Selection and Use of Pipettes

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Pipetting Injuries

- 128 female subjects
- Higher rate than female Swedish state employees in general

MJ Bjorksten et al., 1994

Pipetting Injuries

- 80 subjects
- 55% return rate
- Hand pain
- Dose/response

David & Buckle, 1997

Pipetting Injuries – Hand

- 300 hours = 6 hrs/wk

Bjorksten et al (1994)

Pipetting Injuries – Hand

- 15 subjects
- Male/female
- Six healthcare sites

British Columbia Institute of Technology (2003)
Risk Factors

- Force
- Personal
- Environment
- Posture
- Repetition

Risk Factors:

- National Research Council and Institute of Medicine, 2001

Awkward postures

- Primary factor in repetitive strain injuries
- Increased level of risk with
  - Force
  - Repetition

Risks and Injuries

- Elevated arm
  - Extended reach
    - Neck strain
    - Upper back strain
    - Low back strain
    - Rotator cuff tendinitis
- Lateral epicondylitis
- Radial tunnel
- Cubital tunnel

Risks and Injuries

- Elevated arm
  - Forearm pronation
  - Elbow flexion
  - Wrist extension
  - Radial deviation
  - Tight grip
    - Lateral epicondylitis
    - Radial tunnel
    - Cubital tunnel

Risks and Injuries

- Tight grip
  - Wrist ulnar deviation
  - Thumb strain
    - DeQuervain’s tendinitis
    - Ulnar nerve at wrist

Risks and Injuries

- Tight grip
  - Wrist ulnar deviation
  - Thumb strain
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    - Ulnar nerve at wrist
Risks and Injuries
- Tight grip
- Repetitive wrist deviation, extension and flexion
- Carpal tunnel syndrome

Risks and Injuries
- Tight grip
- Repetitive finger extension and flexion
- Trigger finger
- Radial tunnel
- Extensor tendinitis
- Flexor tendinitis

Awkward Postures and Strength
- Leaning on elbow
  - Cubital tunnel

Awkward Postures and Strength
- Grip strength is related to wrist position
  - Neutral = 100% hand strength
  - 25º = 80% strength
  - 45º = 80% strength

Awkward Postures and Strength
- Force is related to elbow position
  - 45º = 50% strength
  - 90-120º = 100% strength
  - 160º = 85% strength
Posture and Strength
- Non-neutral postures increase:
  - Physical effort
  - Muscle fatigue
  - Exposure to risk
  - Musculoskeletal injuries

Maximum Force Capacity

<table>
<thead>
<tr>
<th>Thumb-pinching activities</th>
<th>% of Maximum Strength Capacity</th>
<th>Force (kg)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>Maximum strength</td>
<td>100%</td>
<td>10 kg</td>
</tr>
<tr>
<td>Dynamic Peak Force</td>
<td>30%</td>
<td>3 kg</td>
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Traditional Pipetting Forces

<table>
<thead>
<tr>
<th>Thumb force to operate plunger</th>
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<tr>
<td>Should not exceed .5 kg (18 ounces)</td>
</tr>
<tr>
<td>continuous loading to accommodate weakest women</td>
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</tbody>
</table>

Fredriksson, K., (1995)
Posture & Force: High risk issues

- Repetitive wrist flexion/extension and forearm rotation increases fluid pressure in carpal tunnel
- Increase of 40-50mmHg for 1 hour can affect median nerve
- 30mmHg pressure over 4 hours can affect median nerve
- Full supination can increase pressures 285%


What does this mean?

- When pipetting:
  - Limit forearm rotation and wrist flexion
  - Maintain 45 degree forearm pronation


Posture & Force: High risk issues

- High precision tasks
  - Increased static muscle activity (10.6% to 13.3%)
    Close to endurance limits recommended by Bjorksten and Jonsson 1977
  - Increased thumb motion control
  - Increased potential for fatigue
  - Potential increased risk for tendon related diseases (i.e. deQuervain’s disease)


Force: High risk issues

- High viscosity fluids
  - Requires increased thumb force (11%)
  - Increases mean cycle time


Force: High risk issues

- Volume adjustment
  - Highest level of muscle activity during pipetting
    - Small dial diameter
    - Limited contact friction between dial and fingers
    - Force required to turn dial

Force: High risk issues

- Volume adjustment
  - Revolutions to turn volume dial:
    - Eppendorf Research - 20
    - Rainin Pipet-Lite - 20
    - Firepipette - 20
    - Ovation - 4 primary stops with push button

Pipette Selection

- Application-specific design
- Cost (instrument and tips)
- Accuracy and reproducibility
- Durability/maintenance
- Ergonomics

Pipette Selection

- Volume ranges
  - .5 – 10.0 µl
  - 10 – 100 µl
  - 20 – 200 µl
  - 100 – 1000 µl
  - 500 – 5000 µl

Pipette Selection

- Volume range
  - Mid to high end of recommended volumes (most accurate)
  - Pipetting volume = 50 µl
    - 10 – 100 µl?
    - 20 – 200 µl?

