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ERGONOMICS IN MANUAL MATERIALS HANDLING TASKS

The emphasis on ergonomics in manual materials handling (MMH) tasks arises from the potential risks of workplace accidents and injuries. The tasks include diverse activities such as lifting, lowering, holding, pushing, pulling, carrying and turning of weights. The primary focus has been placed on low back injuries[1]. The types of back injuries most frequently reported are strains and sprains, dislocation (herniation) of the lumbar disc, fracture, joint inflammation (mostly L4/L5 and L5/S1; occasionally other joints such as the shoulder and hip), laceration of muscle tissue, contusion, and nerve (sciatic) involvement[2,3], often leading to activity limitation and workplace accidents. In the United States, nearly 7 million people are added each year to the total number of Americans who have suffered back injuries[4], representing 19 to 25% of all workers' compensation claims[5,6] and loss of approximately 170 million working days annually. Troup and Edwards[7] report that handling is the single highest cause of accidents in British factories. While there is a limitation in the classification of causes of accidents in Indian industries, sample records of industries suggest that nearly 63% of the total non-fatal industrial injuries with average 9 man-days loss per accident and about 35% of the fatal injuries [National Institute of Occupational Health (NIOH), Ahmedabad; unpublished observations] are attributed to handling related accidents. The magnitude of the MMH problems in the larger unorganized sectors, trade and commerce in rural areas goes unnoticed.

MMH is an expensive public health problem. The governments and industries of many industrialized nations, including USA, UK, Germany, Japan pay not only for workman's compensation, but also spend billions on their treatment, employee insurance claims, *etc.* for back and other musculo-skeletal injuries. Recognizing the menace of MMH tasks, 62 countries have placed some limitation on the weight for manual lifting and/or carrying[8]. Also, emphasis has been given to the administrative and personal interventions for better modes of handling loads, to minimize injury risk potentials. This review gives an overview of the current research in ergonomics and examines how to curb the workplace hazards as also the common control paradigms related to manual materials handling tasks.

Weight Limit Recommendations

For decades, researchers have been proposing ceilings on weights/forces for MMH tasks. The majority of these efforts, however, have been limited to manual weight lifting as it is the most demanding of all MMH activities, and is invariably the primary cause of back injuries. The manual lifting design database developed at the US Liberty Mutual Research Centre[9] is most comprehensive and widely used. Among the recommendations proposed by various agencies, the National Institute of Occupational Safety and Health (NIOSH) Work Practices Guide[10,11] has been more widely distributed and/or adopted. Many countries either do not have a limit on weights for safe lifting/carrying and/or limits set on weight have no scientific basis[8]. The revised NIOSH guideline[11] considers the location of the load, vertical distance traveled, and average and maximum frequency of lift. Based on the various design criteria, two limits are proposed. Action limit (AL) — loads under this limit can be lifted by 99% of men and 75% of women, and maximum permissible limit (MPL = 3AL) — loads that can be sustained by only 25% of men and 1% of women. At the workplace, administrative controls (*eg.*,selection) and engineering controls (*eg.*, mechanization) are required for weights between the action limit and maximum permissible limit.

Considering the range of weight limits proposed in the revised NIOSH guideline[11], its applicability in the Indian context is yet to be examined. Also, the principal social instrument, the Indian Factory's Act has limited jurisdiction on the legal provision for optimization of MMH tasks, and there is a complete disregard of the unorganized sectors where the workers are self-employed or casual labourers. For instance, at the docks, food grain storage depots and many other places of trade and commerce, the maximum weight that is handled may be as high as 100 kg[12]. In the unorganized sectors, the weight handled by an individual worker may be as high as 135 kg and the loads are carried for a long distance[13]. Manual load transportation using the transverse yoke and head load are preferred than the frontal yoke. Women and children have to fetch water in large quantities from a distance. Different methods of water carriage involve carrying on the head, on the hip, on the back and on the shoulder. The NIOH study[14] suggests that the load optimization that can be carried by men may be obtained from the nomogram shown in Fig 1. For example, with an oxygen demand of 1.4 l/min (approximate equivalent of 50% of one's maximum working capacity) and walking speed of 30 m/min, the optimum load would be about 65 kg.

