (1989). A physiological evaluation of lifting capacity of Indians. In : K.B. Sahay and R.K. Saxena (Eds). Biomechanics. New Delhi : Wiley Eastern, Pp.65, 66.

Ramachakravarthi, S. (1986). Development adds to women's work load : Decade for women. Everyman's Science : 31 : 3, Pp.89-91.

Ramapaduka, P. (1986). Assessment of fatigue conditions of selected homemakers. Unpublished master's thesis. Bharathiar university, Coimbatore, Pp.37-40.

Rameshwaram G. (1989). Medical and health administration in rural India. New Delhi : Ashish publishing, P.1.

Rappaport, M. (1970). Human factors applications in medicine. Human Factors : 12:1, Pp.25-35.

Ray, G.G., Chatterjee, L and Varghese, M.A. (1990). Body dimensions of Indian housewives. J. Human. Ergol : 19, Pp.31-40.

Ray, G.G., Sen, R.N., Nag, P.K., De, A and Basu, S. (1981). Relationship between segmental and whole body weights and volumes of Indians. J. Human. Ergol :10, Pp.35-48.

Reddy, R.C. (1995). The missing trillion dollars of women's work. The Hindu, August, 21, P.20.

Regan, M.C and Roland, H.E. (1985). Rearranging family and career priorities : Professional women and men of the eighties. Journal of Marriage and the Family: 47, Pp.985-992.

Reichman, B., Chessex, P and Verellen, G. (1983). Dietary composition and Macronutrient storage in preterm infants. pediatrics : 72, Pp.322-328.

Rice, A.S and Tucker, S.M. (1986). Family life management. New York : Macmillan P.43.

Robinson, S., Dill, D.B., Ross, J.C., Robinson, R.D., Wagner, J.A and Tzankoff,S.P. (1973). Training and physiological aging in man.Federation Proc: 32, Pp.1628-1634.

Robinson, S., Dill, D.B., Robinson, R.D. Tzankoff, S.P and Wagner, J.A. (1976). Physiological aging of champion runners. J. Appl. Physiol : 41, pp.46-51.

Rodgers, S.H. (1984). Working with backache. New York : Peringon, Pp.1-15.

Ronco, P.G. (1972). Human factors applied to hospital patient care. Human Factors: 14 : 5, Pp.461-470.

Rowland, V.T., Nickols, S.Y and Doddler, R.A. (1986) 'Parents' time allocation : A comparison of households headed by one and two parents. Home Economics Research journal : 15, Pp.105-114.

Rudrabasavaraj, M.N. (1980). Human factor in management - Organizational behaviour. Bombay : Himalaya, P.28.

Ruffell - Smith, H.P. (1967). The role of ergonomics in abnormal physical conditions at work. In C.N. Davies, P.R. Davis and F.H. Tryer (Eds). The effects of abnormal physical conditions at work. London : E and S Livingstone, Pp.5-8.

Sakurai, S and Miyashita, M. (1985). Mechanical energy changes during treadmill running. Medicine and Science in Sports and Exercise : 17, Pp.148-152.

Salvendy, G. and Pilitsis, J. (1971). Psychophysiological aspects of paced and unpaced performance as influenced by age. Ergonomics : 14 : 6, Pp.703-711.

Sanchez, D and Grieve, D.W. (1992). The measurement and prediction of isometric lifting strength in symmetrical and asymmetrical postures. Ergonomics : 35, Pp.49-64.

Sandhu, M.K. (1972). A study of the utilization of the time spent in performing household activities by homemakers in the rural area. Masters thesis, Punjab agricultural university, Ludhiana, Pp.149-153.

Sanik, M.M. (1981). Division of household work : A decade comparison - 1967-'77. Home Economics Research Journal : 10:2, Pp.175-180.

Saris, W.H.M. and Binkhorst, R.A. (1977). The use of pedometer and actometer in studying daily physical activity in man. Part I : Reliability of pedometer and Actometer. Eur. J. Appl. Physiol : 37, Pp.219-228.

Schnappe, R.H. (1965). Motion element synthesis : An assessment, perceptual and motor skills : 20, Pp.103-106.

Schneider, F.M. (1985). Why ergonomics can no longer be ignored? Office administration and automation, Pp.26-29.

Schoeller, D.A. (1988). Measurement of energy expenditure in free-living human by using doubly labeled water. J. of Nutr: 118, Pp.1278-1289.

Schoeller, D.A., Ravussin, E., Schutz, Y., Acheson, K.J., Baertschi, P and Jequier, E. (1986). Energy expenditure of Doubly labeled water : Validation in Humans and proposed calculation. Am. J. Physiol; 250 : R.823-830.

Schoeller, D.A and Van Santen, E. (1982). Measurement of energy expenditure in humans by Doubly labeled water method. J. Appl. Physiol:53, Pp.955-959.

Scholten, R and Rohrle, H. (1978). Force flow calculation and movement studies for the biomechanics of the lower limbs. In : S.K.Guha (Ed). Proceedings-workshop on trends in biomedical engineering. New Delhi : CBME publications, Pp.149-151.

Schultz, A.B and Andersson, G.B.J. (1981). Analysis of loads on lumbar spine. Spine : 6, Pp.76-82.

Schultz, A.B., Andersson, G.B.J., Ortengren, R., Bjork, R and Nordin, M. (1982). Analysis and quantitative myoelectric measurements of load on the lumbar spine when holding weights in standing postures. Spine : 7, Pp.390-397.

Seireg, A and Arvikar, R.Y. (1973). A mathematical model for evaluation of the forces in lower extremities of the muscular-skeleton system. Journal of Biomechanics : 6, Pp.313-326.

Sen, R.N. (1969). Tentative classification of strains in different types of jobs according to the physiological responses of Indian workers in comfortable climates. ICMR research report.

Sen, R.N. and Pal. D. (1989). A new ergonomic method for postural analysis. In : K.B. Sahay and R.K. Saxena (Eds). Biomechanics. New Delhi : Wiley Eastern, Pp.262-269.

Senior, J. (1975). Work study in the kitchen. London : Pitman, P.1-30.

Sharma, B.A.V., Prasad, R.D and Sathyanarayana, P. (1989). Research methods in social sciences. New Delhi: Sterling, P.197.

Shramsakthi, (1987). Report of the National Commission on Self employed women and women in the informal sector: Pp.27, 142, 157.

Simard, T and Balakrishnan, A. (1971). Bio-mechanic investigations of squatting with below knee amputies. Annual report of the department of research rehabilitation. Canada : Institute of Montreal, P.23.

Singh, K.N. and Bhattacharya, H.C. (1990). Crop production for farm women - A critical appraisal. In : C. Prasad and Shriram (Eds). Women in agriculture - Technological perspective. New Delhi. International federation for women in agriculture. ICAR, P.60.

Singleton, W.T. (1971). The measurement of man at work with particular reference to arousal. In : W.J. Singleton, J.G. Fox and D. Whitfield (Eds). Measurement of man at work. London : Taylor and Francis, Pp.17-25.

Smith, H.W. (1975). Strategies of social research. The methodological imagination. New Jersey : Prentice, Pp.61-183.

Snook, S. (1978). The design of manual handling tasks. Ergonomics :21, Pp.963-985.

Snook, S.H. (1985). Psychophysical considerations in permissible loads. Ergonomics : 28: 1, Pp.327-330.

Spady, D.W. (1980). Total daily energy expenditure of healthy free-ranging school children. Am.J.Clin.Nutr:33, Pp.766-775.

Spengler, D.M., Bigos, S.J., Martin, N.A., Zeh, J., Fisher, L and Nachemson, A. (1984). Back injuries in industry : A retrospective study, 1. Overview and cost analysis. Spine : 11, Pp.241-245.

