Selection and Use of Pipettes

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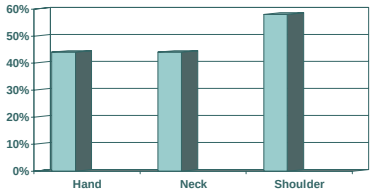
NECE Las Vegas, November 2005

Pipetting Injuries

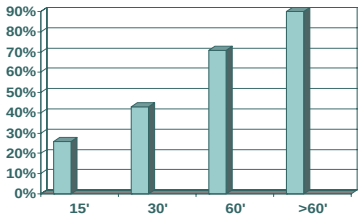
- 128 female subjects
- Higher rate than female Swedish state employees in general



MJ Bjorksten et al, 1994

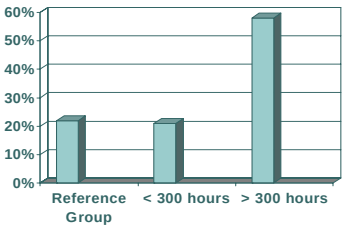
Pipetting Injuries

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



David & Buckle, 1997

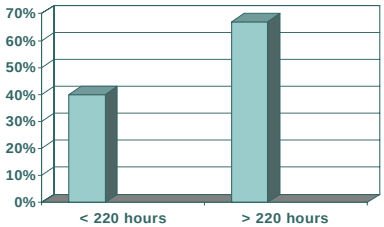
Pipetting Injuries – Hand



300 hours = 6 hrs/wk

Bjorksten et al (1994)

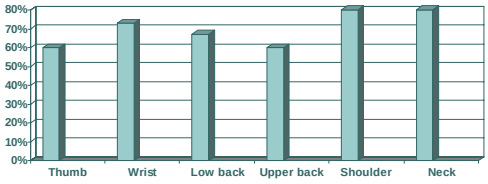
Pipetting Injuries- Hand



220 hrs = 4 hrs/wk

David and Buckle (1997)

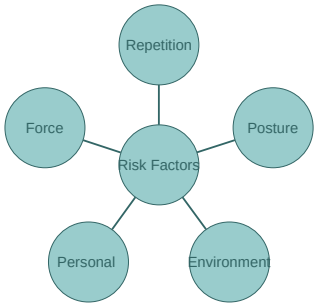
Pipetting Injuries



- 15 subjects
- Male/female
- Six healthcare sites

British Columbia Institute of Technology (2003)

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

Risks and Injuries

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

Risks and Injuries

- Elevated arm
- Forearm supination
- Elbow flexion
- Wrist flexion
- Ulnar deviation
- Tight grip
  - Medial epicondylitis

Risks and Injuries

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

Risks and Injuries

- Tight grip
- Repetitive wrist deviation, extension and flexion
  - Carpal tunnel syndrome

Risks and Injuries

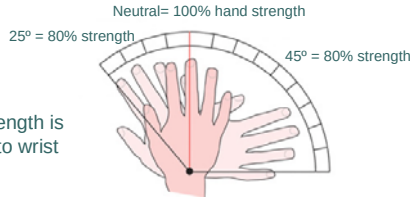
- Tight grip
- Repetitive finger extension and flexion
  - Trigger finger
  - Radial tunnel
  - Extensor tendinitis
  - Flexor tendinitis

Risks and Injuries

- Leaning on elbow
  - Cubital tunnel

Awkward Postures and Strength

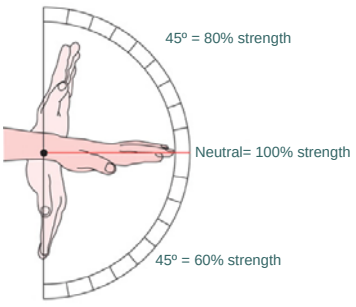
Grip strength is related to wrist position



Putz-Anderson, V. 1988

Awkward Postures and Strength

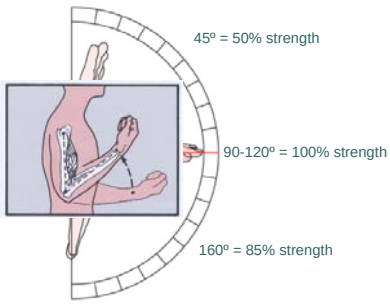
Grip strength is related to wrist position