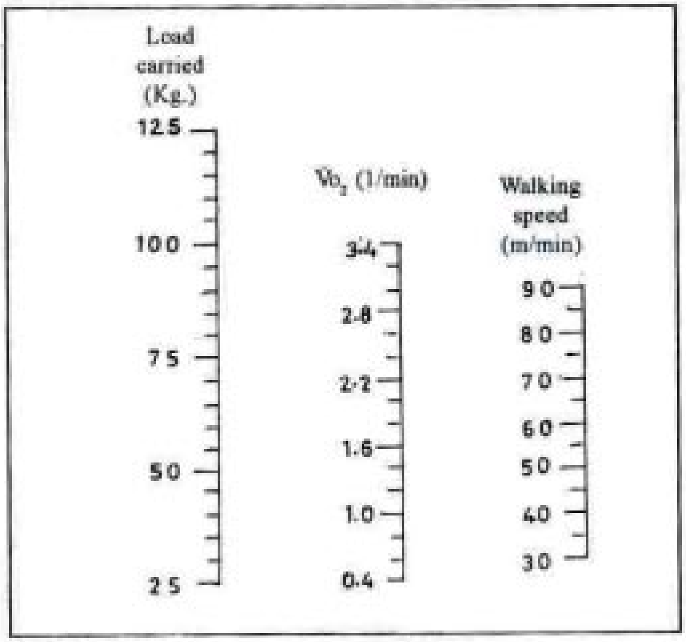

Fig. 1. A nomogram to arrive at the optimum load to be carried with reference to oxygen demand and walking speed.

MMH Task Design Approaches

Several attempts have been made to rationalize the MMH tasks in industry, using specific design approaches, *eg.*, physiological, psychophysical and biomechanical. The fundamental assumptions underlying these control approaches include that (i) the incorrect method of handling the load is a risk factor for low back pain, and (ii) a protective, correct technique can be identified for most of the population. These approaches have been differently examined with reference to human characteristics (age, sex, isometric strength and endurance capacity), material characteristics (size and shape of the object handled), task component (movement distance, duration, frequency, *etc*.) and the work practices including posture, techniques of load handling and safety functions.

Physiological Approach

The physiological approach assesses the stress imposed upon the cardio-respiratory system. Mostly, the oxygen demand of work is determined and generally if it is less than a third of the individual's aerobic capacity, the task is considered acceptable for an 8 h work day. While this approach works reasonably well for frequently performed tasks, it is not sensitive to tasks that are performed occasionally or in tasks like holding loads, *etc.* There are also concerns about what percentage of the aerobic capacity should be considered safe[15] and how should it be determined, *eg.*, bicycle ergometry, treadmill, lifting. Often the technique requires trained personnel to carry out the testing under standard laboratory conditions.

Psychophysical Approach

The psychophysical design approach establishes lifting weights that are acceptable to the individual. This approach assumes that both physiological and biomechanical stresses are present in any MMH task. While the contribution of each may vary as the task changes from frequent to occasional, both these stresses can be integrated under the measure of perceived stress. Using perceived stress that can be sustained without overexertion, individuals determine the maximum weight they are willing to lift occasionally or frequently for different durations[16]. Some researchers have expressed concern about the psychophysical approach due to its subjective nature, however, there is a reasonable agreement that the subject's perceived workloads are also compatible with the physiological approach.

Biomechanical Approach

The biomechanical approach refers to kinetic or kinematic analysis of the body segments in a MMH activity. The mechanical stresses imposed on the spinal column, for a given task condition (weight, load size, *etc*.) are compared with the stress tolerance limit of the spine in order to determine if the task under consideration is within the acceptable range. However, limitations exist with the biomechanical approach, primarily on the efficacy of the biomechanical models. Even the best of the currently available models leaves most of the variance in the experimental data unexplained. There are concerns about the role of various factors on spinal loading, *eg.*, the mechanical characteristics of the spine, the type of spinal loading in real life MMH tasks, the role of the intra-abdominal pressure (IAP), the interplay of the trunk and hip muscles and the relative load sharing between the active and passive tissues in stabilization and protection of the lumbar spine.