Spurr, G.B. (1987). Effect of chronic energy deficiency on stature, work capacity and productivity. In : B.Schurch and N.S. Scrimshaw (Eds). Chronic energy deficiency : Consequences and related issues. Switzerland : Nestle foundation and United Nations university, P.96.

Spurr, G.B., Barac-Nieto, M and Maksud, M.G. (1975). Energy expenditure in cutting sugarcane. J. Appl. Physiol : 39, Pp.990-996.

Spurr, G.B., Ferro-Luzzi, A., Guzman, D., Husaini, M.A., Norgan, N.G., Reina, J.C., Shetty, P.S., Solomons, N. and Torun, B. (1987). Work capacity, work performance. A working group report. In : B. Schurch and N.S. Scrimshaw (Eds). Chronic energy deficiency : Consequences and related issues. Guatamala : Proceedings of an I/D/E/C/G. Workshop, Pp.183-185.

Spurr, G.B., Prentice, A.M., Murgatroyd, P.R., Goldberg, G.R., Reina, J.C and Christman, N.T. (1988). Energy expenditure from minute-by-minute heart rate recording : Comparison with indirect calorimetry. Am.J.Clin.Nutr:48, Pp.552-559.

Spurr, G.R. and Reina, J.C. (1989). Estimation and validation of energy expenditure obtained by the minute-by-minute measurement of heart rate. In : B.Schurch and N.S. Scrimshaw (Eds). Activity, energy expenditure and energy requirements of infants and children. Proceedings of an I/D/E/C/G Workshop. USA, Pp.57-67.

Spurr, G.B., Reina, J.C and Barac-Nieto, M. (1986). Marginal malnutrition in school-aged Colombian boys : Metabalic rate, and estimated daily energy expenditure. Am.J.Clin.Nutr: 44, Pp.113-126.

Srivastava, J.C.(1985). Harnessing technology for improving the quality of life of rural women. In : S.C. Jain (Ed). Women in technology. Jaipur : Rawat, Pp.38-69.

Steidl, R.E. (1972). Difficulty factors in homemaking tasks : Implications for environmental design. Human Factors : 14 : 4, Pp.471-482.

Steidl, R.E and Bratton, E.C. (1980). Work in the home. New York : John Wiley, Pp.1-38, 119-178, 265,295.

Stephens, J.A and Taylor, A. (1972). Fatigue of maintained voluntary muscle contraction in man. J. Physiol. London : 220, Pp.1-8.

Super, C.M. (1989). The cultural regulation of infant and child activities. In : B. Schurch and N.S. Scrimshaw (Eds). Activity, energy expenditure and energy requirements of infants and children, proc. of an I/D/E/C/G workshop. USA; P.332.

Svedenhag, J., Wallin, B.G., Sundlof, G and Henriksson. J. (1984). Skeletal muscle sympathetic activity at rest in trained and untrained subjects. Acta. Physiol. Scand : 120, Pp.499-504.

Swaminathan, M. (1983). Human nutrition and diet, Bangalore : The Bangalore printing and publishing Co. Ltd, Pp.13-14.

Swanson, B.B. (1981). Introduction to home management, New York : Macmillan, Pp.7-242.

Tandon, P.N. (1978). Health care and biomedical engineering. Proc.of the international symposium and workshop on biomedical engineering. New Delhi, P.1-12.

Tara bai (1977). Emergence of home science. In : Perspectives in home science. Published by Home Science Association of India, Coimbatore : Vani printers, P.56.

Thews, G. (1986). Oxygen supply to the dynamically working skeletal muscle. In : M. Meyer and N. Heisler (Eds). Topics in respiratory and comparative physiology. New York : Gustav Fisher Verlag, Pp.70, 74.

Tiwari, A.K., Ahmed,A.M., Shastry, A., Aiyar, S.K and Dixit, A. (1976): Transceiving equipment for telemetry of physiological data. Proceedings of the VI All India symposium on biomedical engineering. Bangalore, P.13.

Tiwari, S.C. (1994). Role of technology and relevance of self-reliance. Current Science : 66:1, P.13.

Torun, B. (1989). Energy cost of various physical activities in healthy children. In : B. Schurch and N.S. Scrimshaw (Eds). Activity, energy expenditure and energy requirements of infants and children. Proc. of an I/D/E/C/G workshop. USA, Pp.139-183.

Travis, J.W. (1977). Wellness inventory. Mill valley, California : Wellness resource centre, Pp.5-10.

Tremblay, A and Bouchard, C. (1987). Assessment of energy expenditure and physical activity pattern in population studies. In : F.E. Johnston (Ed). Nutritional anthropology. New York : Alan. R. Liss, Pp.101-116.

Trevathan, S.W and Maloch, F. (1967). Angles of body bend in loading dishwashers. Journal of Home Economics: 59, Pp.375-377.

Tripathi, P.C. (1991). Research methodology in social services. New Delhi : Sultan Chand, P.12.

Tryon, W.W. (1987). Activity as a function of body weight. Am.J. Clin. Nutr: 46, Pp.451-455.

Valiathan, M.S. (1994). Science as service. Current Science : 66:3, Pp.189-90.

Van Wely, P. (1970). Design and disease. Applied Ergonomics :1 Pp.262-269.

Varghese, M.A., Ogale, N.N and Srinivasan, K. (1994). Home management. New Delhi: Wiley Eastern, Pp.17-20, 53-65.

Vink, P and Kompier, M.A.J. (1991). Participative ergonomics : An intervention strategy for reducing musculoskeletal injuries. In : Y. Queinnec and F.Daniellou (Eds). Designing for everyone : Proceedings of the XI. IEA congress. Vol. II. London : Taylor and Francis, Pp.1669-1671.

Vink, P., Lourijsen, E., Wortel, E and Dul, J. (1992). Experiments in participatory ergonomics : Results of a round table session during the XI. IEA congress (Paris, 1991). Ergonomics : 35:2, Pp.123-127.

Von Gierke, H.E. (1973). Dynamic characteristics of the human body. In : R.M.Kenedi, (Ed). Perspectives in biomedical engineering. London :Macmillan, P.193.

Vos, H.W. (1973). Physical work-load in different body postures, while working near to, or below ground level. Ergonomics : 16:6, Pp.817-828.

Wadhera, K. (1976). The new bread winners. New Delhi : Vishwa Yuvak Kendra,P.122.

Walker, V. (1970). Time used by husband for household work. Family Economics Reviews. ARS : 52-5, Pp.24-30.

Warnold, I and Lenner, R.A. (1977). Evaluating the heart rate method to determine the daily energy expenditure in disease : A study in Juvenile diabetics. Am.J.Clin. Nutr:30, Pp.304-315.

Waterlow, J.C., Hautvast, J.G.A.J., Henry, C.J.K. Schurch, B., Shetty, P.S. and Weisell, R.C. (1991). Research needs. In : B. Schurch and N.S Scrimshaw (Eds). Protein-energy interactions. Proceedings of an I/D/E/C/G workshop. Waterville Valley, USA: United Nations university, Pp.415, 420.

Watson, J and Hill, A (1991). A dictionary of communication and media studies. New Delhi : Universal book stall, P.133.

Weinberg, E. (1983). Data collection - planning and management. In : P.H. Rossi., J.D. Wright and A.B. Anderson (Eds). Handbook of survey research. London : Academic press, P.329.

Weissman, C., Damask, M.C., Askanazi, J., Rosenbaum, S.H.and Kinney, J.M. (1985). Evaluation of a non-evasive method for the measurement of metabolic rate in humans. Clin. Sci : 69, Pp.135-141.

Welford, A.T. (1974). Man under stress. New York : John Wiley, P.140.