Putz-Anderson, V. 1988

Awkward Postures and Strength

Force is related to elbow position



Grandjean, E. 1988

Posture and Strength

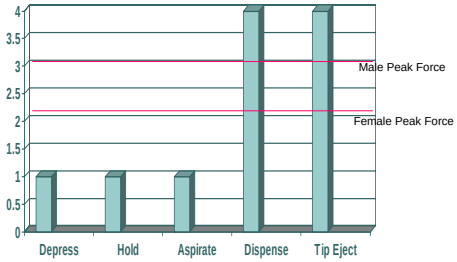
- Non-neutral postures increase
  - Physical effort
  - Muscle fatigue
  - Exposure to risk
  - Musculoskeletal injuries

Maximum Force Capacity

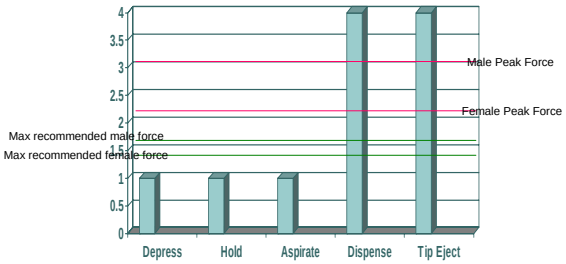
Thumb-pinching activities	% of Maximum Strength Capacity	Force (kg)	
		Male	Female
Maximum strength	100%	10 kg	7 kg
Dynamic Peak Force	30%	**3 kg**	**2.1 kg**

Kroemer, K.H.E., (1989)

Traditional Pipetting Forces

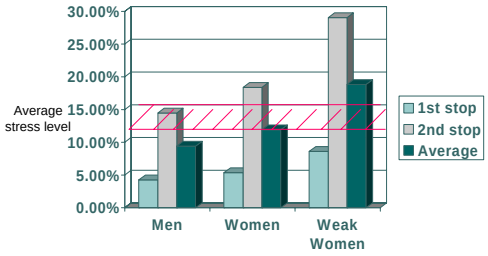


Traditional Pipetting Forces



Bjorksten and Jonsson, 1977

Pipetting Strain



Fredriksson, K., (1995)

What Does This Mean?

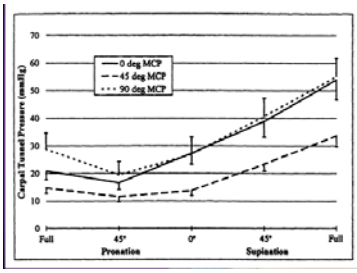
- Thumb force to operate plunger
  - Should not exceed .5 kg (18 ounces) continuous loading to accommodate weakest women

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%

Rempel,D., Bach,J.,Gordon,L,& So,Y. (1998)

Posture & Force: High risk issues



Rempel,D., Bach,J.,Gordon,L,& So,Y. (1998)

What does this mean?

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

Rempel, D., Bach, J., Gordon, L., So, Y. (1998)

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)

Asundi, KR, Bach J.M., & Rempel, D.M., (2005)

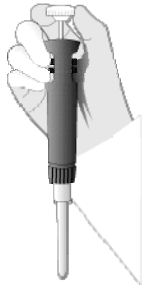
Force: High risk issues

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

Asundi, KR, Bach J.M., & Rempel, D.M., (2005)

Force: High risk issues

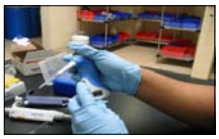
- Volume adjustment
  - Highest level of muscle activity during pipetting
    - Small dial diameter
    - Limited contact friction between dial and fingers
    - Force required to turn dial



Asundi, KR, Bach J.M., & Rempel, D.M., 2005)

Force: High risk issues

- Volume adjustment
  - Revolutions to turn volume dial:
    - Eppendorf Research - 20
    - Rainin Pipet-Lite - 20
    - Finnpipette - 5
    - 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

Pipette Selection

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

Pipette Selection

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

Pipette Selection

- **Magnetic Assist Manual Pipette**
  - Magnet helps find and hold the piston at the zero position before aspiration
  - Reduced blowout spring force