Combined spinal loading

The spinal loading primarily refers to external and internal reaction forces to the intervertebral discs, the apophyseal joints and the supporting structures. The loading components (*eg.*, stress, strain, shear, torsion and bending moment) are not usually independent but coupled and concordant[17]. Based on cadaver studies, the mechanical characteristics of spinal loading, especially to lumbar spine have been examined. Brinckmann *et al.*[18] investigated fatigue fracture probability of 35 fresh lumbar motion segments. When the lumbar specimens were loaded at 50-60% of the ultimate compressive strength, about 90% of the specimens suffered fractures after 5000 cycles, and when the load was increased to 75% of the compressive strength, the fatigue factors were precipitated in 10 cycles only. It is suggested that the first component of the functional spinal unit to fail is the vertebral bodies. Failure occurs in the cranial end plate of the caudal vertebral body of the segment[18,19], and damage to the cortical shell of the vertebral body and the annulus of the disc is rare. The tissue changes of the central part of the disc are common. Torsional load has been considered more recurrent and detrimental than compressive loading. The shear stresses during torsional loading are not uniform (*ie.*, high along the periphery and low in the center of the disc). The facets and neural arch appear to withstand about 2000 N of shear stress, and may fail only under combined shear, torsional load in hyperextension.

Association of in vitro findings to epidemiological evidence

Subject to validation from epidemiological investigations, *in vitro* studies indicate that there are causal evidences of mechanical property changes in the spine, not only associated with high loads, but also with the low loads that are combined, repeated or sustained[17]. Even given that the structural failure of spinal units can precipitate in either acute or chronic loading situations, the etiologic uncertainty[20] of *in vivo* tissue changes makes it difficult to ascertain the magnitude of exposure and its tangible outcome. Kelsey *et al*.[21] in a case control study (N=232) of prolapsed lumbar disc showed an association between frequent lifting and low back pain; also that twisting, especially without bending the knees, increases the risk of disc prolapse in lifting tasks. Liles *et al*[22], in a prospective study of 453 MMH workers, found that the incidence of back injuries rose rapidly at a job severity index (JSI) value of 1.5; this index is a function of the job requirement to that of the lifting capacity of an individual. Kumar[23] reported a strong association between cumulative load (biomechanical load and exposure time integral over entire work experience) and low back pain in a group of age, gender, body weight, height and occupation matched subjects. Using a cross-sectional study of 403 jobs from 48 manufacturing firms, Marras *et al.*[24] emphasized the multi-factorial etiology of back disorders, including lifting frequency, loads, trunk motions and postures. Increased trunk motion has been associated with increased trunk muscle activity and intra-abdominal pressure.

Limits of spinal compression

The compressive strength of the lumbar spine appears to be the only strength that has been widely used in biomechanical analysis and prediction. In order to determine the task severity, either static or dynamic biomechanical models have been used to predict compressive forces in simulated modes. Given that the ultimate compression of the lumbar spine is affected by personal and physical factors, including spinal level and type of specimen[18,19,25], there is a great deal of variability in compressive strength values. Jager and Luttmann[26] and Genaidy *et al.*[27] integrated the results of several studies to predict the compressive strength of the lumbar spine. According to Jager and Luttmann[26], the male lumbar spine fails at a compression of 5700 ± 2600 N and for females, the failure occurs at a compression of 3900 ± 1500 N. Genaidy *et al.*[27] found that the compressive strength of lumbar motion segments averaged 7915 ± 2545 N (for males) and 6638 ± 1213 N (for females) in the 20-29 years age group; for people over 60 years, the compressive values were 4392 ± 1169 N and 3336 ± 897 N for males and females respectively. As generic norms these values may serve a useful function, with suitable amendment in the NIOSH MMH guideline[11].