Welle, S., Forbes,G.B., Statt, M., Barnard, R.R. and Amatruda, J.M. (1992). Energy expenditure under free-living conditions in normal-weight and overweight women. Am.J.Clin.Nutr:55:1, Pp.14, 17 .

Westgaard, R.H. and Aaras, A. (1984). Postural muscle strain as a causal factor in the development of musculo skeletal illnesses. Appl. Ergonomics:15, Pp.162-174.

Wilkinson, T.S. and Bhandarkar, P.L. (1982). Methodology and techniques of social research. Bombay : Himalayan Publishing house, Pp.188-197.

Williams, K.R. (1985). The relationship between mechanical and physiological energy estimates. Medicine and science in sports and exercise : 17, Pp.317-325.

Williams, K.R. and Cavanah, P.R. (1987). Relationship between distance running mechanics, running economy and performance. J. Appl. Physiol : 63, Pp.1236-1245.

Williams, M and Lissner, H.R. (1962). Biomechanics of human motion. London : W.B. Saunders, Pp.1-108, 129-135.

Willis, A. (1977). The organisations of household work and role problems for employed women and men. Paper presented : National conference on marriage and family. San Diego, P.1.

Willmore, J.H. (1977). Training or sport and activity : USA, P.105.

Winter, D.A. (1979). A new definition of mechanical work done in human movement. Jour. Appl. Physiol : 46, Pp.79-83.

Wolff, H.S. (1970). Biomedical Engineering. London : World university library, Pp.100-134.

Wools, R and Canter, D. (1970). The effect on the meaning of buildings on behaviour. Appl. Ergonomics : 1 : 3, Pp.144-150.

World Development Report (1995). Workers in an integrating world. New York : Oxford, P.25.

Wright, S. (1971). Applied physiology. London : Oxford university press, Pp.105-468.

Yates, J.W. and Karwowski, W. (1992). An electromyographic analysis of seated and standing lifting tasks. Ergonomics : 35 : 7/8, Pp.889-899.

Yerg II, J.E., Seals, D.R., Hagberg, J.M and Holloszy, J.O. (1985). Effect of endurance exercise training on ventilatory function in older individuals. J. Appl. Physiol:58:3, Pp.791-794.

Yogacharya, K.K. (1986). Energy conservation for health. Herald of Health : 20:1, P.23.

Appendices

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APPENDIX I

INTERVIEW SCHEDULE TO ELICIT INFORMATION ON THE ACTIVITY PROFILE OF SELECTED HOMEMAKERS

I. General Family Background

1. Name of the interviewee
2. Type of family :
3. Nature of House :
4. Religion :
5. Family background

Joint ☐	Nuclear	
Owned	Rented	Quarters
Hindu	Christian	Muslim

S.No.	Relation to the head of the family	Age	Educational Status			Occupation and nature	Income per month	
			Standing	Studied upto	Illiterate		Salary	Supplementary

6. Actual description of employment
   a. Reasons for taking up employment
   b. Problems faced by you due to employment
   c. Time spent on household activity (in min)

II. Affective Domain

1. Performance of household activities
   a. Who is responsible for performance of household activities?
   b. Indicate the activities and state the division of labour followed to home

S.No.	Activities	Persons performing the tasks				
		Homemaker	Spouse	Children	Domestic help	Others

C. Indicate the household activities you like to perform and those you dislike-state reasons

III. Cognitive Domain

1. Indicate the attitude of other family members towards performance of household activities
2. Housing
   a. State if you pay rent : Yes No
   b. Are you satisfied with your house? Yes No
   c. Give information on the housing facility enjoyed

Particulars	Satisfied	Not satisfied	Reasons
Area is adequate			
Structural aspects			
Spacious organisation			
Allocation of area considered			
Privacy assured			
Bathrooms of adequate size			
Convenient placement of toilets			

Adequacy of windows
Kitchen counter at comfortable height
Adequacy of windows
Convenient kitchen counter
Adequacy of storage facility
Good flooring
Copious water supply
Potable water supply
Proper set back for the house
Space for gardening
Proper drainage
Thermal comfort
Spacious rooms
Provision of bath/toilet consistent with the size of family Liability

3. Possession of labour saving devices
   a.List the labour saving devices possessed by you : State reasons for possessing the same
4. Details on domestic help enjoyed : Full time Part time State reasons
   b.Activities allotted

	Activities allotted		Time spent in min
	Full time	Part time	

c. Indicate the problems faced, if any, with domestic help

IV. Temporal Domain

1. Time :
   a. Details on your daily time expenditure pattern on household activities
      Household activities Time spent in min

How do you manage time effectively?

b. Information on peak loads

Time of day	Actual time	Activities performed during the peak load	Management of peak load

e. Do you enjoy leisure time? Yes No State reasons

V. Physical Component

1. Posture : a. Indicate the posture adopted while performing activities
   b. If done at floor level, indicate position of sitting
   Squatting on the floor Sitting Squatting on wooden plank
   c. Mention the activities done adopting various postures
2. Fatigue : a. When do you feel fatigued?
   b. Indicate the factors which induce fatigue while performing activities (tick whichever is applicable)

Posture	Time cost of performance	Time of the day	Working environment	Work itself

3. Perception of fatigue: a. Indicate the specific condition under which you feel fatigued?
   b. Rank your perception of fatigue as related to household work (Rank them according to your personal experience)

Activity	Household chores which are fatiguing		
	Highly	moderately	Less

c. Mention the symptoms (Physical) you associate with fatigue as related to household activities, state What steps you take to alleviate fatigue?

APPENDIX II

SIMPLE EXPLANATIONS OF LAND MARKS AND / OR MEASURING METHODS OF ANTHROPOMETRY

1. Arm reach : arms and fingers extended horizontally. Distance from back shoulder to the middle finger tip.

2. Elbow-finger tip elbow bent at right angles. Distance from back of elbow the middle finger tip

3. Shoulder-elbow length : Acromial height minus elbow height

4. Trochanteric : Hip to foot length

5. Knee-to-foot length : Proximal point of knee to floor.

6. Thigh length : From highest point of hip (pelvic bone) to knee

7. Elbow height from floor : Lowest bone point of the elbow bent at right angle while standing, squatting or bending (left & right hands)

8. Foot length : The max : length from back heel to the longest toe tip.

9. Squatting height : as for measuring stature; but in squatting posture.

10. Bending height : total height from highest surface of buttocks to floor.

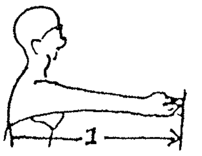
11. Buttocks height : lowest point of buttocks to floor (squatting).

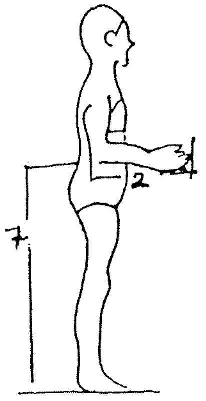
12. Upper arm length : shoulder to floor length - while squatting and bending i mopping action

