HANDPAK

Ergonomics Software

User's Manual

An Integrated Software Package for the Ergonomic Assessment
of Hand Intensive Tasks

Work in Progress Ergonomics

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INTRODUCTION

HANDPAK is a software package designed to determine recommended acceptable forces and torques for a wide variety of manual, hand intensive tasks commonly found in the workplace. These guidelines will be very valuable to those interested in assessing task designs and determining the injury risk associated with tasks with different grips, postures, frequencies, durations and effort requirements. This software has been developed by integrating a large body of scientific research published in the literature.

For every analysis, there are a number of common inputs, including: 1) gender, 2) percentage of the population you wish to design for, 3) units (empirical or metric). In addition, **HANDPAK** has a number of modules for specific tasks demands. These include:

Torques

This module accounts for tasks that require the application of a torque or moment to some object that has been grasped with the hand.

Forearm Pronation or Supination: For a variety of grasp interfaces, elbow postures, forearm orientations and frequencies, the maximal acceptable torque can be determined for both the pronation and supination direction.

Wrist Flexion, Extension, Ulnar or Radial Deviation: The maximal acceptable torque can be determined for a number of grips, frequencies and wrist torque directions.

Grips and Pinches

This module accounts for tasks that are limited by the amount of force required to grip or pinch and object.

Power Grip: For power grips with one or two hands, different spans, wrist and elbow postures, durations and frequencies, the maximal acceptable power grip force can be determined.

Pinches: For different types of grips (chuck, lateral/key, pulp, tip), apertures, wrist postures, durations and frequencies, the maximal acceptable pinch forces can be determined.

Pushes and Pulls

This module accounts for tasks where the hand interfaces with an object so that it can be pushed or pulled.

Finger Pulls: For pulls with various finger interface locations (tip or knuckle), glove use, finger clearance, object dimensions, effort durations and frequencies, the maximal acceptable finger pull force can be determined.

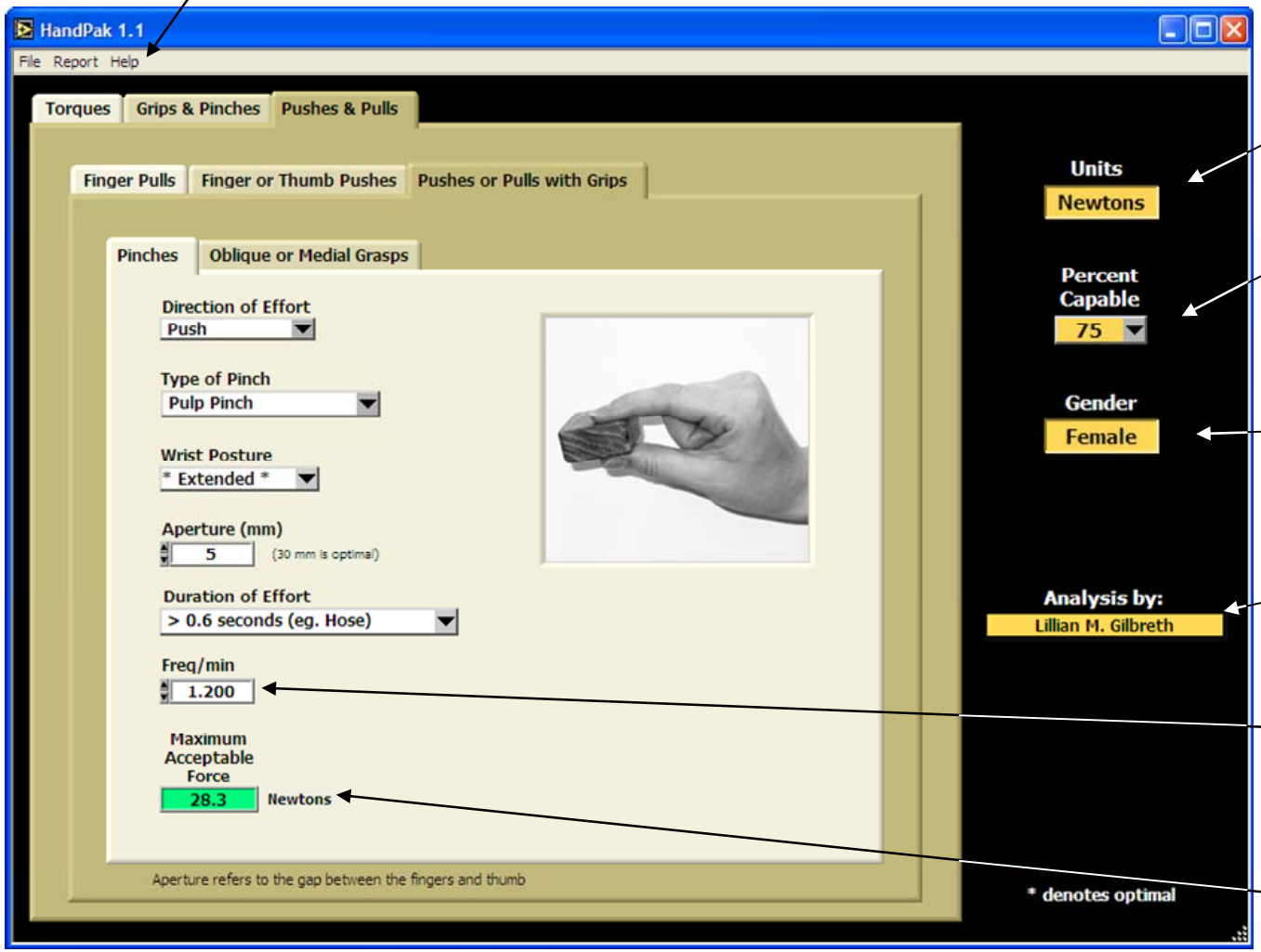
Finger and Thumb Pushes: For pushes with different numbers of fingers or thumbs, contact location (tip or pad), wrist postures, effort durations and frequencies, the maximal acceptable push forces can be determined.

Pushes or Pulls with Grips: For different types of pinches or grasps, wrist postures, object apertures or spans, surface coatings, effort durations and frequencies, the maximal acceptable push or pull forces can be determined

HANDPAK

Common Inputs and Outputs

Menus
- File: exit
- Report: save reports
- Help: load User's Manual



Units
- Newtons
- Pounds

Percent Capable
Select the percentage of the population for whom you want the task to be acceptable.

Gender
- Male
- Female

Analysis by:
Enter the name of the analyst

Frequency
Number of discrete efforts per minute
(0.002/min gives MVC)

Maximum Acceptable Value
This value represents the recommended limit for gender and percent capable selected.