Intra-abdominal pressure development

Studies emphasize on the role of the intra-abdominal pressure (IAP) in lifting tasks as either a directly generated extension force that pushes the diaphragm upward or an indirectly generated secondary extension force produced by lateral tension in the lumbo-dorsal fascia[28]. Using 90 to 100 mm of Hg as the upper limit of acceptable IAP, Davis and Stubbs[29] have developed recommendations for maximum force for frequent and infrequent MMH activities. This criterion has been used in biomechanical predictions, since IAP development during trunk extension is also concomitant with the activity of the abdominal muscles and erector spinae[30]. The anatomic orientation of the obliquous externus and internus, and the transversus abdominis give them a functional advantage for IAP development. Cresswell *et al.*[31] placed a critical importance on the transversus abdominis, which run horizontally around the abdomen, attaching through the thoraco-dorsal fascia to the transverse processes of the lumbar vertebra. The activity of the transversus abdominis precedes not only the acceptance of the load but also the onset of activity of other trunk muscles. McGill and Norman[32] suggested that the contraction of the hoop-like transversus abdominis creates a rigid cylinder, resulting in enhanced spinal stiffness. Similarly, any lateral tension through the transverse processes of the lumbar spine would limit its translational and rotational motion. Also, the creation of a pressurized visceral cavity against the apex of the lumbar lordosis, increases spinal stability for a variety of postures and movements, as in increasing lifting velocity[33]. Obviously, any delayed onset of contraction of transversus abdominis may indicate a deficit of motor control in stabilization of the spine[34]. Studies have also identified rectus abdominis and erector spinae activity before the initiation of upper limb movement[35], suggesting the anticipatory role of the muscles in spinal control.

Morris *et al.*[36] were of the view that the IAP generated during MMH tasks helps to relieve the force exerted on the spine. The compressive force of about 30% on the lumbo-sacral level and 50% on the lower thoracic portion may be sustained by IAP development during the lifting of a load. The role of IAP in reducing compressive load on the spine, however, is inconclusive[37]. Leskinen *et al.*[38] were of the view that the abdominal cavity diaphragm area is inadequate to generate sufficient IAP to alleviate spinal compression.

Origin of extensor moment

Besides the characteristics of the weight handled (*eg.*, size, shape, weight), several factors influence the force exerted on the spine (*eg.*, position of the load, flexion and rotation of the trunk, bent, stoop or squat posture, position of the feet). A basic premise is that under combined loading, as in the case of MMH tasks, any inefficient muscular mobilization and stabilization of the lumbar spine leads to undue stress on the spinal joints and ligaments. However, the load sharing responsibilities between active muscles that exert force and other tissues that provide passive resistance at the joints (*eg.*, lumbar spine) have been debated. Adams and Hutton[39] compared the maximal *in vivo* range of flexion of the lumbar and lumbo-sacral vertebral joints with that of an osteoligamentous preparation. The active range of flexion of the lumbar and lumbo-sacral vertebral joints has been reported to be 10% short of the osteoligamentous preparation, indicating that the difference of the extent of forward flexion and elastic limit of the osteoligamentous preparation ensures the margin of safety.

Gracovetsky *et al.*[28] using a biomechanical model, with the method of optimization of disc compression and shear forces emphasized the role of ligaments rather than the extensor muscles in providing greater mechanical advantage to resist the flexion moment. In contrast, McGill and Norman[40], using an EMG driven model, suggested that the back extensor moment generated in the sagittal plane comes largely from tension in the erector spinae muscles, with some contribution of other trunk muscles, and the ligaments play only a minor role in lifting. This has further been supported[41] using CT scan radiography, to show that the cross-sectional area of the erector spinae muscles is sufficient to produce the required extensor moment. The erector spinae muscles generate a posterior shear force to support the effects of gravity acting on the upper body and any additional load lifted. Dolan and Adams[42] discussed that under isometric contraction, the extensor moment is linearly related to the EMG activity of the back muscles. During the static lifts, peak extensor moment was generated with the lumbar spine flexed by 78 to 97% between erect standing and full flexion. Only 16 to 31% of the peak extensor moment generated during lifting were unrelated to EMG activity of the erector spinae, indicating the greater role of the muscles in extensor moment generation. With full lumbar flexion (stooped posture), however, the erector spinae apparently become electrically silent[43]. In a true sense, the electrical silence of the muscle may not be referred to as relaxation[44], since the lumbar extensors generate substantial force elastically through stretching. The loading of the interspinous and supraspinous ligaments, in particular, was also found to be high relative to their failure tolerance. Hindle *et al.*[45] showed that the loading rates change ligament sharing proportions and the discs might become axially stiffer with increasing compressive load, thus affecting the ligament rest length.