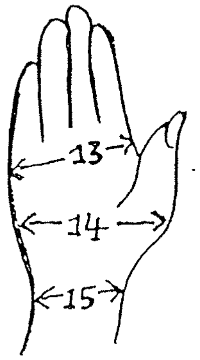
13. Circumference of hand

14. Breadth of hand

15. Circumference of wrist





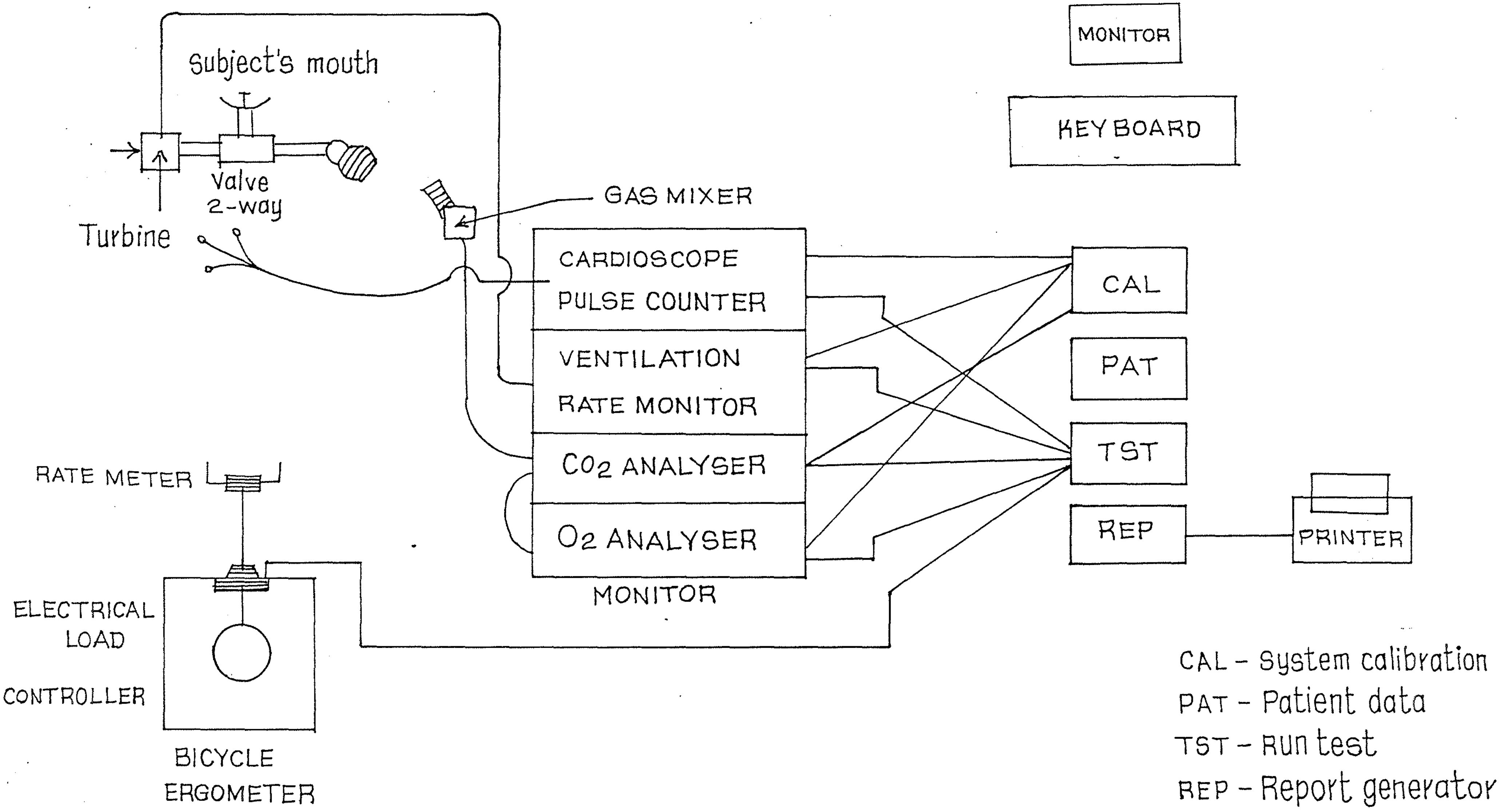


APPENDIX III

ANTHROPOMETRY

Sample No./ Parameter	1	2	3	4	6	6	7	8	9	10	11	12	13	14	16	16	17	18	19	20	21	22	23	24	26	26	27	28	29	30	31	32
Age (years)	42	41	41	39	39	40	38	42	38	38	38	41	39	39	42	42	42	41	39	38	42	38	42	42	38	40	39	42	40	42	38	42
Stature (cm)*	151	156	152	154	158	153	156	161	154	151	157	152	160	155	150.5	154	151	160	154.5	156.5	158	156	151.5	155.5	150.5	153	162	152	152	157	156	155.5
Body size (kg)	56	64	70	80.5	85	56.5	62	73	64	68	50.5	75	54	55	40	67	59	60	59.5	59	64	61.5	61.5	52	42.5	57	80.5	48.5	57	69.5	57	67
Per cent body fat	.31	.30	34	46	.42	.29	.35	.31	.31	46	.23	.47	.27	.29	.27	.37	38	.28	.32	.27	.35	.30	.29	.31	.29	.26	.40	.29	.35	50	.28	.38
Lean body mass	38.6	44.8	46.2	31.5	49.3	40.1	40.3	50.7	44.2	36.7	39.9	39.8	39.4	39.1	29.2	42.2	36.6	43.2	40.5	43.1	41.6	43.1	43.7	35.9	30.2	42.2	48.3	34.4	37.1	34.8	41.0	41.5
Body mass index	24.6	26.3	30.3	25.5	34.1	24.1	25.5	28.2	27	29.8	20.5	32.5	21.1	22.9	18.4	28.3	25.9	23.4	24.8	24.0	25.6	25.3	28.6	21.4	18.6	24.4	30.7	21.0	24.7	28.3	23.5	27.6
STANDING																																
Arm reach	71	72	69	73	74	69	68	77	67	67	73	68	76	72	69	71	67.5	74	72	73	76	72	69	70	70	73	71	69	68	72	72	74
Forearm	43	43	43	44	46	41	43	44	40	40	44	41	44	47	42	43	42	47	43	44	45	44	43	41	44	46	44	43	42	44	46	45
Upper arm	30	30	32	30	35	31	31	34	30	31	30	33	34	32	30	31	29	33	32	32	32	32	31	33	32	32	29	32	32	32	31	32
Trochanteric ht	97	97	97	98	104	96	100	106	100	99	96	97	100	98	94	97	98	100	100	103	102	99	98	101	97	101	102	96	97	100	100	101
Length-lower limb	43	44	51	49	47	44	43	51	45	44	47	44	45	42	43	44	43	47	44	50	47	43	44	46	47	45	47	45	45	48	45	49
Length of thigh	57	55	51	52	57	54	57	56	50	56	51	54	61	57	52	53	56	55	57	57	56	56	56	56	51	54	54	49	56	54	54	55
Elbow ht	100	96	94	100	100	95	96	106	96	96	95	92	98	92	91	99	92	100	96	102	100	94	92	102	89	99	109	96	93	105	101	96
Foot length	23	24	24	25	25	23	24	26	24	22	25	23	24.5	24	23	24	24	24	24	25	25	23	24	24	23	23	26	24	23	24	25	25
SQUATTING																																
Squatting height	80	97	97	92	87	100	92	100	101	97	92	101	92	92	94	90	91	99	99	101	99	101	99	90	94	90	87	87	97	83	88	92
Buttocks ht (from floor)	16	19	19	17	15	18	16	16	18	19	17	26	11	17	18	18	15	18	15	22	18	19	19	18	15	19	14	18	17	16	15	17
Elbow height	30	43	42	35	34	42	40	41	43	46	42	49	35	31	36	36	41	49	37	42	42	44	43	37	38	37	51	33	38	39	37	39
Height of upper arm	60	74	75	69	70	67	68	75	75	76	71	80	68	65	67	70	63	79	77	74	78	77	76	69	68	71	68	66	72	66	72	73
BENDING																																
Height	97	90	92	91	110	89	92	104	84	94	95	92	89	91	89	89	88	97	85	94	96	89	88	83	88	91	101	79	88	96	92	92
Elbow height (left)	53	31	64	51	70	54	63	57	59	53	72	56	57	58	50	40	53	56	55	63	65	50	53	58	63	59	55	53	67	67	53	58
Elbow height (right)	40	39	47	40	48	38	43	38	35	57	43	44	43	42	41		44	40	31	36	49	38	42	37	37	34	40	29	42	47	38	35
Height - upper arm (left)	78	79	85	80	87	71	82	72	74	69	92	74	73	83	74	68	81	71	76	74	95	71	75	81	75	71	71	68	87	93	73	79
Height - upper arm (right)	70	66	73	68	77	79	71	74	66	60	86	71	67	74	70	67	73	70	60	64	78	67	70	68	66	61	69	56	75	78	67	68
HAND DIMENSIONS																																
Hand circumference	18	20	21	17	20	17	20.5	20	18	17	20	18	19	19	17	18	16	18	19	18	19	20	20	18	18	18	20	18	19	20	20	19
Hand breadth	10	10	10	10	10	10	10	10	10	10	10	10	10	10	9.5	10	10	10	10	10	10	10	10	10	9	10	10	10	10	10	10	10
Wrist circumference	14	17	13	15	17	15	15	17	15	14	15	15	14	16	13	15	15	15	15	16	15	15	17	13	12	15	16	14	14	16	16	15
Max grasp	14.5	15	15	14	11	15	14	15	15	9	141	13	15	14	13	14	15	15	14	15	15	15	15	14	14	15	16	14	13	14	15	15