SAMPLE REPORT

HandPak Ergonomics Software

This analysis was completed on Monday, January 08, 2007

Analysis Completed by: Lillian M. Gilbreth

SELECTED INPUTS

Gender:

Female

Percent Capable:

75

Frequency:

0.002/minute

Module:

Pushes & Pulls

Effort Type:

Pushes or Pulls with Grips

Grip Type:

Pinches

Direction of Effort:

Push

Direction of Effort:

Chuck Pinch

Wrist Posture:

* **Extended** *

Aperature:

30 mm

Duration of Effort:

* **< 0.2 seconds (ie. snap)** *

Maximum Acceptable Force: **54.2 Newtons**

* **Denotes Optimal**

NOTE
When saving Report files, their extension must be **".htm"**

TORQUES

Forearm Pronation and Supination

Psychophysical data were taken from Ciriello, Webster, Dempsey (2002) and were assumed to apply to females with a horizontal forearm orientation. Based on the pronation and supination conditions (31 mm screwdriver, 40 mm screwdriver, 39 mm yoke) it was observed that the maximum acceptable torque (MAT) was an average of 17.8% of maximum at a frequency of 20/min. A logarithmic effect of frequency on MAT was assumed for other frequencies, with anchors at the MVC (frequency = 1/day or 0.002/min) and 20/min.

Based on the research of Sullivan & Gallwey (2002), it was assumed that supination MATs were 15% higher than corresponding pronation values. This research was also used to determine corrections for elbow angle. No correction was made with elbow angles between 45 and 90 degrees, but corrections were made with elbows at full extension or when flexed 135 degrees.

The MVC data of Peebles and Norris (2003) were used to estimate female MATs at a frequency of 1/day. All Peebles and Norris (2003) data used in the **HANDPAK** were taken from their 31 to 50 year age groups. These data were used for the 45 mm lid, 65 mm lid, 85 mm lid, butterfly nut, ridged knob, tap, circular knob, door knob interfaces and to determine that a vertical forearm orientation results in strengths that are 21% higher than horizontal orientations.

Based on the data of Greig & Wells (2004), it was assumed that male forearm pronation maximum strength and MAT values are 80% higher than corresponding values for females. Based on the data of Peebles & Norris (2003) and Greig & Wells (2004), it was assumed that acceptable supination values are 50% higher for males.

Torques

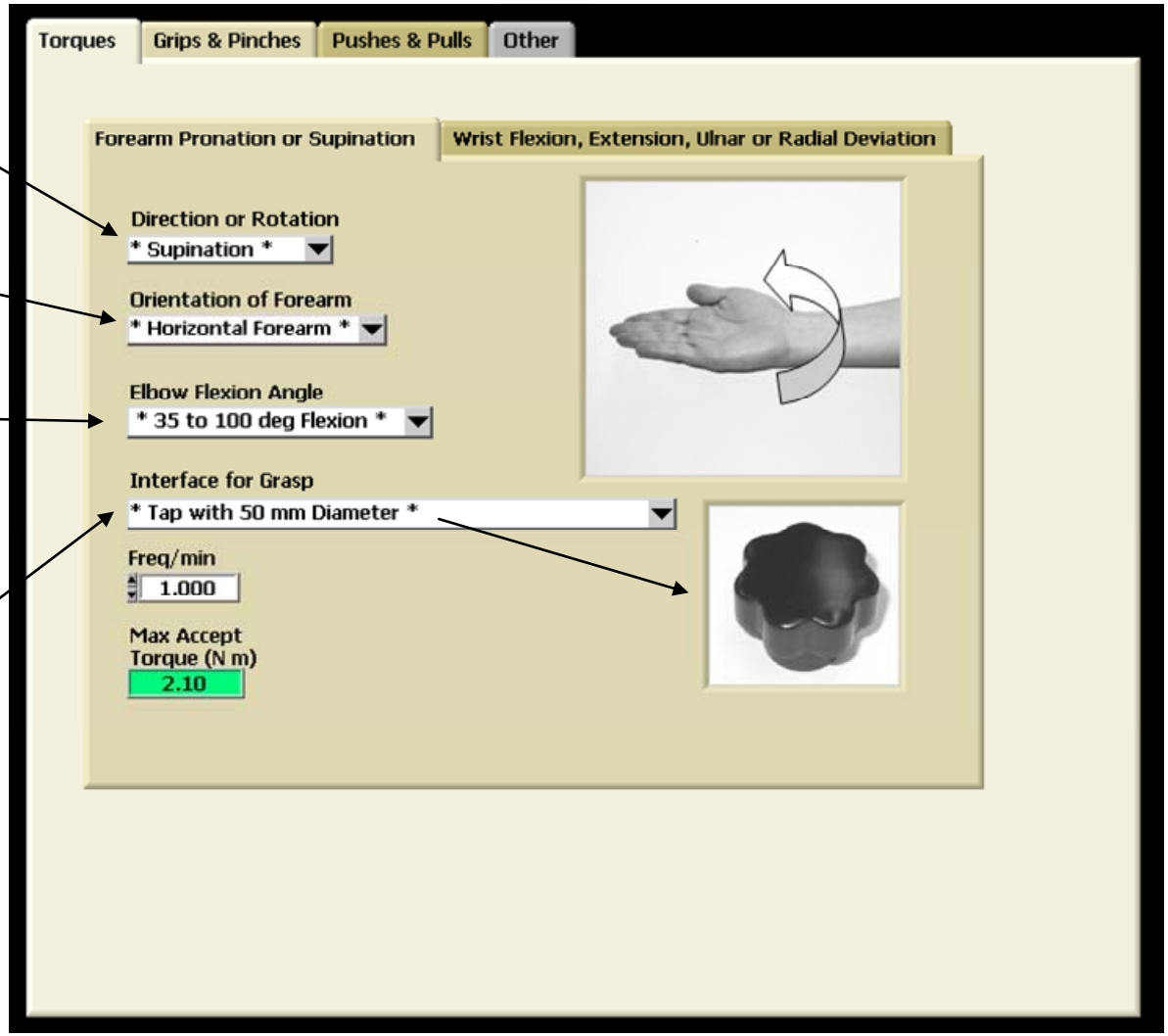
Forearm Pronation or Supination

Direction of Forearm Rotation
- Pronation
- Supination

Orientation of Forearm
- Horizontal
- Vertical

Elbow Flexion Angle
- 0 to 35 deg (fully or almost extended)
- 35 to 100 deg
- 100 to 135 deg (very flexed)

Interface for Grasp
- Screwdriver (30 mm Handle)
- Screwdriver (40 mm Handle)
- Yoke (40 mm Handle)
- Lid (45 mm Diameter)
- Lid (65 mm Diameter)
- Lid (85 mm Diameter)
- Butterfly Nut (40 mm length, 10 mm depth)
- Ridged Knob (40 mm length, 15 mm depth)
- Tap (50 mm Diameter)
- Circular Knob (40 mm Diameter)
- Door Knob (65 mm Diamter)



Wrist Flexion, Extension, Ulnar and Radial Deviation

Strength data from Greig & Wells (2004) were integrated with psychophysical and strength data from Snook, Vaillancourt, Ciriello & Webster (1995, 1997) and Snook, Ciriello & Webster (1999) (see Table 1). Specifically, the female maximum voluntary contraction (MVC) strength values from these studies were used to estimate maximum acceptable torques (MAT) for the wrist at a frequency of 1/day.