Pipette Selection

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

Pipette Selection

- **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

Pipette Selection

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

Latch-Mode Pipette

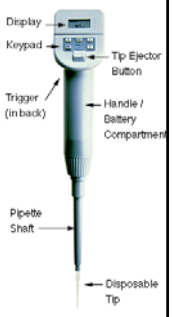
- Unexpected increased thumb muscle activity
  - Users extended thumb MCP joint after depressing plunger
  - Increased static muscle load
  - Solutions
    - Thumbrest
    - User training re: posture

Asundi, KR, Bach J.M., & Rempel, D.M., (2005)

Pipette Selection

Electronic Pipettes

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



Pipette Selection

- **Electronic Pipettes**
  - Volume capacity affects length and weight of pipette

Pipette Selection

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

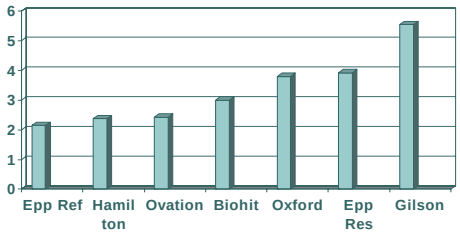
Pipette Selection

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

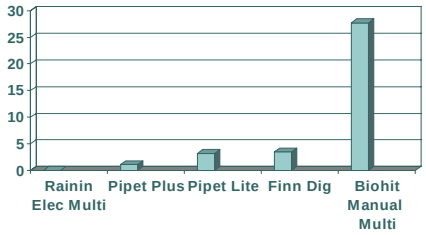
Pipette Selection

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

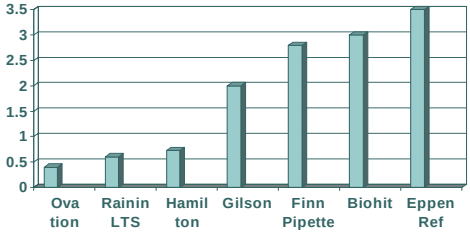
Pipette Plunger Forces



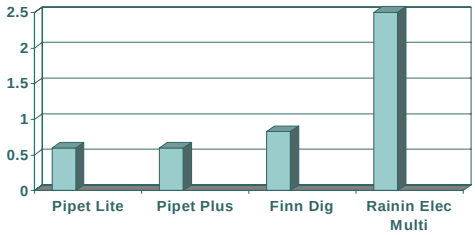
Pipette Plunger Forces



Pipette Tip Ejection Forces

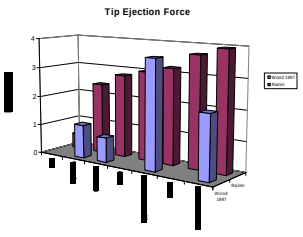


Pipette Tip Ejection Forces



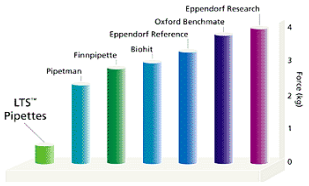
Tip Ejection Forces

- Tip ejection forces are significant
- Studies vary in reported force
  - Hamilton versus Rainin

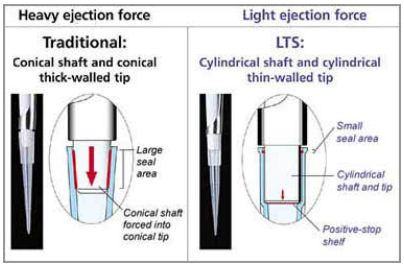


Tip Ejection Forces

- Rainin LTS tips reduce tip ejection force to .6 kg (reported by Rainin)



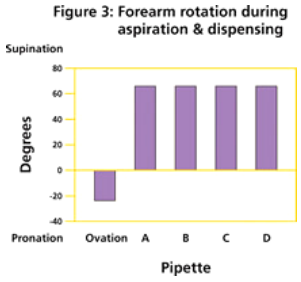
Rainin LTS Tip



Pipettes

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

Posture: Forearm



Ovation

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

James and Glascock, 2005

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

James and Glascock, 2005

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
  - Rotate pipetting tasks among several people
  - Rotate pipetting activities between laboratory tasks
  - Vary activities

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)

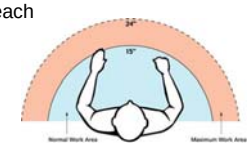
Recommendations

- Work practices
  - Keep pipettes clean
  - Use electronic pipettes repetitive 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