* Unless otherwise specified all are in centimetres



APPENDIX. IV

ERGOMETER– GAS ANALYSER–TELEMETER–COMPUTER CONFIGURATION

APPENDIX V

INDIVIDUAL OBSERVATION ON HR & VO_2 OF EIGHT SUBJECTS TO VARIED WORKLOADS (EXERCISE TEST)

S. No.	Parameter recorded	30	60	90	120	150	180	210	240	270	300	330	360
1.	HR (bpm)	77	83	102	102	102	104	107					
	VO (ml.min^{-1})	114	145	375	400	392	438	562					
2.	HR	90	102	102	108	111							
	VO	310	323	528	568	639							
3.	HR	101	114	115	116	116	117	123	126	131	135	137	
	VO	240	224	257	421	578	626	826	846	925	964	1023	
4.	HR	88	106	109	114	118	123	126	130	133	138	135	
	VO	295	353	459	499	516	549	592	780	993	396	810	
5.	HR	96	98	111	122	129							
	VO	335	369	608	807	850							
6.	HR	99	117	125	134	147	146	145	151	151	149	156	157
	VO	190	262	311	394	567	548	593	531	673	751	695	650
7.	HR	95	113	119	122	125	127	133	134	140	137		
	VO	205	269	454	497	508	610	650	628	579	467		
8.	HR	96	105	115	118	126	123	126					
	VO	360	470	631	642	723	695	770					

Regression equations : VO DAT Vs PVO (N=68)

Programme	x mean	SDx	SEx	Y mean	SD Y	SEY	CORR	REGR	INT	SEE	T-value	T-corr
1.Basic	540.706	216.629	26.270	540.75	142.560	17.288	0.64810	0.43287	306.69	107.378	1.4032 E-03	6.91376
2.Lotus 1-2-3	"	"	"	551.471	124.529	15.101	0.64836	0.37827	346.94	93.768	0.35525	6.91856

1. VO = (7.895298 x HR (beats) - 403.0145

2. VO = (6.899273 x HR (beats) - 273.174

APPENDIX VI

FORMULAE USED FOR VARIOUS CALCULATIONS

1. Mean arterial blood pressure = Diastolic pressure + 1/3 pulse pressur

   where, pulse pressure (PP) = Systolic pressure (SP) - Diastolic pressure (DP

2. Predicted Max : Heart rate (bpm) = 210 - (0.65 x age)

3. Predicted $VO_{2\ (max)}$ (Maximal aerobic power) = 48 -(.37xage) x weight

   (in l. min)

4. Working VO_2 ($l.min^{-1}$)
$$= \left[\frac{(7.895298 \times \text{Working HR bpm}) -(403.0145)}{1000}\right]$$

5. Incremental VO_2 ($L.min^{-1}$)
$$= \left[\frac{(7.895298 \times \text{Incremental HR (beats)} -403.0145}{1000}\right]$$

6. Energy expenditure (K.cals/min) = ($\dot{V}O_2$ x 5)

7. Respiratory Quotient (RER) $= \left[\frac{VCO_2}{VO_2}\right]$

8. O_2 pulse ($ml\ beat^{-1}$) $= \frac{VO_2}{f_c}$ where f_c = ($beats.min^{-1}$)

9. Relative Aerobic Strain (RAS %) $= \frac{VO_2 \text{ working}}{VO_2 \text{ (max)}} \times 100$

10. Rate of work (sq.m/min) $= \frac{\text{Area mopped (Sq.m)}}{\text{Endurance (min)}}$

11. Rate of recovery (s) $\frac{\text{Recovery time (s)}}{\text{Endurance (s)}}$

12. Range of movement (sq.m) = (a-b)

    where $a = \left[\frac{x}{360} \times \frac{22}{7} \times r_1^2\right]$ where r_1 = outer radius

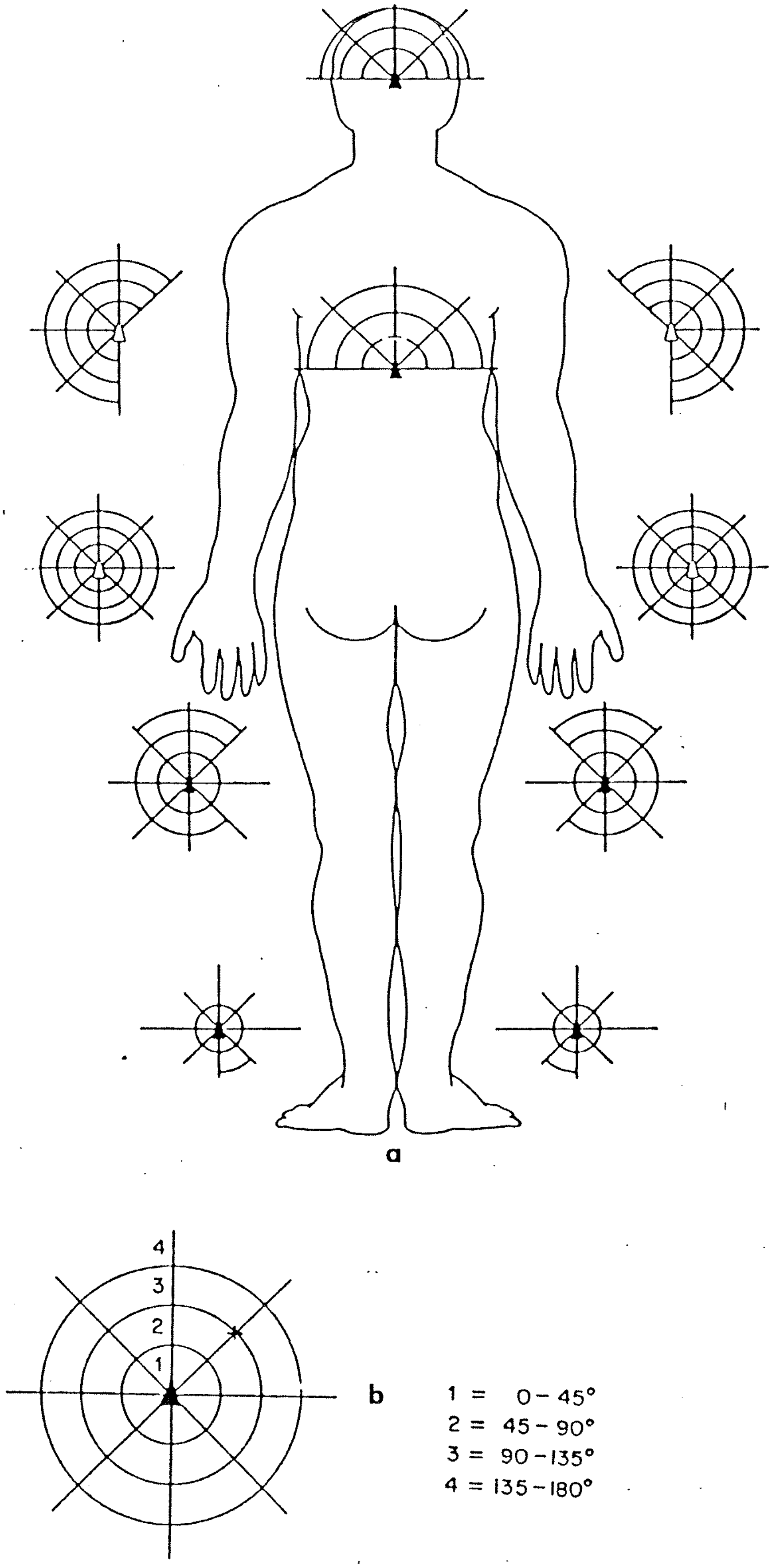
    $b = \left[\frac{x}{360} \times \frac{22}{7} \times r_2^2\right]$ where r_2 = inner radius