Table 1: This table indicates which studies were used and/or integrated for each combination of wrist/forearm torque and hand grip. Female data were used for each.

		Snook et al (1995)	Snook et al (1997)	Snook et al (1999)	Greig & Wells (2004)
Flexion	Power Grip	■			
	Pulp Pinch	■			
	Lateral Grip	no data available			
Extension	Power Grip	■			
	Pulp Pinch			■	
	Lateral Grip	no data available			
Ulnar Deviation	Power Grip		■		
	Pulp Pinch	■	■	■	
	Lateral Grip	■	■	■	■
Radial Deviation	Power Grip		■		■
	Pulp Pinch	■	■	■	■
	Lateral Grip	■	■	■	■

Based on the data of Snook et al (1995, 97, 99), it was assumed that the acceptable values at frequencies of 20/min were 25.0% MVC for wrist flexion, 19.0% MVC for wrist extension and 22.1% MVC for both wrist ulnar deviation and radial deviation. A logarithmic effect of frequency on MAT was assumed for other frequencies, with anchors at the MVC (frequency = 1/day or 0.002/min) and 20/min.

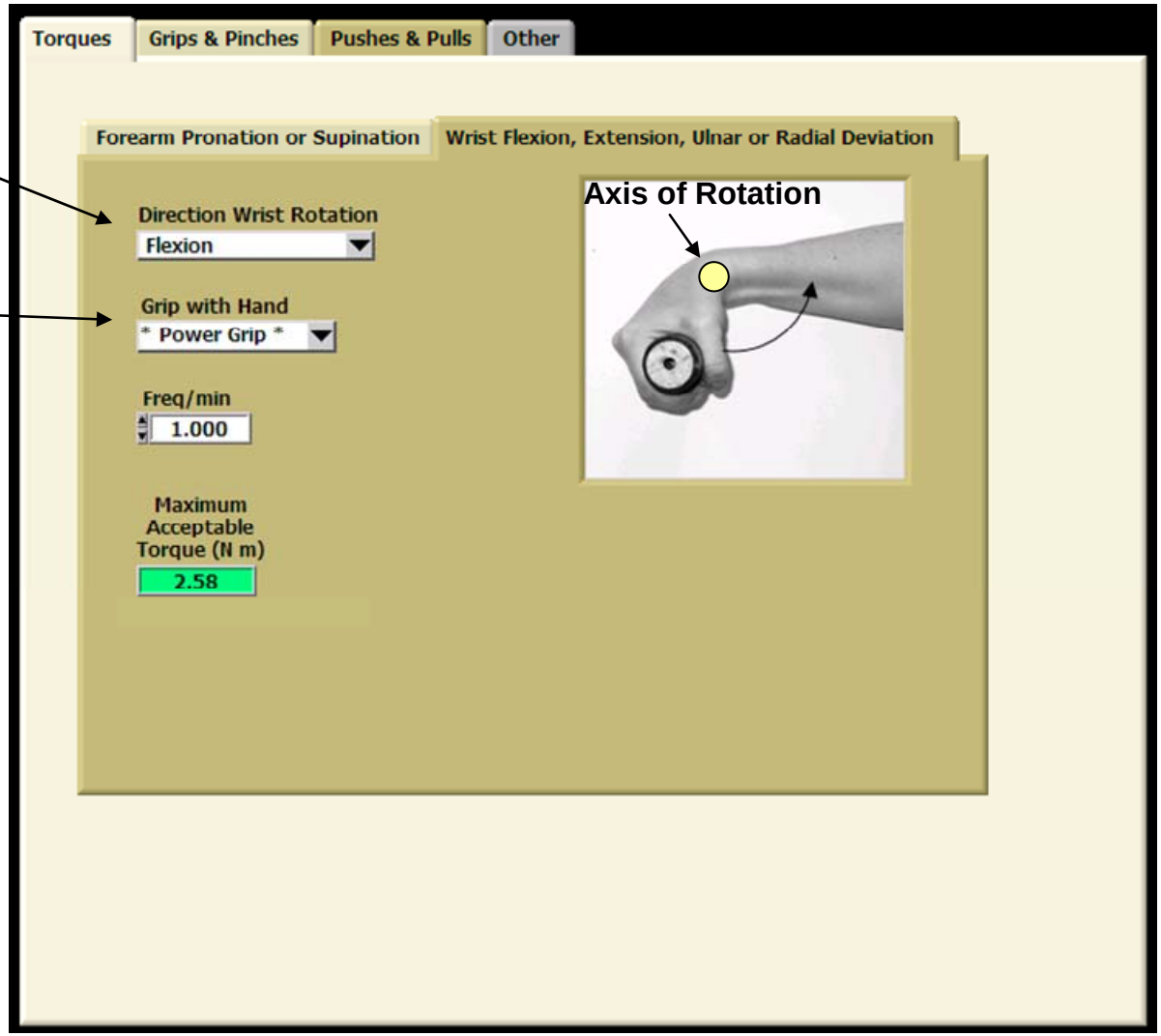
Based on the data of Greig & Wells (2004), it was assumed that male wrist flexion, extension, ulnar deviation and radial deviation maximum strength and MAT values are 50% higher than corresponding values for females.

Torques

Wrist Flexion, Extension, Ulnar or Radial Deviation

Direction of Wrist Rotation
- Flexion
- Extension
- Ulnar Deviation
- Radial Deviation

Grip with Hand
- Power Grip
- Pinch Grip
- Lateral Grip



GRIPS & PINCHES

Power Grip

The data of Mathiowetz et al. (1985), Imrhan & Loo (1989) and Peebles & Norris (2003) were averaged to determine maximum hand grip strengths, at a grip span of 50 mm, for females (312 N) and males (502 N). These values are corrected to account for the use of a second hand, and for grip spans above or below 50 mm, based on the data of Peebles & Norris (2003). Further corrections were made for wrist flexion, ulnar deviation and elbow flexion, based on the data of Kattel et al (1996).

The maximum hand grip strength values were assumed to be those acceptable for one effort per day (f=0.002/min). For efforts at higher frequencies, further corrections were made based on the psychophysical data of Snook & Ciriello (1991), Potvin et al (2006), Andrews et al (2005). For further details, please see Appendix A.

Pinches

The female maximum pinch strength values were determined with averages from a number of studies for each grip type (see Table 2).

Table 2: This table indicates which studies were averaged to determine maximum chuck, lateral, tip and pulp pinch strengths. Female data were used for each.

Grip	Mathiowetz et al (1985)	Astrand & Rodahl (1986)	Imrhan & Loo (1989)	Fernandez et al (1992)	DiDomenico & Nussbaum (2003)
Chuck	■	■	■	■	■
Lateral	■	■	■	■	■
Tip	■	■		■	
Pulp (Thumb & Index)			■	■	■
Pulp (multiple fingers)				■	

Corrections for wrist flexion, extension, ulnar deviation and radial deviation postures were based on an integration of the results from Imrhan (1991) and Fernandez et al. (1992), as reported in Mital and Kumar (1998). Further, corrections for aperture were made based on the data of Imrhan & Rehman (1995).

