Work requiring considerable Muscle force

Arbete med stor muskelkraft

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“Arbete med stor muskelkraft”
Part I

About:
How muscular endurance and strength determine the ability to work (from a physiology point of view)

Part II

About:
How the risk factors at the work place, affect the stress on the worker's body and which strategies of prevention could be adapted for certain load handling tasks.
Work can be thought of simply as activity - either mental or physical. Although it may not seem like it sometimes, the body is working constantly even when asleep!

**Types of physical work**

Physical work is carried out by the muscles and is therefore often called muscular work.

There are 2 types:

**Static** (or *isometric*).

Holding a static or fixed posture can be very tiring because the muscles don't get time to relax. A muscle which is heavily contracted squeezes against the blood vessels next to it, restricting blood flow. This cuts down the delivery of oxygen to the muscle and the removal of a waste product, lactic acid, from the muscle. This results in muscular aches or pain. Any fixed posture will bring on these symptoms, for example, standing to attention or sitting upright.

**Dynamic** (or *isotonic*).

Dynamic work is less tiring and more efficient than static work. This is because during dynamic work a muscle contracts and relaxes rhythmically which makes it act like a pump for the flow of blood in the blood vessels, allowing the blood to supply more oxygen and take away more lactic acid than during static work.
Muscular endurance is the ability of a muscle or a muscle group to remain contracted over a period of time.

- **Endurance can be static or dynamic.**
  - Static endurance can be determined by the length of time a limb can maintain a certain position.
  - Dynamic endurance can be measured by the number of times a limb can perform a movement against a certain resistance.

- **Muscular strength** is the maximum amount of force that a muscle can exert under maximum contraction.
- The amount of force that can be exerted by the limbs depends on body posture and the direction of force.
Factors that influence the muscle strength and endurance

- **Age**: strength increases in teens and early 20s, reaches its maximum by the middle to late 20s, remains at this level for 5 to 10 years, and afterwards begins to decrease gradually.

- **Sex**: in general, women are about two thirds as strong as men. This is because men have greater muscle mass as a percentage of body mass compared to women.

- **Body build**: usually the 95th percentile person of a population will be stronger than the 5th percentile person. Among people of equal body size, differences in strength may be due to the amount of muscle tissue, body shape and proportions.

- **Fatigue**: the build up of lactic acid in the muscles due to static muscle work causes a gradual decline in muscle strength; fatigue can be delayed by adopting comfortable working postures, decreasing the intensity or duration of muscular effort, training or practice, having adequate rest periods, and good nutrition.
Exercise: can increase muscle strength and endurance

Heat: heat, especially when combined with high humidity, decreases muscular performance, especially endurance.

Cold: cold will not affect muscle strength if someone wear adequate protective clothing, but it may affect manual dexterity.

Clothing & equipment: bulky clothing may make movement more difficult and not be possible to achieve the best positions for exerting maximum force. Clothing and any equipment someone carries will add to the overall weight and therefore will need extra muscular energy to move.
Motivation and emotional state: fear, anger or excitement can temporarily increase the muscular strength but skill and accuracy may suffer.

Nature of the job: manual workers are significantly stronger than other types of worker

Postural aids: backrests increase pushing strength by directing all the strength forwards. Footrests increase pulling strength by allowing to brace the legs.
Neuromuscular system modeling

- Muscle-Tendon Length
- Central Command & reflexes
- Muscle-Tendon Velocity

Activation Dynamics → Contraction Dynamics

Tendon Compliance → Force

Tendon

Force

Muscle
Motor unit recruitment

All-or-nothing event
2 ways to increase tension:
- Stimulation rate
- Recruitment of more motor unit

Size principle
Smallest m.u. recruited first
Largest m.u. last
Work load measurements...

Electromyography

“...is the study of muscle function through the inquiry of the electrical signal the muscles emanate.”