    x = angle formed (in degrees) which is dependent on the sample's full arm reach in flexion

13. Incremental recovery cost (beats) = Recovery pulse - resting pulse (for each individual minute of recovery)

14. Oxygen debt = (Total VO_2 during recovery period) - (resting VO_2 for that period)

APPENDIX VII



MODEL OF POSTUREGRAM

APPENDIX VIII

SCALE TO ASSESS HOMEMAKER'S PERCEPTION OF FATIGUE/DRUDGERY INDEX AS RELATED TO MOPPING

(One after bending and one after squatting)

A number of statements pertaining to your perception of fatigue/drudgery while mopping are given below. Read each statement and tick whichever you feel is appropriate to your experiences : <u>how you feel right now</u>. There are no right or wrong answer. Spend minimum time and give the answer which seems to describe how you feel now after mopping

Statements	Strongly agree (5)	Agree (3)	Disagree (1)
I <u>Boredom - A dull sleepy factor</u>			
1. Feel heavy in the head			
2. Feel tired			
3. Stifle a yawn			
4. Feel drowsy			
5. Feel rigid and clumsy in motion			
6. Feel unsteady while standing			
7. Feel like lying down			
II <u>Psychological - decline of working motivation</u>			
8. Feel unable to concentrate attention			
9. Feel unable straighten up in posture			
10. Feel impatient			
11. Feel anxious about completion			
12. Feel the posture inconvenient			
13. Feel unable to maintain the posture			
III <u>Physical strain fatigue/drudgery</u>			
14. Feel drained of energy			
15. Have a headache			
16. Experience anorexia			
17. Feel stiff in the shoulders			
18. Feel pain in the neck			
19. Have pain in my whole hand			
20. Have pain in the calf muscles			
21. Feel pain in the waist			
22. Have tremor in the limbs			
23. Feel pain in the knees			
24. Feel the activity is a drudge			
25. Feel thirsty			
26. Feel very ill			
27. Problems with varicose veins has developed			
28. Feel severe pain in the lower back			
29. Have developed cramps			
30. Have severe hip pain			
31. Have a non-spinal joint pain on the sides of the abdomen			
32. Am totally fatigued			

Statements	Strongly agree (5)	Agree (3)	Disagree (1)
33. Feel dizzy			
34. Have difficulty with vision			
35. Feel breathless/have palpitation			
IV Feel frustrated			
36. Feel restricted in clearance and reach			
37. Feel the movement is awkward			
38. Feel unstable/may lose my balance			
39. Am under stress			
40. I feel tensed			

APPENDIX IX

INTERVIEW SCHEDULE TO ELICIT INFORMATION ON TYPES OF MANUAL MOPPERS AVAILABLE IN THE MARKET

Name of interviewee :

Address :

1. Indicate the models of moppers sold by you

2. Give details on the moppers sold by you

Brand	Types	Cost	Mode of operation

3. Construction details of moppers

a. Materials used

Brand	Handle	Mopping component	Swab fixer	Assembly materials	Controls provided

b. Dimensions

Brand	Handle	Handle with swab fixer	Swab fixer	Mopping component

4. Give details on spare parts available for the moppers

5. Indicate the most popular model sold by you

state reasons

APPENDIX X

PHYSIOLOGICAL RESPONSES OF THE SUBJECTS TO DIFFERENT LOADS IN ERGOMETRY

Parameter	Loads (w)	Serial order of sample 1	2	3	4	5	6	7	8	9	10
Heart rate (bpm)	20	134	126	118	103	130	130	100	135	154	130
	30	144	139	127	112	140	135	108	145	156	144
	40	155	152	136	122	152	143	115	163	161	155
Skin temperature (°C)	20	33.0	36.2	33.8	34.6	32.6	34.2	32.5	35.2	35.1	34.0
	30	33.1	36.2	33.9	34.7	32.7	34.2	32.4	35.0	35.2	34.1
	40	32.9	35.9	34.0	34.8	32.8	34.1	33.3	34.9	35.3	34.1

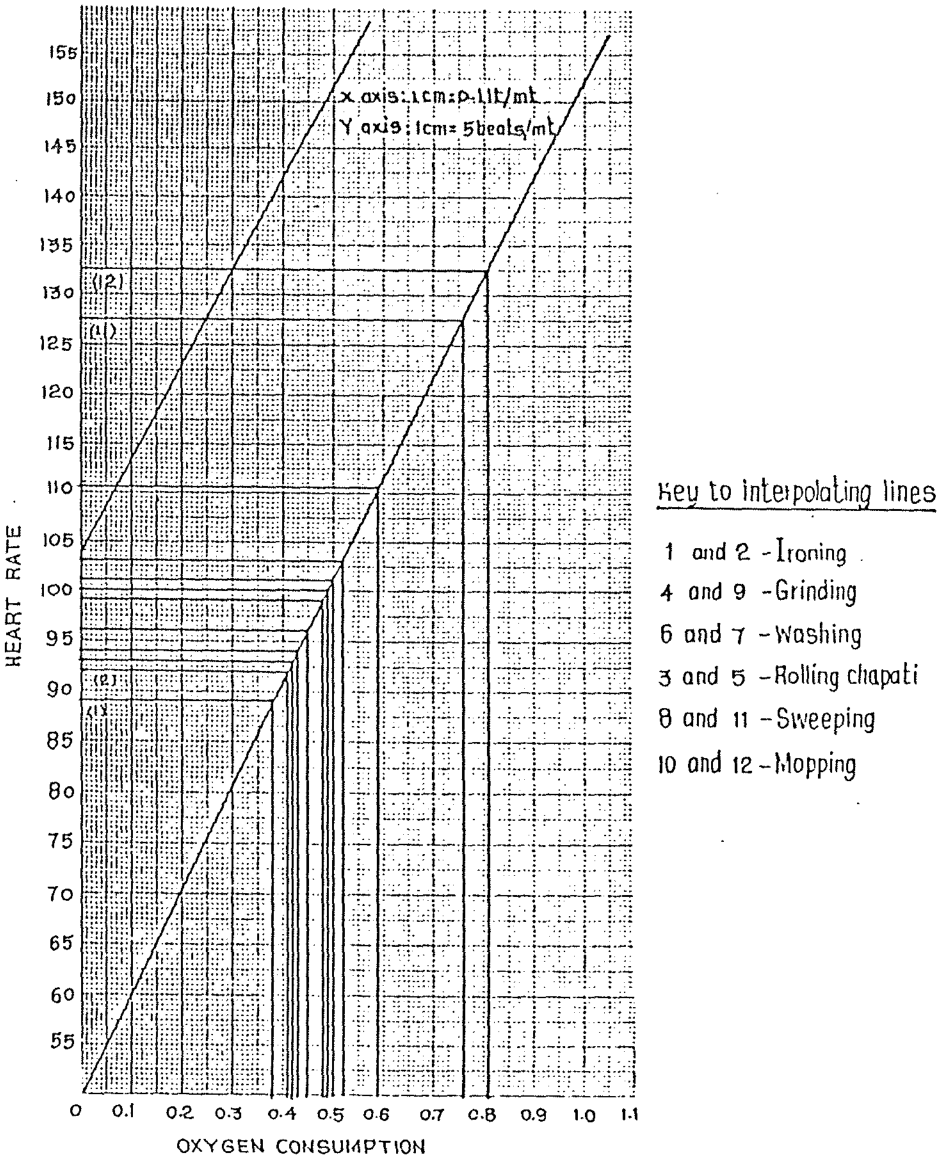
O_2 consumption ($L.min^{-1}$)	Load (Watts) 20	30	40
	0.25	0.37	0.49