Based on the data of Mathiowetz et al (1985), Imrhan & Loo (1989), Fernandez et al (1992), DiDomenico & Nussbaum (2003) and Greig & Wells (2004), it was assumed that male pinch strengths and MAT values are 47% higher than corresponding values for females.

The maximum pinch strength values were assumed to be those acceptable for one effort per day (f=0.002/min). For efforts at higher frequencies, further corrections were made based on the psychophysical data of Snook & Ciriello (1991), Potvin et al (2006), Andrews et al (2005). For further details, please see Appendix A.

Grips & Pinches

Power Grip

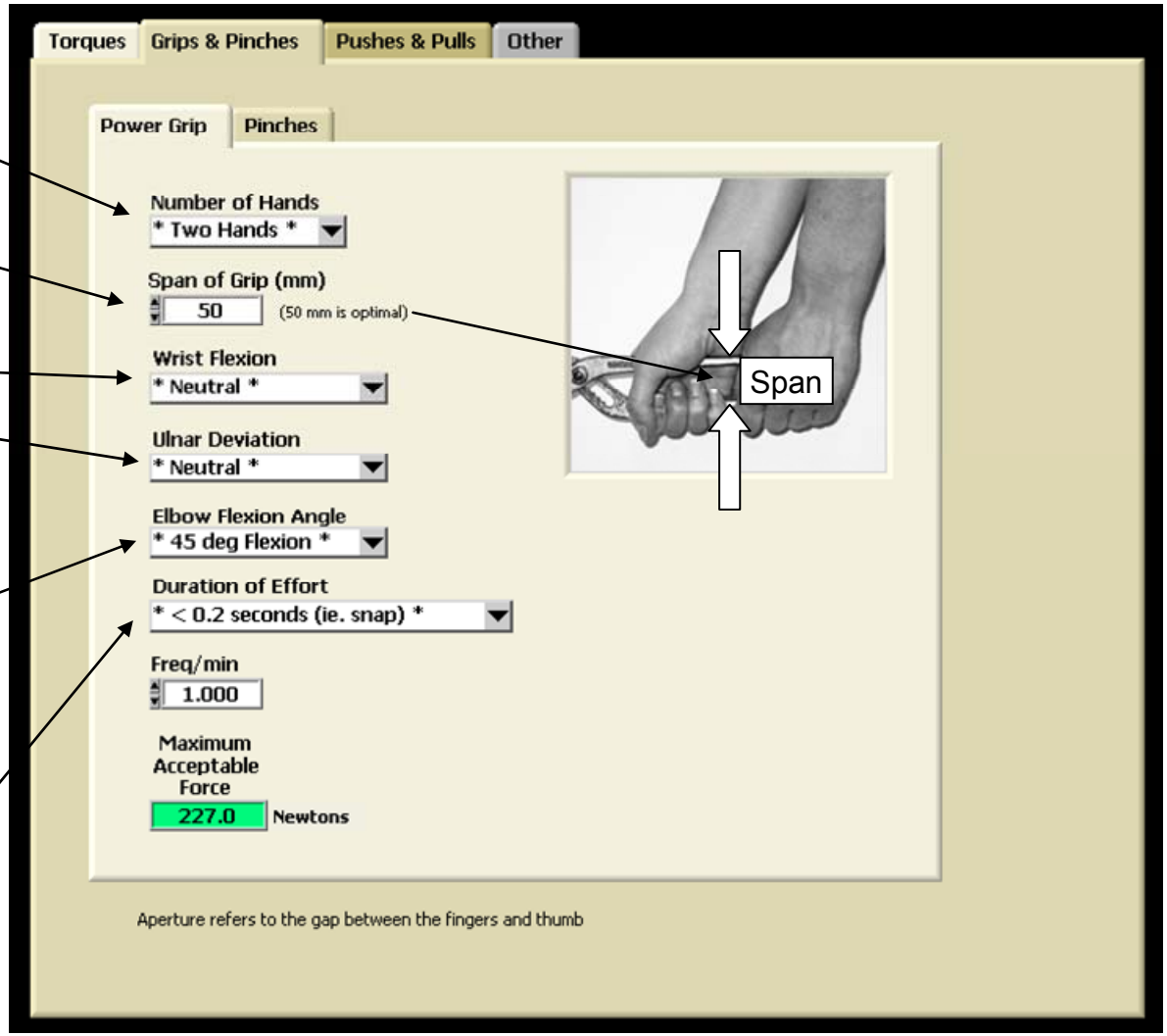
Number of Hands for Grip
- One Hand
- Two Hands

Span of Grip (see photo)
- the specific value can be entered here in millimetres

- **Wrist Flexion During Grip**
- **Ulnar Deviation During Grip**
  - Neutral
  - One Third Flexed
  - Two Thirds Flexed

Elbow Flexion Angle During Grip
- 0 degrees (fully extended)
- 45 degrees
- 90 degrees

Duration of Effort
This indicates how long it took to perform the grip effort
- less than 0.20 seconds or 200 ms
  - quick effort, snap (eg. electrical connector)
- between 0.2 and 0.6 seconds
- greater than 0.6 seconds or 600 ms
  - longer effort (eg. hose insertion)