Basmajian & DeLuca, Muscles Alive 1985
Origin of the EMG Signal

Muscle Contraction / Muscular Work

Nervous contraction command produces a muscle action potential on the muscle membranes

From: Kumar/Mital 1996, p. 61.
Generation of Muscle Action Potentials

Bipolar Electrode Configuration

From: Kumar/Mital 1996, p. 73
Motor Unit Recruitment and Frequency

Firing Frequency of Motor Units

Recruitment of Motor Units

Superposed Surface Signal:

Laurig 1983
EMG/Force Relation due to muscle conditions

Redrawn from von Ow 1987

Analysis of intramuscular training effects
Postural Analysis

- Pelvic Rotation
- Classical Compensation
- Internal Trunk Stabilisation
EMG Posture Analysis

Spontaneous Standing

Corrected Standing

5 = Rectus Abd.
6 = Ext. Abd.
7 = Int. Obliquus
8 = Rectus Fem.
**EMG Posture Analysis - Therapeutic Consequences 1**

Static correction of posture:

- Yes - but using the right muscle coordination!

**Important target muscle:**
M. internus obliquus / transversus abdominis

**Avoid unnatural co-contraction (glutaeus max.)**

*From: Ida Rolf 1989, p. 208*
Effects of Disuse and Immobilization

- Immediate or early motion may prevent muscle atrophy after injury or surgery =>
- Muscle fibers regenerate in more parallel orientation, capillarization occurs rapidly, tensile strength return more quickly
- Atrophy develop due to immobilization and can not be reverse by isometric exercises.
- Type I fibers atrophy with immobilization; cross-sectional area decreases & oxidative enzyme activity reduced
Fatigue

Drop in tension followed prolonged stimulation
Fatigue occurs when the stimulation frequency outstrips rate of replacement of ATP
the twitch force decreases with time
Fatigue can describe a variety of conditions such as:

- Decrease of attention
- Slowed and impaired perception
- Decrease in motivation
- Decrease in the speed of physical and mental performance
- Decrease in accuracy and increase in errors
- Greater energy expenditure to keep up the same output
- Feelings of dullness, tiredness, irritability
Fatigue can result from hard physical effort or prolonged but less physical activity

- The efficiency in a job depends on a number of things:
  - the ability to do the tasks involved
  - the capacity for physical work
  - the design of the instruments, tools and machines that are used
  - the workplace layout
  - the workers training

- **However**... any prolonged work, physical or mental, is tiring and nobody can work all the waking hours without fatigue
Boredom or monotony can lead to fatigue and occur when there is no stimulation in either the work itself or the working environment and may happen when:

- There’s no interest or motivation by the work
- The work makes no demands on the workers skills
- The work rate is too slow for the worker
- The work environment is dull
In order to reduce fatigue, need to take a break from the activity. This can be either a complete rest or just a change of activity. If a break or a rest pause is taken at appropriate times, a fresh period of optimum activity will result.

There are four types of work pauses:

- **Spontaneous**: taken by the worker, especially during strenuous work.

- **Disguised**: these may form secondary work that is not necessary at a given moment for the task in hand, e.g. cleaning a machine part, tidying the work bench, etc.

- **Work-conditioned**: these are waiting periods dependent on the organization of the work or the movements of a machine. On conveyor belts, the length of the work-conditioned pause depends on the skill and work rate of the operator.

- **Prescribed**: these are usually taken at a set time in the form of tea breaks or lunch breaks.
Medium intensity work with waiting times created by the working process: one break in the morning and one in the afternoon, of 10-15 minutes each. Refreshments should be available.

High intensity work without waiting time and with a high work rate: a refreshment pause in the morning and in the afternoon, and one or two short pauses of 5 minutes each during each half of the working day.
Increasing EMG Amplitude Due to Fatigue

Static Work Condition:

From: Kumar/Mital 1996
Frequency Based Fatigue Analysis

- **Muscle Fatigue Index**

  Typically in Static positions
  - EMG Power Spectrum shifts to lower Frequencies

*DeLuca 1997: The use of surface electromyography in Biomechanics*
Test Arrangements for Fatigue Tests

Select a save static/submaximal contraction position:

Test duration between 30 - 60 s.
Each second a calculation of EMG amplitude and frequency parameters is performed.