Pipette Selection

- Cost
  - Instrument
  - Replacement parts/repair
  - Calibration
  - Batteries
  - Tips

Pipette Selection

- Durability
  - Materials
    - Plastic versus metal
  - Weight trade-off
  - Down-time for repair
Pipette Selection

- Specialty applications
  - Biohazardous material exposure
    - Autoclavable?
    - Chemical compatibilities
    - Exposure to UV light

- Manual Pipette
  - 5 step process
    - Depress
    - Hold
    - Aspirate
    - Dispense
    - Blowout

Definitions

- Aspirate – to draw up the sample
- Dispense – to deliver the sample
- Blow-out – to empty the tip completely

- Magnetic Assist Manual Pipette
  - Magnetic latch locks at zero position
  - No blowout spring
  - Trigger releases latch and tip fills at set aspiration speed
  - Reduces pipetting from 5 steps to 2

- Magnetic Assist
  - Traditional plunger force = 3-4 kg
  - Pipet-Lite = 1.7 kg
  - 70% reduced force

- Latch-Mode Pipette
  - Magnetic latch locks at zero position
  - No blowout spring
  - Trigger releases latch and tip fills at set aspiration speed
  - Reduces pipetting from 5 steps to 2

- Magnetic Latch
  - Rainin Pipet-Lite™
  - Magnetic-assist pipette

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Pipette Selection

- Pipet-plus Latch Mode Pipette
  - Traditional plunger force = 3-4 kg
  - Pipet-Plus = 1.1 kg
  - 80% reduced force

- Latch-Mode Pipette
  - Unexpected increased thumb muscle activity
    - Users extended thumb MCP joint after depressing plunger
    - Increased static muscle load
  - Solutions
    - Thumbrest
    - User training re: posture

Pipette Selection

- Electronic Pipettes
  - Eliminates forceful actions
  - Varied modes of operation (pipette, multi-dispense)
  - Can be heavy
  - Accuracy varies
  - Expensive

Pipette Selection

- Multichannel Pipettes
  - Manual and electronic models
  - Multi-shafts (6-12)
  - Faster
  - Decrease repetition

Pipette Selection

- Multichannel Pipettes
  - High plunger forces
  - High tip loading force
  - Potential uneven tip sealing causing inconsistent sample loading
  - Heavy
  - Expensive

Pipette Selection

- Specialty Pipettes
  - Powerpette
  - Digital Powermate
  - Finnpipette Biomate
  - Eppendorf Easypet
  - Variety of controls
  - Ambidextrous use

Pipette Plunger Forces

- Epp Ref
- Hamil
- Ovation
- Biohit
- Oxford
- Epp
- Res
- Gilson

Pipette Plunger Forces

- Rainin
- Pipet
- Plus Pipet Lite
- Finn Dig
- Biohit Manual Multi

Pipette Tip Ejection Forces

- Ovation
- Rainin LTS
- Hamil
- Biohit
- Fnn Pipette
- Biohit Multi
- Eppen Ref

Pipette Tip Ejection Forces

- Pipet Lite
- Pipet Plus
- Finn Dig
- Rainin Elec Multi

Tip Ejection Forces

- Tip ejection forces are significant
- Studies vary in reported force
  - Hamilton versus Rainin
Tip Ejection Forces
- Rainin LTS tips reduce tip ejection force to 0.6 kg (reported by Rainin)

Rainin LTS Tip
- Heavy ejection force
- Light ejection force
- Traditional: Conical shaft and conical thick-walled tip
- LTS: Cylindrical shaft and cylindrical thin-walled tip

Pipettes
- Ovation BioNatural
  - Promotes forearm pronation
  - Promotes 10° wrist flexion
  - Promotes relaxed hand posture
  - Stand alone - no racks
  - Volume adjustment pad

Posture: Forearm
- Figure 3: Forearm rotation during aspiration & dispensing

NIOSH/Duke Pipette Study
- Compared traditional pipettes with Ovation
- N = 61
- Pre-intervention discomfort survey:
  - 100% reported discomfort
  - 56% neck
  - 51% shoulder
  - 26% wrist
  - 16% thumb

NIOSH/Duke Pipette Study
- No significant difference between control and intervention group
- Users preferred Ovation for comfort, accuracy, general use
- Cap opener developed to address productivity issue
NIOSH/Duke Pipette Study
- Measured MSD physical risk factors associated with pipetting
- N = 11 female and 1 male
- Force and goniometry measures
- Ovation, Oxford Benchmate II, and Eppendorf Reference Pipettes

Lu and Sudhakaran, 2005

NIOSH/Duke Pipette Study
- Ovation significantly reduced:
  - Thumb force
  - Total finger force
  - Wrist deviation
  - Shoulder elevation
  - Wrist flexion/extension during aspiration

Lu and Sudhakaran, 2005

NIOSH/Duke Pipette Study
- Ovation increased
  - Forearm rotation
  - Rotation less of risk factor than wrist deviation, flexion and extension

Lu and Sudhakaran, 2005

Recommendations
- Work design changes
- Selection of appropriate pipettes
- Administrative controls
- Work practice controls
- Training