CATEGORISATION OF WORKLOAD (JOB HEAVINESS) FOR INDIAN INDUSTRIAL WORKERS

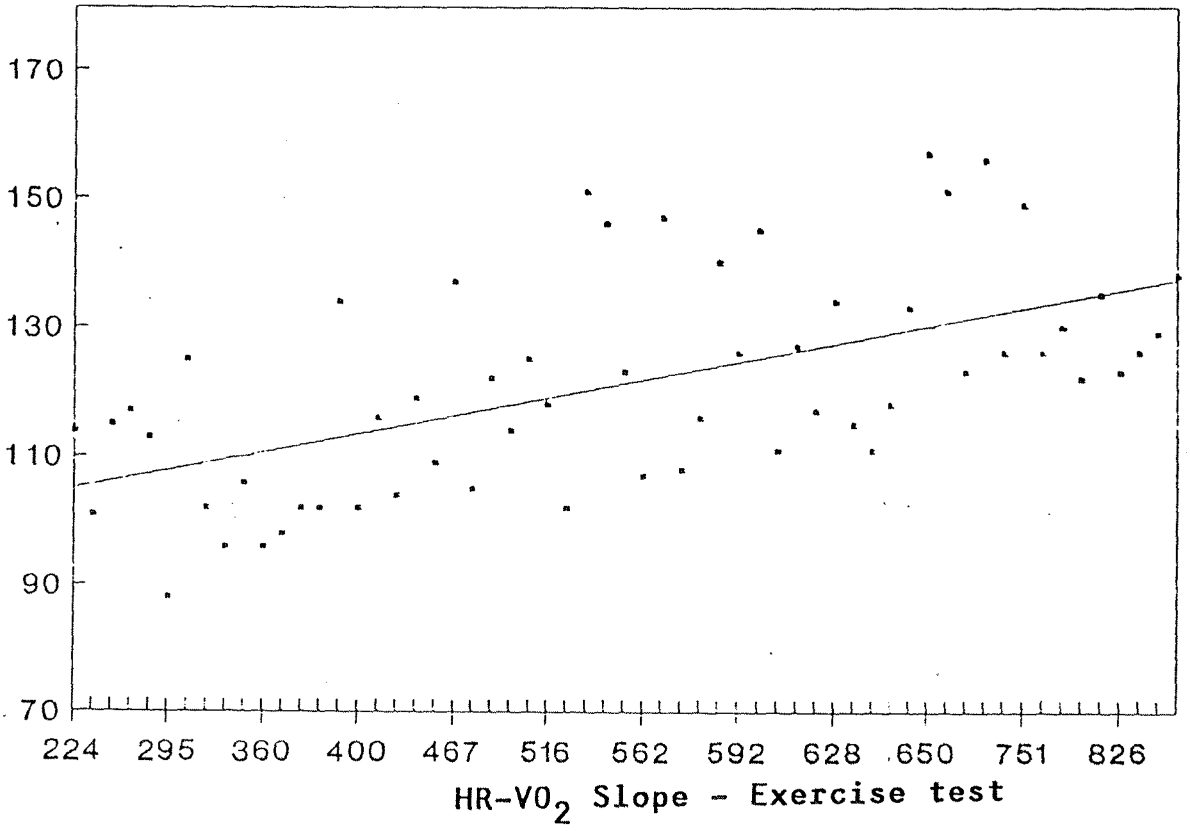
(Source : R.N. Sen (1969) - Indian Council of Medical Research Report and Central Labour Institute Report)

Parameter (Unit)	Very light	Light	Moderately heavy	Work load Heavy	Very heavy	Extremely heavy
Energy Expenditure ($K.cal.min^{-1}$)	1.75	1.75- 3.50	3.50 5.25	5.25- 7.00	7.00- 8.75	8.75
Oxygen consumption tion ($l.min^{-1}$)	0.35	0.35- 0.70	0.70- 1.05	1.05- 1.40	1.40- 1.75	1.75
Relative aerobic strain (%)	12.5	12.5- 25.0	25.0- 37.5	37.5- 50.0	50.0- 62.5	62.5
Heart rate (bpm)	75	75 - 100	100 - 125	125 - 150	150 - 175	175
Heart rate (one minute after and afwork)[bpm]	-	85	85 105	105 - 125	125 - 145	145