Dolan *et al.*[46] suggested that since in the lordotic posture the passive extensor moment does not fall much below 25 Nm (Newton-meter) even with a small tension in the posterior ligaments and fascia, this fraction may be attributed to the raised IAP. McGill[47] noted that human lumbar motion segments loaded at slow rates in bending and shear, result in excessive tension in the longitudinal ligaments. However, the ligamentous tears in lifting or other occupational activities, particularly to the interspinous complex are uncommon. In occupational activities, only the modest ranges of spinal motion are invoked, when a given degree of muscle contraction is evoked for spinal stability and readiness for the next phase of activity. Any sudden force may tend to overcome the viscoelastic resistance of the supporting muscle and ligaments due to high strain deformation, resulting in possible strain injuries. Crisco and Panjabi[48] noted that the muscular coactivation is largely responsible for stabilizing the spinal column to prevent buckling. A lumbar spine stripped of muscles may buckle under compression in less than 100 N, suggesting that the muscles may be subjected to a greater risk of injury during heavy lifts.

In summary, it appears that the muscles play a greater role in extensor moment generation in lifting and they do receive assistance from passive tissues. The relative share of active and passive tissues depends on the degree of trunk flexion and type of posture adopted. The injury potential increases with the excessive repetitive or chronic spinal loads, with the possibility of muscle fatigue and creeping of passive tissues. Therefore, the crucial aspect of MMH task design is to evolve optimization strategies, based on the spinal load bearing mechanism and plausible control paradigms as primary prevention for risk elimination at workplaces.

Optimization Strategies in MMH Task Design

A variety of biomechanical models have been developed for predicting and optimizing multiple components of spinal stresses[49-52]. Apart from the wide variability in model prediction[53], the primary intent of the ergonomics intervention is to arrive at acceptable task design strategies, so that the muscles do not exert too laboriously while the equilibrium of the joint is maintained, and that the forces transmitted by the joints are optimal. For the benefit of industrial practitioners, the common task design paradigms which have been applied in optimization of the kinematic and kinetic factors contributing to spinal loading have been examined (Table).