Grips & Pinches

Pinches

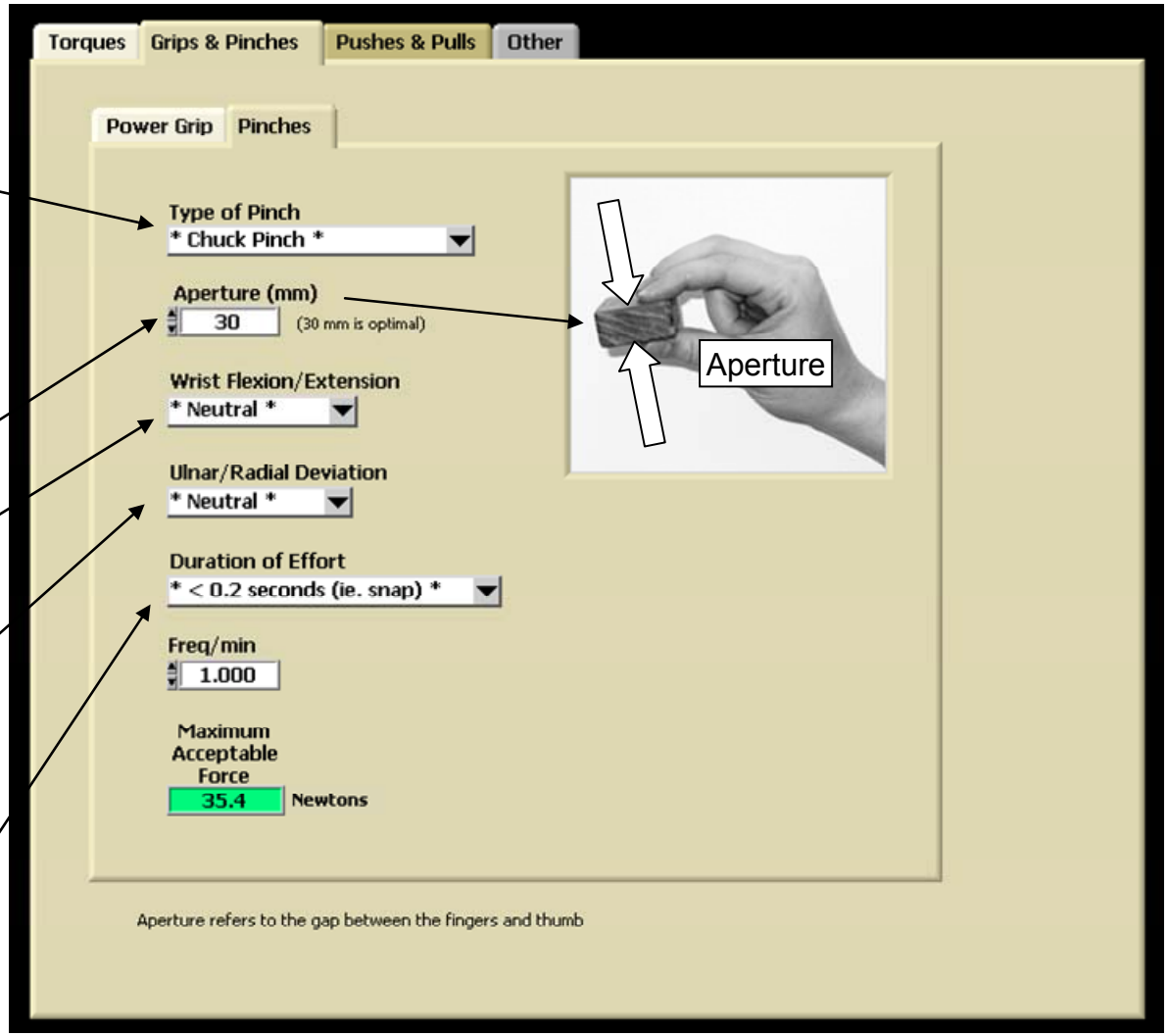
Type of Pinch Grip
- Chuck (Thumb vs Index & 2nd Finger)
- Lateral (Thumb vs Side of Index Finger)
- Tip (Thumb vs Index Finger Tip)
- Pulp Pinch - Thumb vs Pad of:
  - Index finger
  - Middle finger
  - Ring finger
  - Little finger
  - One Hand

Aperture (see photo)
- this is the distance between the fingers and the specific value can be entered (mm)

- Wrist Flexion or Extension
- Neutral
- Extended
- Flexed

- Ulnar or Radial Deviation
- Neutral
- Radial Deviation
- Ulnar Deviation

Duration of Effort
This indicates how long it took to perform the pinch effort
- less than 0.20 seconds or 200 ms
- between 0.2 and 0.6 seconds
- greater than 0.6 seconds or 600 ms



PUSHES AND PULLS

Finger Pulls

The female data of Cort et al. (2006) was used to determine all maximum finger pull strengths. Based on the data of DiDomenico & Nussbaum (2003), it was assumed that male finger pull capabilities are 44% higher than corresponding values for females.

The maximum finger pull strength values were assumed to be those acceptable for one effort per day (f=0.002/min). For efforts at higher frequencies, further corrections were made based on the psychophysical data of Snook & Ciriello (1991), Potvin et al (2006), Andrews et al (2005). For further details, please see Appendix A.

Finger or Thumb Pushes

The female data from a number of studies were used to determine the maximum strengths for pushes with the thumb pad (133.5 N from Peebles & Norris, 2003), thumb tip (99.9 N from Longo et al., 2002), finger pad (86.6 N from Peebles & Norris, 2003) and finger tip (61.8 N from Potvin et al., 2006), The use of a second finger, on the same hand, was assumed to add 70% to the acceptable force. Using the index finger from the second hand was assumed to double the acceptable force. Similarly, the acceptable force for two thumbs was assumed to be double that for one. Corrections were made for neutral, extended, flexed or ulnar deviated wrist postures, based on Potvin et al. (2006).

The maximum finger and thumb push strength values were assumed to be those acceptable for one effort per day (f=0.002/min). For efforts at higher frequencies, further corrections were made based on the psychophysical data of Snook & Ciriello (1991), Potvin et al (2006), Andrews et al (2005). For further details, please see Appendix A.

Pushes & Pulls

Finger Pulls

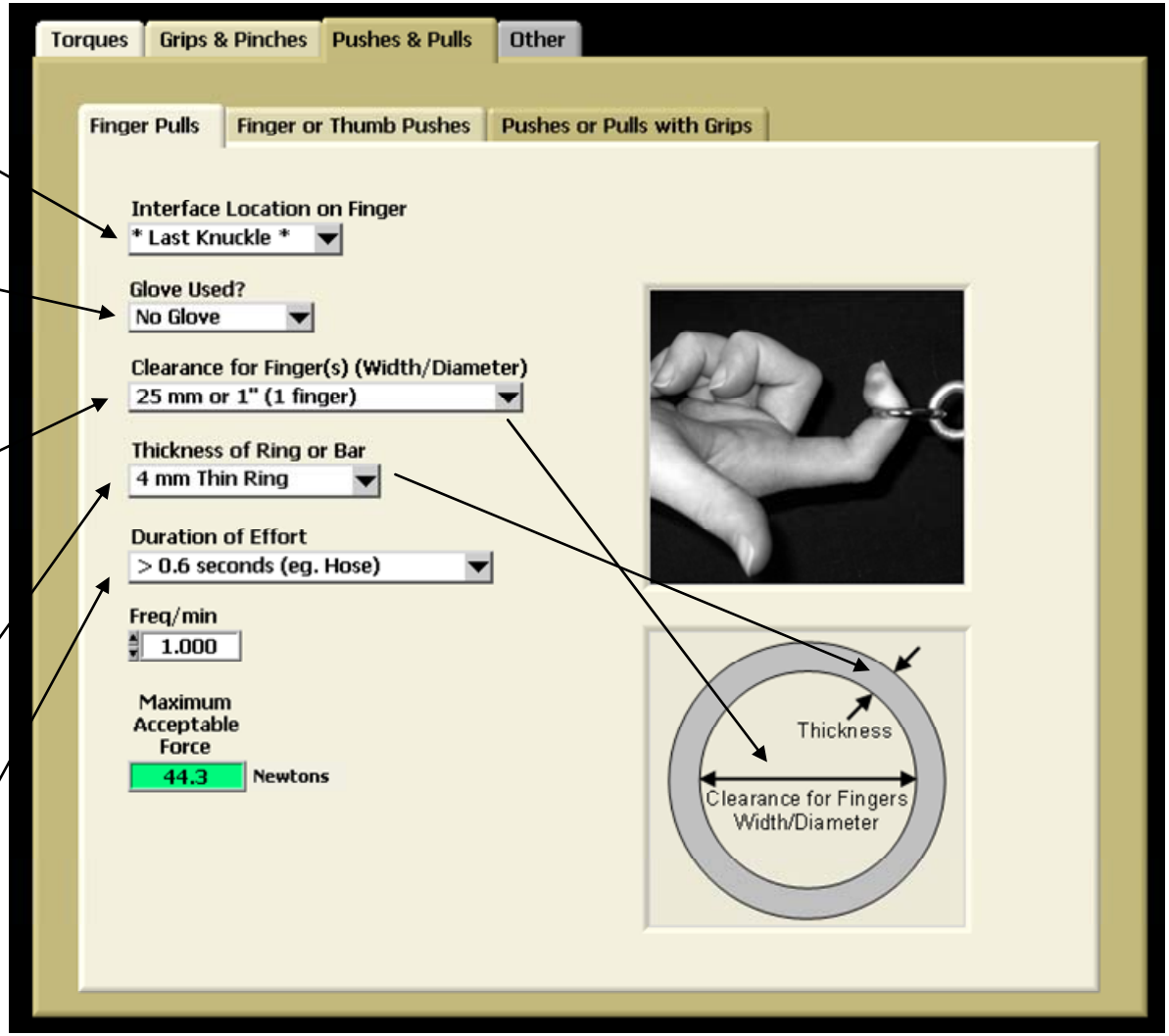
Interface Location on Finger
- Finger Tip Pad
- Last/Distal Knuckle