The mean frequency decreases within each second step, the amplitude increases!

The steepness of the regression line (slope) is used to analyse the results:

⇒ Steeper decrease/increase = more fatigue
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Part II

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How the risk factors at the work place, affect the stress on the worker’s body and which strategies of prevention could be adapted for certain load handling tasks.
Description of the Work place

- Workers
  - Physical & mental abilities

- Equipment
  - tools
  - things
  - Furniture

- Work Environment
  - Vibrations
  - Noise
  - Clime
  - atmosphere
  - light

- Environment

- Physical Demands

- Mental Demands

- Task Demands
RISK FACTORS

Physical Characteristics – direct interaction between worker and work place

- Body Stance
- Forces
- Speed/ Acceleration
- Repetition
- Recovering Time
- Heavy dynamic trial
- Abrupt – Acute or Repetitive vibrations
RISK FACTORS

Environmental Characteristics

- Stress from Heating...
- Stress from Cold – freezing...
- Total body vibration
- Unreasonable high or less lighting
Examples of physical loadings at work which may be dangerous to health:

- Kneeling for long duration
- Manipulation of heavy loads
- Whole body vibration
- Static work and awkward posture
- Sitting for long duration

To prevent musculoskeletal disorders, a balance between mechanical load at work and load-bearing capacity of the musculoskeletal system is most important.
### Table: Main factors contributing to musculoskeletal disorders

<table>
<thead>
<tr>
<th>Factor</th>
<th>Possible result or consequence</th>
<th>Example</th>
<th>Good practice example or solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exertion of high-intensity forces</td>
<td>Acute overloading of the tissues</td>
<td>Lifting, carrying, pushing, pulling heavy objects</td>
<td>Avoid manual handling of heavy objects</td>
</tr>
<tr>
<td>Handling heavy loads over long periods of time</td>
<td>Degenerative diseases especially of the lumbar spine</td>
<td>Manual materials-handling</td>
<td>Reduce mass of objects or number of handling per day</td>
</tr>
<tr>
<td>Frequently repeated manipulation of objects</td>
<td>Fatigue and overload of muscular structures</td>
<td>Assembly work long time typing, check-out work</td>
<td>Reduce repetition frequency</td>
</tr>
<tr>
<td>Working in unfavourable posture</td>
<td>Overload of skeletal and muscular elements</td>
<td>Working with heavily bent or twisted trunk, or hands and arms above shoulders</td>
<td>Working with an upright trunk and the arms close to the body</td>
</tr>
<tr>
<td>Static muscular load</td>
<td>Long-lasting muscular activity and possible overload</td>
<td>Working overhead working in a confined space</td>
<td>Repeated change between activation and relaxation of muscles</td>
</tr>
</tbody>
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<tr>
<td>Muscular inactivity</td>
<td>Loss of functional capacity of muscles, tendons and bones</td>
<td>Long-term sitting with low muscular demand</td>
<td>Repeated standing up, stretching of muscles, remedial gymnastics, sports activities</td>
</tr>
<tr>
<td>Musculoskeletal manipulations</td>
<td>Unspecific complaints in the upper extremities (RSI)</td>
<td>Repeated activation of the same muscles without relaxation</td>
<td>Repeated interruption of activity and pauses alternating tasks</td>
</tr>
<tr>
<td>Application of vibration</td>
<td>Dysfunction of nerves, reduced blood flow, degenerative changes</td>
<td>Use of vibrating hand-tools, sitting or vibrating vehicles</td>
<td>Use of vibration-attenuating tools and suits</td>
</tr>
<tr>
<td>Physical environmental factors</td>
<td>Interaction with mechanical load and aggravation of slips</td>
<td>Use of hand-held tools at low temperatures</td>
<td>Use gloves and heated tools at low temperatures</td>
</tr>
<tr>
<td>Psychosocial factors</td>
<td>Augmentation of physical strain, increase in absence from work</td>
<td>High time pressure, low job decline, low social support</td>
<td>Job rotation, job enrichment, reduction of negative social factors</td>
</tr>
</tbody>
</table>
Usual problems reported…