Table. Analysis of MMH task design paradigms

Control paradigms	Remarks
Minimize external and internal reaction forces (*ie.*, to reduce load weight and speed of work).	• MMH task design refers to joint optimization of load magnitude, handling frequency and exposure duration[54]. • MMH jobs yielding a JSI in excess of 1.5 may cause substantial increase in back injuries[55]. • Lifting in excess of 20 kg repetitively is a prognosis variable for low back pain[56]. • High risk of prolapsed lumbar disc in lifting more than 11 kg in excess of 25 times per day[21]. • Spinal compression at L5/S1 greater than 3900 N (men) and 2700 N (women) is likely to trigger back problems[57].
Optimize repetitive loading. (*eg.*, speed of work)	• Increased speed of work causes less power output per unit contraction of the muscle[58]. • Torque-producing capabilities of the upper and lower back muscles decrease with increased velocity of exertion[59] • Faster lifting speed results in increased compression and shears at the intervertebral discs[60]. • Peak extensor moment increases by over 60% in the fastest lift (about 1 sec duration)[61].
Minimize jerky movements by smoothening motion trajectory.	• A heavy load can be lifted by ballistic or jerking up technique. • Excessive jerky movements should be avoided to minimize injuries[62].
Maximize the force mechanical advantage by using the large muscle groups or keeping the load close to the body (lifting technique)	• Leg (squat) and back (stooped) lifting are the frequently used lifting techniques[38, 63]. • Load holding and lifting is better performed in stooped (trunk-bent/ knee straight) posture, and when the loads are placed closer to the body at the height of 32 to 44 cm[64]. • However, stooped lifting increases bending torque on the spine, with a consistent reduction in the extensor moment generated by the muscles and fascia[61]. • Long femoral neck of the hip extensors and its insertion on the tibia provide a long moment arm in lifting. In squat lifting, this mechanical advantage is diminished when the hip position falls below the knees[65]. • Load handlers may be trained to maintain body position about the horizontal and vertical load position and maximize body stability by increasing the base support.
Adopt a spinal curvature specific to the type of job performed.	• Exaggerated lumbar lordosis, holding the trunk rigid and forcing torso flexion to be accomplished at the hip joints, has been advocated when lifting weights with the knees flexed[63, 66]. • However, keeping of lumbar lordosis during lifting appears to be based upon unreliable visual estimates of spinal posture[46]. • During lifting, knee and hip flexion links with the backward pelvic tilt and a marginal concavity at T9-L1 region. Limited flexion of the spine allows partial transfer of forces to the posterior ligaments, and adjusts spinal flexion and bending of the knees. This advocates free style posture (combination of squat and stoop).
Minimize torsion due to twisting.	• Twisted posture, including the repeated cycles of torsion is an injury risk[67]. • Asymmetrical MMH results in increased IAP development and intra-discal shear stresses, and activity of erector spinae, external oblique and other torso musculature[68,69]. • Decline in lifting capabilities ranges from 8.5 to 22%, depending on the feet position[70,71].
Use handles and couplings for stability in MMH tasks.	• Good handles and couplings are essential to provide load and postural stability in MMH activity. • Provision of handles can increase lifting capacity by about 10 to 15% [72,73].
Avoid heavy MMH tasks at early hours of the day and minimize the structural creep of the disc.	• Intervertebral discs are hydrated fully after night's recumbence[74]. • Bending resistance increases by about 300%, when a high compressive load is applied on a fully hydrated disc [75]. • Repeated loading of the disc with a high bending torque may result in rupture of the posterior annular fibers [76]. • Fluid creep can cause inflammatory reaction in the innervated tissues resulting in pain sensation [77].

Critical Views on the Control Paradigms

In the vast majority of instances, studies connecting MMH tasks and low back pain disability, or workers compensation claims have not directly assessed the disability in relation to the lifting techniques or other modes of handling loads[78,79]. In perhaps the sole exception, Kelsey *et al*.[21] reported that twisting and specifically twisting without bending the knees, increased the risk of a prolapsed disc for certain lifting tasks. In a well designed prospective study, Daltroy *et al*.[80] found no statistical differences in low back injury rates between trained and untrained groups of postal workers, though knowledge and skills were improved among trained workers.

The control paradigms reflect a multi-factorial influence of the MMH tasks in spinal injury risks, and suggest that caution be exercised in forming MMH guideline[11]. Some of the findings summarized in the Table are surprising. For example, it is common sense that one should lift gradually, but research indicates that the disc can handle extremely high forces for very brief periods of time fairly well, but if these forces are sustained for longer periods, the disc will suffer damage. Rapid lifting may minimize the time of exposure of the disc to the forces, but at the same time it can maximize the force itself due to the increased force in high acceleration. The effect of acceleration during lifting has been explained that, initiation of a lift results in a force on the load handle that actually exceeds the weight of the load by about 20%. Therefore, the load, which is heavy to hold at shoulder height can often be lifted from the floor to a shoulder level. This is possible by ballistic or jerking up technique when a large force is generated early in the lift that accelerates the load and effectively reduces the force required for the shoulder muscles to complete the lift at shoulder height[81]. Essentially, an obvious complex trade-off is visible here, as far as all the major lifting techniques and the speed of work are concerned.