Is a Glove Used?
- With Glove
- No Glove (Bare Hand)

Clearance for Finger(s)
This indicates the diameter or width of the opening and will determine the number of fingers that can be used
- 25 mm or 1 inch allowing for 1 finger
- 40 mm or 1.5 inches allowing for 2 fingers
- > 60 mm or 2.25 inches allowing for >2 fingers

Thickness of Ring or Bar
This indicates the thickness of the object being pulled and will determine the contact area with the finger(s) and the contract pressure
- Ring with 4 mm thickness
- Ring with 8 mm thickness
- Straight Bar with 8 mm thickness

Duration of Effort
This indicates how long it took to perform the finger pull
- less than 0.20 seconds or 200 ms
- between 0.2 and 0.6 seconds
- greater than 0.6 seconds or 600 ms



Pushes & Pulls

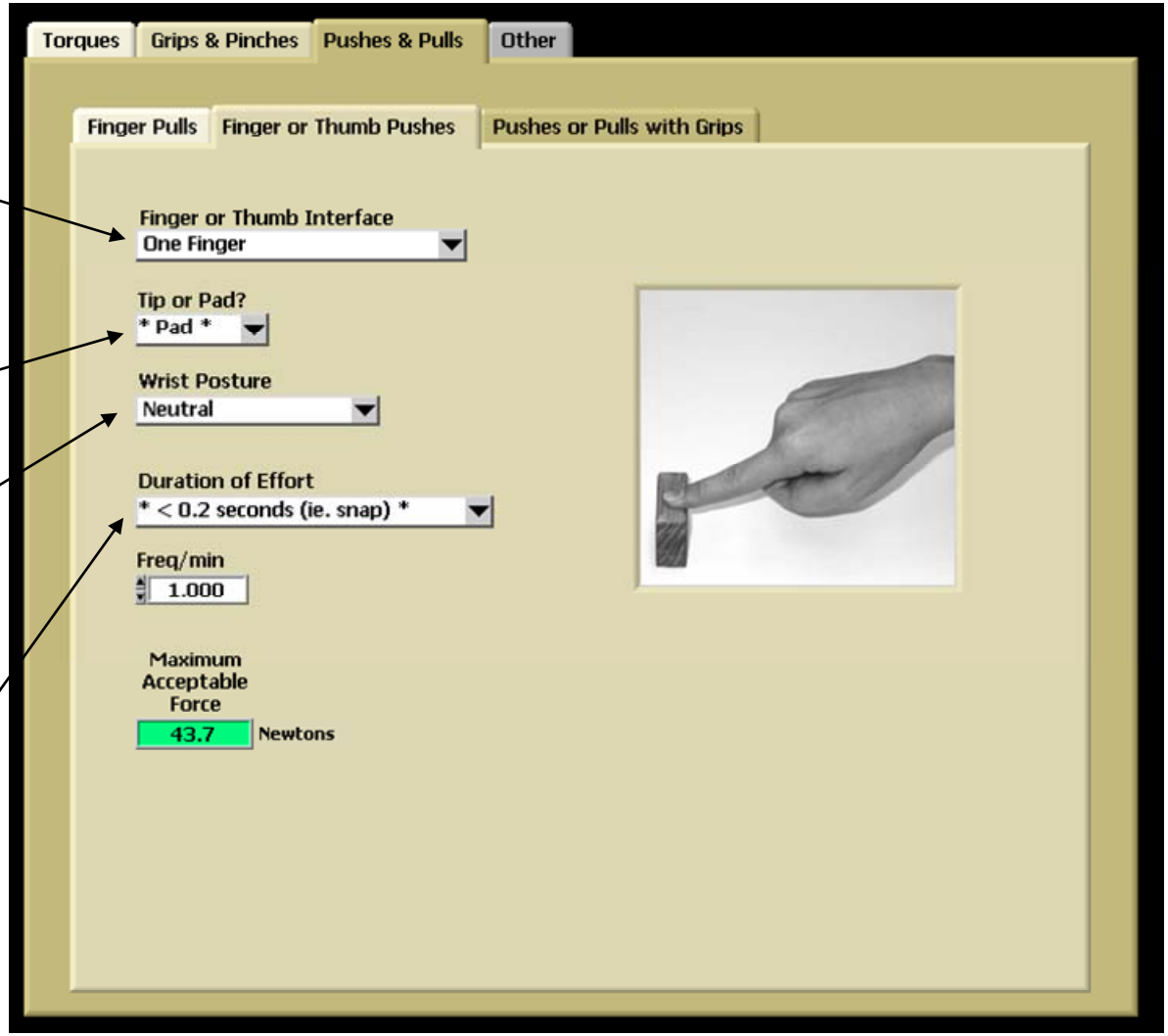
Finger or Thumb Pushes

Finger or Thumb Interface
- One Finger
- 2 Fingers from 1 Hand
- 1 Finger from Both Hands
- 2 Fingers from Both Hands
- One Thumb
- Two Thumbs

Tip or Pad?
This indicates whether the contact is with the tip (end) of the finger/thumb or with the pad
- Pad
- Tip

Wrist Posture during Push
- Neutral
- Extended
- Flexed
- Ulnar Deviated

Duration of Effort
This indicates how long it took to perform the push
- less than 0.20 seconds or 200 ms
- between 0.2 and 0.6 seconds
- greater than 0.6 seconds or 600 ms



Pushes or Pulls with Pinch Grips

The data from Potvin et al (2006), and the unpublished MVC data of Potvin et al (2005), were combined to determine female maximum strength and maximum acceptable forces for pulp pinch and lateral pinch pushes with neutral, extended, ulnar deviated and flexed wrist postures. Potvin et al (2005) studied 24 female subjects and determined maximum push strengths with pulp and lateral pinches in neutral and flexed postures. The ratios of pulp versus lateral push strength and flexed versus neutral wrist posture strength were used to estimate lateral pinch and/or flexed wrist MAFs based on the pulp pinch and/or neutral wrist MAFs of Potvin et al (2006). The data of Peebles & Norris (2003) and Greig & Wells (2004) were combined to allow for estimates of chuck pinch MAFs based on pulp pinch MAFs.