Arndt, R. (2001)

Recommendations
- Administrative controls
  - Limit continuous pipetting to 20 minutes
  - Take 3-5 minute breaks every 20-30 minutes
  - Complete upper extremity stretches

Arndt, R. (2001)
Recommendations

- **Work practices**
  - Keep pipettes clean
  - Use electronic pipettes repetitively dispensing or filling multi-well plates
  - Match pipette with task
  
  Arndt, R. (2001)

Recommendations

- **Behavior/habits**
  - Take regular breaks
  - Use minimal force when applying tips
  - Keep samples and instruments within easy reach
  - Don’t press harder than necessary on the plunger
  - Use variety of grips
  - Try alternating hands

Arndt, R. (2001)

Recommendations

- **Behavior/habits**
  - Keep arms close to sides
  - Keep wrist straight
  - Avoid resting elbows on hard surfaces
  - Avoid arm/elbow contact with table edges
  
  Arndt, R. (2001)

Recommendations

- **Behavior/habits**
  - Adjust chair and work surface to minimize bending of neck and torso
  - Adjust stools or chairs to ensure lower back and thigh support
  - Adjust and use foot supports as necessary (stool rather than ring)
  - Alternate sitting and standing
  
  Arndt, R. (2001)

Recommendations

- **Behavior/habits**
  - Use proper pipetting technique
    - Immersion depth and angle
    - Cadence
    - Tip position in the receiving vessel
    - Force
    - Posture

Costello, K.J., (2005)
**Recommendations**

- Pipette design
  - Finger controls in lieu of thumb controls
  - Separate plunger/tip ejection buttons?
  - Location critical
  - Avoid sharp edges on handles and triggers
  - Avoid finger flutes
  - Diameter between 1 – 1.5 inches

Arndt, R. (2001)

- Pipette design
  - Consider trigger/plunger design and location
    - Multi versus one-finger controls
    - Electronic controls
  - Options to reduce grips (soft grips, finger hooks, contoured surfaces)

BrandTech Handistep
Matrix Impact electronic pipettes
Eppendorf EasyPet

Arndt, R. (2001)

- Pipette design
  - Limit length – shorter is better
  - Limit weight – lighter is better
  - Eliminate static loading force and duration
  - Reduce plunger force
  - Reduce repetition (electronic pipettes for high repetition tasks)
  - Ambidextrous design

Arndt, R. (2001)

- Introduce automation with high volume pipetting
- Reduce button resistance
- Provide adjustable size handles to accommodate different hand sizes


- Consider specialty pipettes
  - Latch-hook
  - Magnetic
  - Multi-channel
  - Electronic

Arndt, R. (2001)
**Recommendations**

- Consider tip ejection forces
  - Design of tip and seal
  - Design of tip ejector
    - Thumb versus finger operated
    - Power versus pinch grip
  - Length of tip

- Train users
  - Design changes
    - Reduce blowout force
    - Volume adjustment dial
      - Increase diameter
      - Reduce rotation force
    - Modify plunger position to reduce awkward thumb postures
    - Add surfaces to rest thumb

- Use proper technique
  - Hold pipette in loose, relaxed grip
  - Use hook to passively support pipette
  - Apply tips with gentle force
  - Select short pipettes, tips, tubes and canisters
  - Adjust height and tilt holders and containers
  - Keep work close
  - Consider arm supports

- Provide ergonomic pipetting workstations
  - Automated height adjustment mechanism
  - Table cutout to reduce reach
  - Floating arm supports
  - Plinths or platforms for variable height test tubes/pipettes
  - Labeled reach zones

**References**

### Recommendations

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<tr>
<th>Provide ergonomic pipetting workstations</th>
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<tbody>
<tr>
<td>- Open space under work benches</td>
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<tr>
<td>- Footrails</td>
</tr>
<tr>
<td>- Portable storage cabinets</td>
</tr>
<tr>
<td>- Ergo mats for standing stations</td>
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<tr>
<td>- Sufficient storage areas</td>
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<tr>
<td>- Proper task lighting</td>
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<th>Provide ergonomic fume hoods</th>
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<tbody>
<tr>
<td>- Adjustable height</td>
</tr>
<tr>
<td>- Clearance for thighs/legs</td>
</tr>
<tr>
<td>- Horizontal and vertical sashes</td>
</tr>
<tr>
<td>- Angled sashes</td>
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<tr>
<td>- Rounded or padded edges</td>
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<tr>
<td>- Turntables</td>
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<tr>
<td>- Appropriate pipettes</td>
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<th>Don’t forget other tasks associated with pipetting</th>
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<tr>
<td>- Set-up</td>
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<tr>
<td>- Labeling</td>
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<tr>
<td>- Lid/cap removal</td>
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<tr>
<td>- Vortex mixing</td>
</tr>
<tr>
<td>- Clean-up</td>
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<thead>
<tr>
<th>Consider other tasks performed at pipetting workstation</th>
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<tbody>
<tr>
<td>- Microscope</td>
</tr>
<tr>
<td>- Computer</td>
</tr>
<tr>
<td>- Administrative</td>
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</table>

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