The assumptions regarding the influence of lifting postures and techniques on the occurrence of low back pain have been the impetus of past research attempts to examine differences in lifting technique using multiple criteria. Though only a few studies have directly linked any aspect of the lifting technique to occurrence of low back pain, there are certain workplace realities, which cannot be ignored:

Industrial workers will continue to lift objects as part of their jobs, and the occupational health and safety practitioners will continue to preach on the pros and cons of different modes of lifting and other modes of MMH tasks. For some workers, the way in which they accomplish the MMH task will be related to the techniques they have been taught.

With the research results nearly devoid of definitive evidence of a causal link between low back pain and the lifting technique alone, the safety practitioners are left with uncertainties about the impact of MMH techniques. Many of the lifting methods proposed are unique, some even bizarre, but one dictum seems to continue to reverberate wherever lifting technique is taught — Keep your back straight ... Lift with your legs, not your back (squat lift). It is this “rule,” above all others that has been taught and publicized in much of the popular safety literature.

The force mechanical advantage should be maximized by using the large muscle groups or keeping the load close to the body (lifting technique). A simulated sequence of lifting in the squat and stoop postures is shown in Fig 2 and the IAP development are shown in Fig 3. On the one hand,

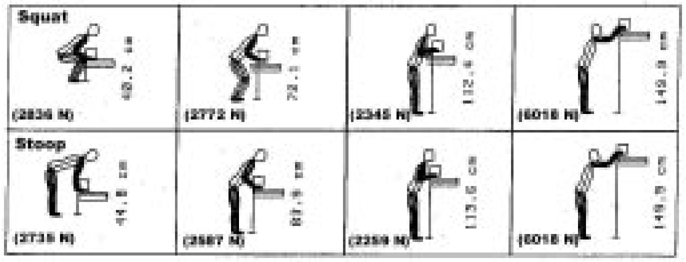

Fig. 2. The sequence of load lifts (squat and stoop posture) from knee level to above shoulder. The compressive forces (N) at L5/S1 level are shown in parenthesis.

the squat lift can be good because it gets the load close to the body, which in turn minimizes forces on the spine and the concomitant strength requirements. This may be true

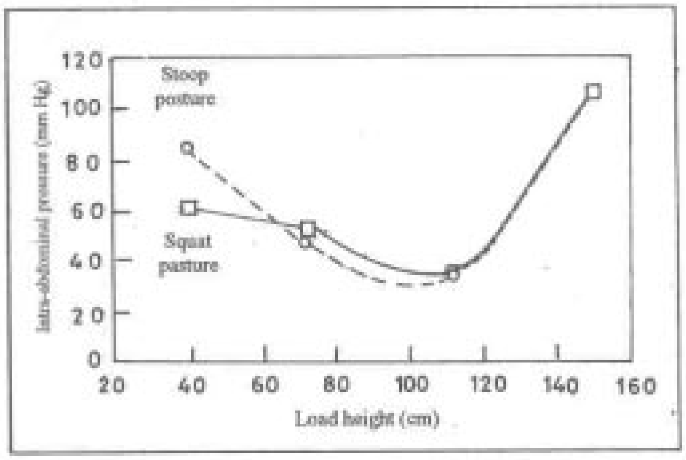

Fig. 3. Intra-abdominal pressure development in squat and stoop postures at different load heights.

for compact loads, and if the lift is occasional and not highly repetitive, and if the lifter is comfortable doing so, the squat lift can minimize the stress on the spine by allowing the object to come close to the body. In an occupational setting, the squat lift does not always result in the load being closer to the body, when the size of the load is large, and invariably the forces go up dramatically and additional shortcomings become dominant; for example, (i) higher compressive force on the L5/S1 disc; (ii) higher energy expenditure compared to stoop due to lifting one's own body weight through a greater vertical distance; (iii) greater stress on the knees, hips, and ankles, and fatigue of the knee muscles which are less suited to prolonged lifting than the hip and trunk muscles (many people do not have strong knees or strong leg muscles to lift heavy objects in a squat stance); and (iv) more pressure on the balls of the feet (as the lifter rocks forward to squat), *etc.*