1. Neck – Shoulder syndrome
2. Discitis, low back pain, schialgie
3. Carpal Tunnel Syndrome
4. Tendinitis at certain areas (e.g. shoulder, achilles, knee etc)
5. Headaches
6. Soft tissues and bones injuries
7. Vision problems, which can lead to headache
8. Respiratory problems in combination with allergies
9. Circulatory problems, mainly of long standing up position
10. Vertebral column pathology, kyphosis, scoliosis
ANTHROPOMETRY

LINK LENGTH STUDIES BASED ON DATA BY DRILLIS AND CONTINI (1966)
ANTHROPOMETRY

The study of the range of human physical dimensions…

…Valuable information for the estimation of the proper dimensions of the work place and work materials

Three criteria must be predetermined for the use of anthropometric data

- Collection of information about the <important> body dimensions
- Definition of the population about this measure is being planning for...(e.g. gender, race)
- Definition of the designing philosophy (does it concerns a person, work group, bound percentages of population e.t.c.)
Manual Handling / Lift & Carry ....
Lifting activities greatly increase the disc pressure. Better body mechanics reduces the force and keeping the load off the floor in an upright position reduces the force further.

The graphic illustrates safe lift zones and appropriate weights in those zones. The green area is the best zone often referred to as the power zone. The red zone is the no lift zone and is appropriately above shoulder and below knee height. Additionally, the further a worker reaches from the body the lesser the weight safely handled (yellow zone).
Lumbar Spine

Flexion & twisting of trunk
At the lower end of a lift, moving below the knee increases the risk and exposure to the back, especially for the lumbar region.

NIOSH recommends limiting lumbar disc pressure to no greater than 770 inch pounds. Forces beyond 770 inch pounds begin to physically change the health of the disc. Lifting properly can reduce the force, but proper technique is a skill rarely mastered or used by people in a dynamic work environment.

Through these studies we know the safest lift range is between standing knee and shoulder height. This is a basic guideline not taking into consideration reaches and twists away from the body as well as coupling (grip). Work environments outside these ranges increase the risks of shoulder and back injuries.
When you push there is one component of force that adds to the weight of the body and hence there is more friction. When you pull the vertical component of force is against the weight of body and hence there is less overall friction. So it is easy to pull than push an object.

Notice that $F \sin \theta$ acts downwards along with the weight $m^*g$ and therefore increases the normal reaction $N$ (Normal reaction is equal to sum of all the vertical forces). And friction is directly dependent on Normal reaction; More is $N$ more is the frictional force.

Notice that $F \sin \theta$ acts upwards along with the weight $m^*g$ and therefore decreases the normal reaction $N$. Therefore the frictional force is reduced.
Think of the Lifting... and positioning......