APPENDIX XI



HR-VO2 SLOPE FOR SIX ACTIVITIES - **Pilot study**



n=8

APPENDIX XII

INDIVIDUAL PARAMETER RECORDINGS OF THE SELECTED SAMPLES

	Parameter\S.No.	1	2	3	4	6	6	7	8	9	10	11	12	12	14	16	16	17	18	19	20	21	22	23	24	26	26	27	28	29	30	31	32
	Max HR (bpm)	183	183	183	185	185	184	185	183	185	185	185	183	185	185	183	183	183	183	185	185	183	185	183	183	185	184	185	184	183	183	185	183
	VO predicted (l min)	1.82	2.1	2.3	2.03	2.85	1.88	2.1	2.37	2.17	2.31	1.73	2.46	1.81	1.85	1.30	2.17	1.92	1.97	2.0	2.0	2.08	2.09	2.0	1.69	1.44	1.89	2.7	1.57	1.89	2.26	1.93	2.17
	Resting HR (bpm)	75	79	83	80	79	82	79	75	72	88	72	83	69	60	65	62	80	73	82	60	85	80	70	75	72	71	69	75	88	79	86	86
	Range of movement(sq m)	0.36	0.28	0.17	0.34	0.55	0.06	0.12	0.41	0.44	0.14	0.26	0.07	0.07	0.05	0.10	0.12	0.12	0.12	0.21	0.13	0.07	0.07	0.08	0.17	0.06	0.11	0.15	0.12	0.11	0.09	0.13	0.08
Data recorded for 9.2 sq m																																	
B	Incremental HR (beats)	49	59	39	64	56	52	43	42	41	36	35	39	45	37	39	38	35	23	62	49	31	61	45	38	44	51	27	51	39	34	19	38
C	"	42	51	39	64	51	35	46	43	43	45	36	50	47	63	49	66	33	35	62	53	33	17	41	41	45	46	42	53	44	35	25	48
B	Actual VO (l)	0.26	0.40	0.16	0.32	0.29	0.64	0.36	0.16	0.11	0.21	0.20	0.42	0.30	0.13	0.44	0.17	0.14	0.06	0.54	0.65	0.24	0.40	0.27	0.10	0.16	0.21	0.12	0.21	0.18	0.23	0.07	0.20
C	"	0.33	0.52	0.19	0.60	0.29	0.41	0.34	0.14	0.16	0.25	0.21	0.34	0.54	0.43	0.59	0.32	0.20	0.21	0.44	0.39	0.26	0.61	0.30	0.15	0.17	0.22	0.30	0.27	0.34	0.21	0.17	0.34
B	Actual calories (K cal)	1.3	2.0	0.8	1.6	1.5	3.2	1.8	0.8	0.6	1.1	1.0	2.1	1.5	0.7	2.2	0.9	0.7	0.3	2.7	3.3	1.2	2.0	1.4	0.5	0.8	1.1	0.6	1.1	1.0	1.2	0.4	1.0
C	"	1.7	2.6	1.0	3.0	1.5	2.1	1.7	0.7	0.8	1.3	1.1	1.7	2.7	2.2	3.0	1.6	1.0	1.1	2.2	2.0	1.3	3.1	1.5	0.8	0.9	1.1	1.5	1.4	1.8	1.1	0.9	1.7
B	RAC (%)	31.7	32.7	24.4	38.1	23.2	34.9	26.6	22.0	22.5	25.0	25.5	22.8	27.4	19.7	32.2	17.8	26.4	18.0	36.7	22.9	24.7	34.0	25.3	29.0	35.6	30.0	13.1	37.6	31.7	21.7	22.0	26.5
C	"	23.7	29.9	24.4	36.1	21.9	27.8	27.8	22.3	23.3	28.0	26.0	26.2	28.3	30.8	38.3	28.0	26.0	22.8	36.7	24.4	25.5	37.4	23.7	30.4	36.1	27.5	17.5	38.6	33.8	22.0	24.5	30.1
Data recorded on endurance																																	
B	Endurance (s)	55	65	12	103	528	123	65	134	304	172	337	110	55	484	110		80	106	220	220	141	231	126	101	96	70	99	128	62	220	92	69
C	"	41	121	74	136	90	228	74	95	90	78	216	52	26	66	611	93	56	48	81	102	80	111	84	68	104	60	39	118	115	62	73	75
B	Area mapped (sq m)	18.4	20.2	36.8	23	29.3	6.7	27.6	46.0	82.8	119.6	64.4	38.6	16.6	36.8	73.6	32.2	27.6	55.2	64.4	46.0	27.6	36.8	27.6	18.4	18.4	25.8	33.1	27.6	18.4	55.2	27.6	27.6
C	"	18.4	16.6	23.0	21.2	18.4	34	11.5	36.8	27.6	18.4	64.4	4.6	9.2	13.8	73.6	18.4	9.2	16.6	16.6	19.3	13.8	13.3	18.6	27.6	16.6	18.4	4.6	16.6	15.6	13.8	16.6	16.1
B	Incre work pulse (beats)	53	62	82	80	60	53	52	76	78	67	49	43	46	84	63	58	49	57	70	68	43	33	59	58	46	77	72	82	51	55	40	75
C	"	43	61	61	75	63	53	50	78	71	49	48	50	47	75	55	67	47	61	61	64	40	51	60	71	48	78	46	81	56	61	42	67
B	Incre VO (l min)	0.42	0.52	0.65	0.83	0.47	0.42	0.41	0.60	0.62	0.53	0.39	0.34	0.36	0.66	0.50	0.48	0.39	0.69	0.55	0.54	0.34	0.66	0.47	0.46	0.36	0.61	0.57	0.65	0.40	0.43	0.32	0.59
C	"	0.34	0.43	0.48	0.59	0.50	0.42	0.39	0.62	0.56 *	0.39	0.38	0.39	0.37	0.62	0.43	0.53	0.37	0.48	0.48	0.51	0.32	0.64	0.47	0.56	0.38	0.62	0.36	0.64	0.44	0.48	0.33	0.53
B	Incre calories (K Cal)	2.10	2.5	3.25	3.15	2.35	2.00	2.05	3.0	3.10	2.65	1.95	1.70	1.80	3.30	2.4	2.3	1.95	3.45	2.75	2.7	1.7	3.3	2.35	2.3	1.8	3.05	2.85	3.25	2.0	2.15	1.6	2.95
C	"	1.70	2.40	2.40	2.95	2.50	2.10	1.95	3.10	2.80	1.95	1.90	1.95	1.85	3.10	2.15	2.65	1.85	2.4	2.4	2.55	1.60	3.2	2.35	2.8	1.9	3.1	1.8	3.2	2.2	2.4	1.65	2.65
B	Incre recovery pulse (beats)	116	24	416	210	4	285	26	83	143	159	94	54	15	69	140	163	82	244	17	8	30	365	37	141	3	49	96	410	12	18	13	78
C	"	16	33	129	136	75	252	22	425	149	58	27	54	10	54	201	98	18	46	29	28	191	425	113	87	3	134	12	436	25	17	56	147
B	Incre recovery Vo (l/min)	0.92	0.19	3.28	1.66	0.03	2.25	0.21	0.66	1.13	1.26	0.74	0.43	0.12	0.54	1.11	1.29	0.65	1.93	0.13	0.06	0.24	2.85	0.29	1.11	0.02	0.39	0.76	3.24	0.09	0.14	0.10	0.62
C	"	0.13	0.26	1.02	1.07	0.59	1.99	0.17	3.36	1.18	0.46	0.21	0.43	0.08	0.43	1.59	0.77	0.14	0.36	0.23	0.22	1.59	2.36	0.89	0.69	0.02	1.06	0.09	3.44	0.20	0.55	0.44	1.16
B	Incre recov calorie (K.cal/min)	4.6	0.95	16.4	8.33	0.15	11.25	1.05	3.3	5.65	6.3	3.7	2.16	0.50	2.7	5.55	6.45	3.25	9.65	0.65	0.30	1.2	1.44	1.45	5.55	0.10	1.95	3.8	16.2	0.45	0.70	0.50	3.1
C	"	0.65	1.3	5.1	5.35	2.95	9.95	0.85	16.8	5.9	2.3	1.05	2.15	0.40	2.15	7.95	3.85	0.7	1.8	1.15	1.1	7.55	16.8	4.45	3.45	0.10	5.3	0.45	17.2	1.0	2.75	2.2	5.8
B	Rate of work (sq m min)	19.2	17.4	5.4	12.6	11.4	7.8	13.2	42.6	37.2	23.4	22.2	6.6	9.0	25.2	9.0	17.4	21.0	31.2	17.4	12.6	12.0	96	13.2	10.8	11.4	22.2	19.8	13.2	16.2	15.	18	24
C	"	27	8.4	18.6	9.6	12.0	9	9.6	23.4	18.6	14.4	18	6	5.6	10.8	7.2	12	9.6	21.0	12	11.4	10.2	7.2	12	24.6	9.6	18.6	7.2	8.4	8.4	13.2	13.8	12.6
B	Rate of recovery (min)	14	3	5	6	1	2	1	5	3	2	3	1	2	5	2	10	5	10	1	1	2	6	2	6	1	3	4	14	2	1	3	5
C	"	5	2	8	4	5	4	2	17	5	5	1	8	[illegible]	4	2	7	3	5	2	2	16	6	9	4	1	10	5	15	2	7	5	8
B	Working calorie (K cal.min)	5.05	5.6	6.50	6.3	5.5	5.35	5.15	5.95	5.9	6.1	5.0	5.0	4.50	5.7	5.05	4.75	5.1	6.3	6.0	5.05	5.05	6.45	5.1	5.25	4.65	5.85	5.55	6.2	5.5	5.3	5.0	6.35
C	"	4.65	5.55	5.7	6.1	5.6	5.35	5.1	6.05	5.65	5.4	4.75	5.25	4.5	5.45	4.75	5.1	5.0	5.3	5.65	4.9	4.95	6.35	5.15	5.75	4.75	5.4	4.5	6.15	5.7	5.55	5.05	6.05