Pull values were estimated based on push versus pull strength ratios from Greig & Wells (2004) for pulp pinch and lateral pinch. Chuck pinches were assumed to have the same push versus pull ratios as pulp pinch. Corrections were made for pinch aperture (distance between opposing fingers) based on Imrhan & Rehman (1995). Male values were estimated based on female versus male strength ratios from Peebles & Norris (2003) for chuck pinches, from Greig & Wells (2004) for lateral pinches and from an integration of Peebles & Norris (2003) and Greig & Wells (2004) for pulp pinches, including different ratios with different apertures.

The maximum push and pull strength values were assumed to be those acceptable for one effort per day (f=0.002/min). For efforts at higher frequencies, further corrections were made based on the psychophysical data of Snook & Ciriello (1991), Potvin et al (2006), Andrews et al (2005). For further details, please see Appendix A.

Pushes & Pulls

Pushes or Pulls with Grips

- Pinches -

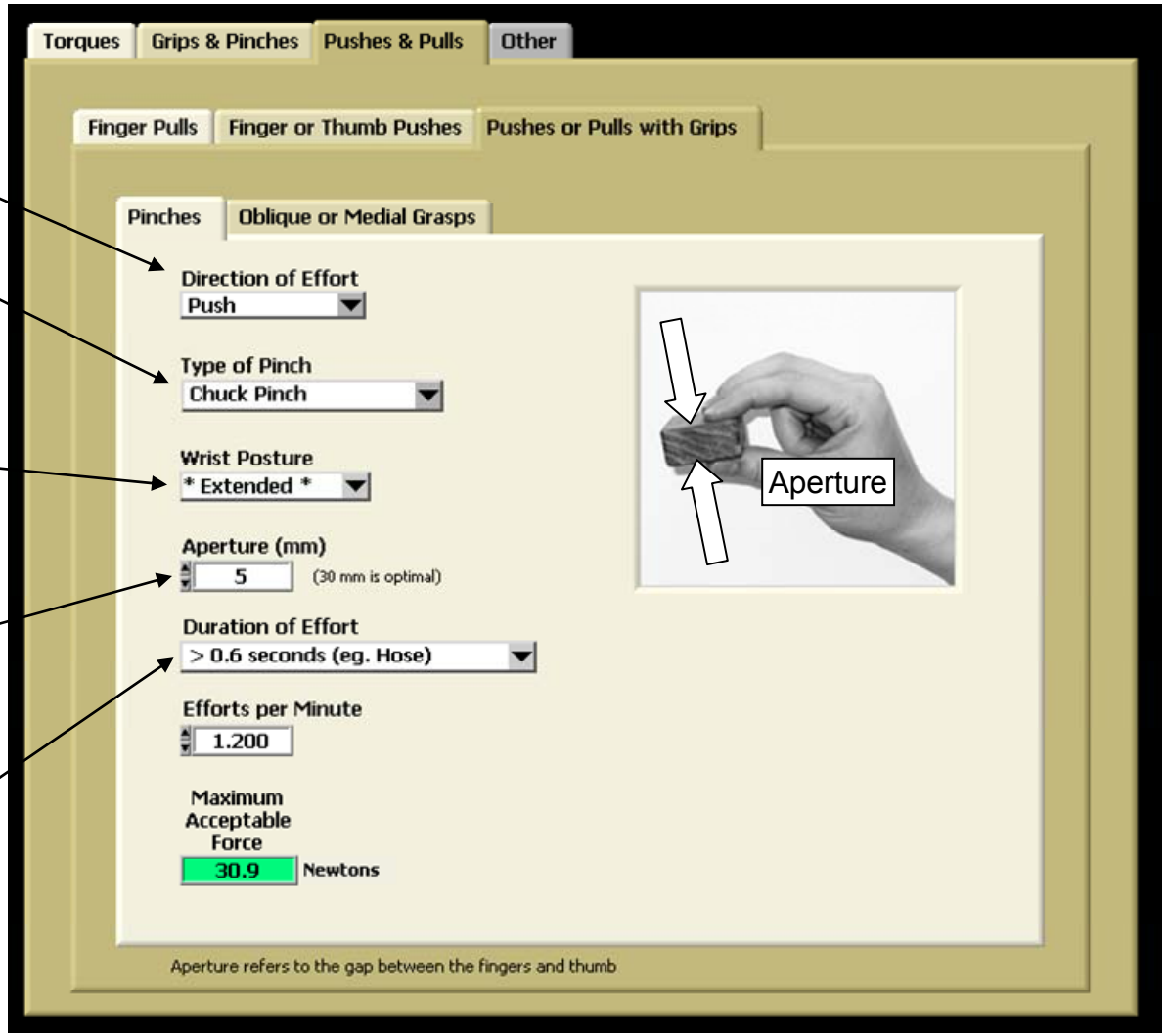
Direction of Effort
- Push
- Pull

Type of Pinch
- Chuck (Thumb vs Index & 2nd Finger)
- Pulp Pinch (Thumb vs Index Finger Pad)
- Lateral (Thumb vs Side of Index Finger)

Wrist Posture during Push
- Neutral
- Extended
- Flexed
- Ulnar Deviated

Aperture (see photo)
- this is the distance between the fingers and the specific value can be entered (mm)

Duration of Effort
This indicates how long it took to perform the effort
- less than 0.20 seconds or 200 ms
- between 0.2 and 0.6 seconds
- greater than 0.6 seconds or 600 ms



Pushes or Pulls with Oblique or Medial Grasps

The data of Teigrob et al (2006) were used to determine maximum forces for pushes with oblique grasps. That study measured strengths while pushing with the line of force directed through the elbow and shoulder, so that values would be limited by the ability of the hand to sustain a grip while pushing. As such, strength was not limited by shoulder or elbow joint strength. Consequently, the **HANDPAK** values, while acceptable to the hands, will often exceed the strength capacity of other joints. Thus, it is recommended that this software be used to determine the hand capacity, and other biomechanics software (eg. 3DSSPP) be used to evaluate the effect of the recommended force on other joints. In many cases, the final acceptable forces will be based on those other joints, and will be substantially lower than the **HANDPAK** value. Teigrob et all (2006) was also used to correct for surface (rubber or plastic) and for the aperture/diameter of the object interfacing with the hand. Diameter was found to have no effect on maximum push forces with a rubber coating, but corrections are made for diameter with a plastic coating. Maximum hand pushes can only be achieved with no moment arm at the shoulder and, to do this, the wrist has to be ulnar deviated. With any other wrist posture, there is a moment arm to the shoulder and the maximum force will undoubtedly be limited by the shoulder or elbow. Thus, no wrist posture effect was incorporated into the software.