Of course the stoop lift is not without its own shortcomings. For example, lifting in the stooped posture increases the bending torque on the spine, with a consistent reduction in the extensor moment generated by the muscles and other supporting tissues. Traffimow *et al.*[82] noted that in prolonged lifting, a person changes posture from a squat to a stoop with fatiguing of the quadriceps. Also, a person may tend to use a combination of stooping and squatting with varying degrees of leg and torso bending, often referred to as free style lifting. This is important concerning placing of the load close to the body to reduce the reaction moment and to avoid full flexion of the spine with minimal posterior ligamental involvement[83].

Conclusions

To conclude, it can be stated that there are two fundamental rules to be observed while lifting (i) keep the load as close to the body as possible; and (ii) avoid twisting. These rules most convincingly embrace the research-substantiated lifting principles. These rules presuppose that everything practical has been done to (i) eliminate the lifting task altogether; (ii) use a mechanical aid instead of manual lifting; (iii) minimize the forces required; and (iv) allow the lift to be done without twisting. In other words, if lifting is to be done, these rules should be followed.

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This write-up has been contributed jointly by Dr P.K. Nag, Deputy Director, National Institute of Occupational Health, Ahmedabad and Dr. S. Hsiang, Senior Research Associate, Liberty Mutual Research Centre for Safety and Health, Hopkinton MA, USA.

ICMR AWARDS & PRIZES, 1997

The Indian Council of Medical Research has awarded the following prizes and awards to various Indian scientists for their outstanding research work in various fields of biomedical sciences.

Dr. B.R. Ambedkar Centenary Award for Excellence in Biomedical Research for the year 1997-98

Dr. V.P. Sharma Formerly Director Malaria Research Centre, and Additional Director- General ICMR New Delhi	Malaria and its control

Basanti Devi Amir Chand Prize, 1998

Dr. S.P. Misra Associate Professor Department of Gastroenterology M.L.N. Medical College Allahabad	Gastroenterology

Kshanika Oration Award for Women Scientists, 1997

Dr. Sudha Suri Professor and Head Department of Radiodiagnosis Postgraduate Institute of Medical Education and Research Chandigarh	Diagnostic and therapeutic abdominal interventional procedures

Dr. M.N. Sen Oration Award for Practice of Medicine, 1997

Dr. Y. Chawla Additional Professor and Head Department of Hepatology Postgraduate Institute of Medical Education and Research Chandigarh	Role of duplex doppler sonography in portal hypertension

JALMA Trust Fund Oration Award for Research in Leprosy, 1997

Dr. Vanaja P. Shetty Senior Research Officer The Foundation for Medical Research 84-A, R.G. Thadani Marg Mumbai	Effects of multi drug therapy on peripheral nerves in leprosy

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National Institute of Mental
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Neurovirology especially Japanese
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All India Institute of Medical Sciences
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Developing new generation immunogens
using nontoxic and permissible
immunoadjuvants and modified delivery
systems

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Dr. V.N. Bhattathri Head Clinical Radiobiology Section, and Associate Professor Department of Radiotherapy Regional Cancer Centre Thiruvananthapuram	Prediction of radiosensitivity by cytology

Dr. D.N. Prasad Memorial Award for Research in Pharmacology, 1997

Dr. B.N. Dhawan Formerly Director Central Drug Research Institute Lucknow	Hepato-protective activity of *Picrorhiza kurroa*

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Dr. A.K. Hemal Additional Professor Department of Urology All India Institute of Medical Sciences New Delhi	Reconstructive urology
Dr. M. Madesh Post Doctoral Fellow The Wellcome Trust Research Laboratory Department of Gastrointestinal Sciences Christian Medical College Vellore	Role of oxidative stress in the pathophysiology of the gastrointestinal mucosa

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