- Maintain proper posture
- Avoid awkward static positions
- Work in neutral arm, wrist and hand positions
  - Maximum 12" above worksurface
  - Elbow 90º position
  - Forearm 45º pronation
  - Wrist within 15º range of neutral

Costello, K.J., (2005)

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

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)

Recommendations

- 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)

Hamilton lever-action ejector

BrandTech Handistep

Matrix Impact electronic pipettes

Eppendorf EasyPet

Arndt, R. (2001)

Recommendations

- 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)

Recommendations

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

Eppendorf epMotion workstation

Fredriksson, K. (1995)

Recommendations

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

Recommendations

- Consider pattern of usage
  - Duration of collection and dispensing
  - First stop might be more important than more forceful second stop
  - Frequency of volume changes
- Effect of design/user on forces
  - User with small hand
  - Location of trigger

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

Recommendations

- 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

Asundi, KR, Bach J.M., & Rempel, D.M. (2005)

Recommendations

- 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

Recommendations

- Use cap and tube openers

Decapitator Micro-tube Opener

Rainin Jimmy Microtube Opener

Thumb openers

Bioworld Cap Openers

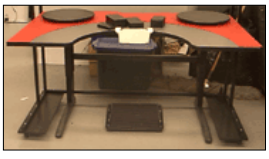
Recommendations

- 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

British Columbia Institute of Technolgy, 2003

Recommendations

- Provide ergonomic pipetting workstations
  - Turntables
  - Central waste receptacle
  - Footrest/footrings
  - Rounded countertop edges
  - Cap-removal device



British Columbia Institute of Technology, 2003

Recommendations

- Provide ergonomic pipetting workstations
  - Open space under work benches
  - Footrails
  - Portable storage cabinets
  - Ergo mats for standing stations
  - Sufficient storage areas
  - Proper task lighting

Recommendations

- Provide ergonomic fume hoods
  - Adjustable height
  - Clearance for thighs/legs
  - Horizontal and vertical sashes
  - Angled sashes
  - Rounded or padded edges
  - Turntables
  - Appropriate pipettes

Recommendations

- Don't forget other tasks associated with pipetting
  - Set-up
  - Labeling
  - Lid/cap removal
  - Vortex mixing
  - Clean-up

Recommendations

- Consider other tasks performed at pipetting workstation
  - Microscope
  - Computer
  - Administrative

References

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Useful Links

- National Institute of Health http://www.nih.gov/od/ors/ds/ergonomics/lab1.html
- Rainin ergonomics http://www.rainin.com/lit_ergopaper.asp
- UC Berkeley Laboratory Ergonomics http://www.uhs.berkeley.edu/facstaff/ergonomics/lab/pipetting.shtml
  Appendix on Ergonomic Pipettes http://www.uhs.berkeley.edu/facstaff/ergonomics/lab/ergopipettes.shtml
- University of Minnesota -- http://www.dehs.umn.edu/ergo/lab/#pipetting

Useful Links

- National Institute of Environment and Health Sciences http://www.niehs.nih.gov/odhsb/ergoguid/home.html
- UC San Diego http://www-ehs.ucsd.edu/ergo/fisher.htm
- Lawrence Livermore National Laboratories http://www.llnl.gov/ergo/lab_rats.html
- Center for Disease Control http://www.cdc.gov/od/ohs/Ergonomics/labergo.htm
- Stanford University http://www2.umdnj.edu/eohssweb/aiha/technical/ergonomics.htm

Useful Links

- UCLA Ergonomics http://ergonomics.ucla.edu/lab.html
- University of Michigan http://www.oseh.umich.edu/Lab_Ergonomics_Brochure.pdf
- Humantech http://www.humantech.com/Level3/publications_resources/applied_lab.htmhttp://www.llnl.gov/ergo/lab_rats.html

Pipette Manufacturers

- Hamilton Company http://www.hamiltoncompany.com/product/pipette/ergo.html
- Rainin http://www.rainin-global.com/
- 3M http://www.3m.com/microbiology/home/products/pipettor/ep_over.html
- Matrix Technology http://www.matrixtechcorp.com/home.html

Pipette Manufacturers

- Brand Tech
  http://www.brandtech.com/
- Eppendorf
  www.eppendorf.com/
- Finnpipette
  http://www.labsystems.fi/
- Ovation
  http://www.vistalab.com/products.asp