Too high

Too low
### Biomechanic Predictions: L5/S1

<table>
<thead>
<tr>
<th></th>
<th>7Kg</th>
<th>10Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Compressive Forces</td>
<td>227.00 N, 61.03 lb</td>
<td>242.84 N, 54.59 lb</td>
</tr>
<tr>
<td>Total Shearing Forces</td>
<td>116.80 N, 33.22 lb</td>
<td>131.96 N, 36.81 lb</td>
</tr>
<tr>
<td>Total Torque or Bending Moment</td>
<td>3.77 N·m, 4.62 lb-ft</td>
<td>8.83 N·m, 11.67 lb-ft</td>
</tr>
<tr>
<td>Total Joint Reactive Force</td>
<td>265.20 N, 73.97 lb</td>
<td>281.43 N, 75.81 lb</td>
</tr>
<tr>
<td>Erector Spine Force</td>
<td>175.49 N, 47.86 lb</td>
<td>187.62 N, 52.37 lb</td>
</tr>
<tr>
<td>Compressive Force-Load</td>
<td>34.32 N, 9.57 lb</td>
<td>49.03 N, 11.43 lb</td>
</tr>
<tr>
<td>Compressive Force-UBW</td>
<td>19.00 N, 5.28 lb</td>
<td>18.90 N, 5.28 lb</td>
</tr>
<tr>
<td>Compression-Erector Spine</td>
<td>173.78 N, 50.06 lb</td>
<td>174.90 N, 48.56 lb</td>
</tr>
<tr>
<td>Shearing Force due to Load</td>
<td>59.45 N, 16.69 lb</td>
<td>64.93 N, 18.19 lb</td>
</tr>
<tr>
<td>Shearing Force due to UBW</td>
<td>32.74 N, 9.15 lb</td>
<td>32.74 N, 9.15 lb</td>
</tr>
<tr>
<td>Shearing Force-Erector Spine</td>
<td>24.42 N, 6.86 lb</td>
<td>24.58 N, 6.93 lb</td>
</tr>
<tr>
<td>Horiz Distance - L5/S1 Hands</td>
<td>0.19 cm, 0.00 in</td>
<td>0.19 cm, 0.00 in</td>
</tr>
</tbody>
</table>

**Comparison:**
- The results show a significant difference between 7Kg and 10Kg loads.
- Total Compressive Forces and Total Shearing Forces increase with the load.
- Torque and Bending Moment also show a notable increase.

**Conclusion:**
The choice between 7Kg and 10Kg loads should be based on ergonomic considerations and the capacity of the individual performing the task.
Lumbar stress can also occur without lifting, but working with excess trunk bending.
Each of these activities includes many requirements which can cause problems at the employ.

Additionally, the Hospitals send the patients home earlier, even though they are not able to care for themselves and this because there’s need for beds at the hospital and also need for reduction of the cost of hospitality…
HAZARDS DURING HANDLING A PATIENT...

- Overstimulation / abrupt movements: we try to stop the patient from a fall or arise him from the floor or bed.
- Repetitive many lifts
- Lift a patient with no assistant
- Lift of a no collaborating patient
- Lift of a patient unable to stand
- Physical weakness of the Therapist / Nurse
- Long distance for carry the patient and distance from his body during the lift and walk
- Uncomfortable stances demanded
- Missing or less education of biomechanics and mobilization and lifting techniques
Carpal Tunnel Syndrome (CTS) an occupational disorder........
When the median nerve entrap into the carpal tunnel because of
the reduction of the functional space, might become many clear
symptoms.

The total number of the signs and symptoms refer as
“SYNDROME” and when we get certain symptoms which declare
the entrapment of the median nerve into the carpal tunnel, the
situation refers as Carpal Tunnel Syndrome (CTS)

The median nerve (and it’s junctions) gives same time sensor and
kinetic inervation at the hand. Damage of the nerve, can cause loss
of sensation and muscle atrophy, which leads the employ sick and
anxious.

This is the reason why, the recognition and the control of the
“occupational” syndrome of the carpal tunnel is up to the area of
the professional Industrial Hygienist
Factors we can correct..........

- The movement/position of the hand against the resistance
- Transmission of the vibrations from the tool to the hand
- Longstanding tough griping of the tool...
- Sinnistrous placement of the hand using the tool
- Repetitive hand and fingers movement
- Deficit design of the hand tools...

acting on every of these factors, we can reduce or disappear the risk of CTS
Conclusion

Prevention of musculoskeletal disorders can be achieved by engineering controls and appropriate organizational arrangements. The first-mentioned aspect involves the whole working environment and deals with the ergonomic design of tools, workplaces and equipment. The latter concentrates upon factors such as training, instruction and work schedule. The primary aim of ergonomic work design is the adaptation of the working conditions to the capacity of the worker. It is supplemented by a secondary way, which is based on the development of the persons’ capacity to the working requirements by training and vocational adjustment.

Alwin Lattmann and Gustav Caffier, “Preventing Musculoskeletal Disorders in the Workplace”, WHO - 2003