Potvin et al (2005) studied 24 female subjects and determined maximum push strengths with oblique and medial grasps. These data were used to determine that medial grasp push forces are 93% of that for oblique grasp pushes. The data of Greig & Wells (2004) were used to estimate that male push and pull capacity was 60% higher than that for females.

The maximum push and pull strength values were assumed to be those acceptable for one effort per day (f=0.002/min). For efforts at higher frequencies, further corrections were made based on the psychophysical data of Snook & Ciriello (1991), Potvin et al (2006), Andrews et al (2005). For further details, please see Appendix A.

Pushes & Pulls

Pushes or Pulls with Grips

- Oblique or Medial Grasps -

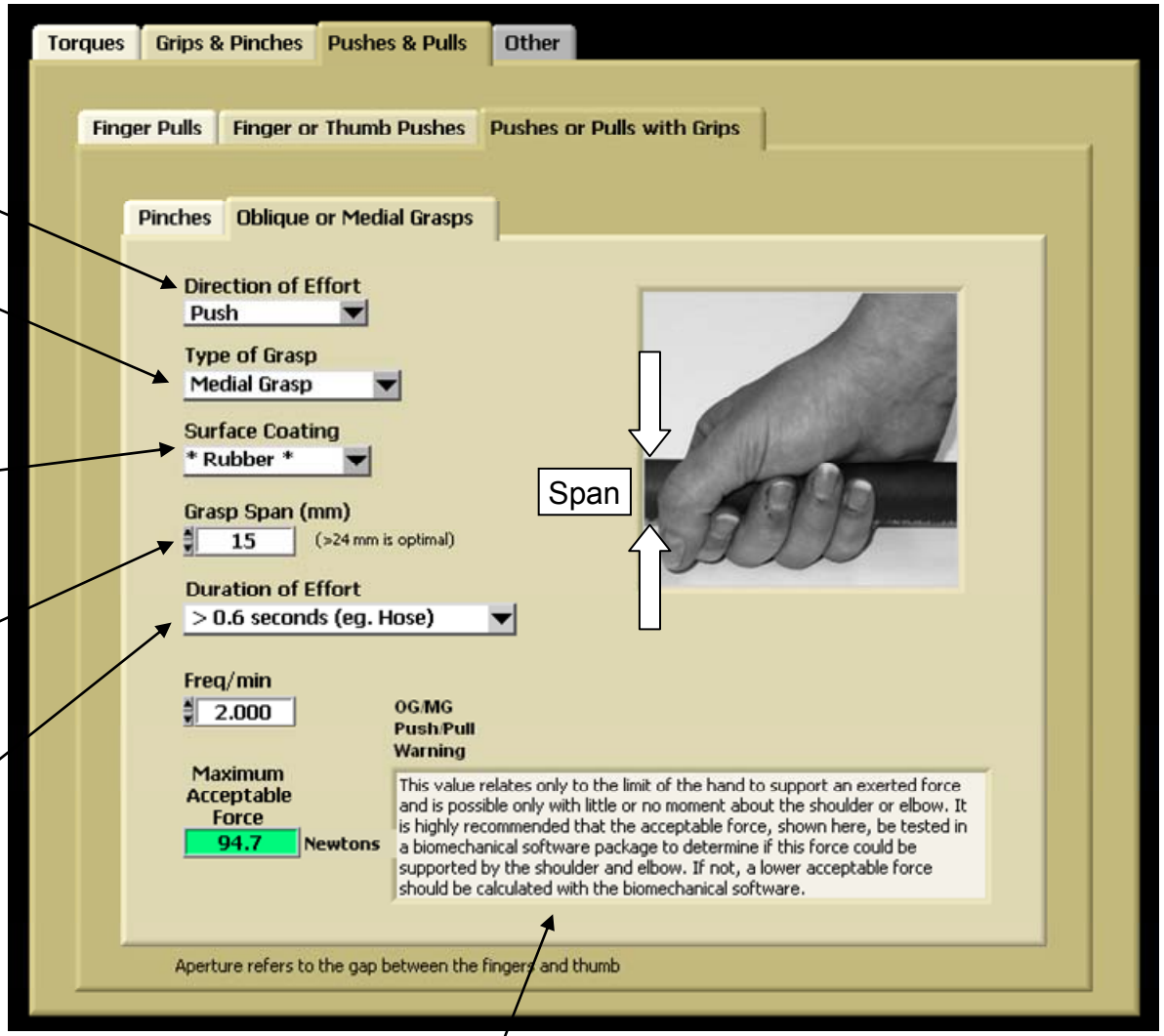
Direction of Effort
- Push
- Pull

Type of Grasp
- Oblique Grasp
  - Thumb points in forward direction
- Medial Grasp
  - Thumb wrapped with other fingers

Surface Coating
Indicates the frictional properties of the object being pushed
- Rubber
- Plastic

Graps Span (see photo)
- the specific value can be entered here in millimetres

Duration of Effort
This indicates how long it took to perform the effort
- less than 0.20 seconds or 200 ms
- between 0.2 and 0.6 seconds
- greater than 0.6 seconds or 600 ms



Warning
The recommended forces from HandPak only indicate hand capabilities. However, it is possible that this force may not be acceptable to some other joint. Thus, biomechanical software should be used in conjuction with this module.

APPENDIX

Frequency Effects

Generally, the maximum strength, or maximum voluntary contraction (MVC), values were used to represent acceptable forces for efforts performed once per day (frequency approximately 0.002/min). For efforts at frequencies between 0.002/min and 1/min, further corrections were made based on the psychophysical data of Snook & Ciriello (1991) who demonstrated a logarithmic decrease in acceptable force in this frequency range for manual materials handling.

At a frequency of 1/min, the data of Potvin et al (2006) and Andrews et al (2005) indicate that the maximum acceptable force (MAF) appears to be consistently close to 65% of maximum strength or MVC, regardless of the grip type or arm posture. This was also consistent with the data of Snook & Ciriello (1991). When averaged across all male and female lift, lower, push, pull and carry data, the average MAF at frequency of 1/min was 68.9±7.1% (n=240) of the value at a frequency of once per day.

For frequencies above 1/min, the psychophysical data of Potvin et al (2006) were used for relatively brief efforts (less than 0.20 s), and the data of Andrews et al (2005) was used for longer efforts (greater than 0.60 s). These studies indicate that the rate of MAF decrease, with increasing frequency, appears to depend on the duration of each effort, with a more pronounced frequency effect for longer efforts. An average of the corrections, based on Potvin et al (2006) and Andrews et al (2005), was taken to create an interpolated correction for effort durations between 0.2 and 0.6 s.

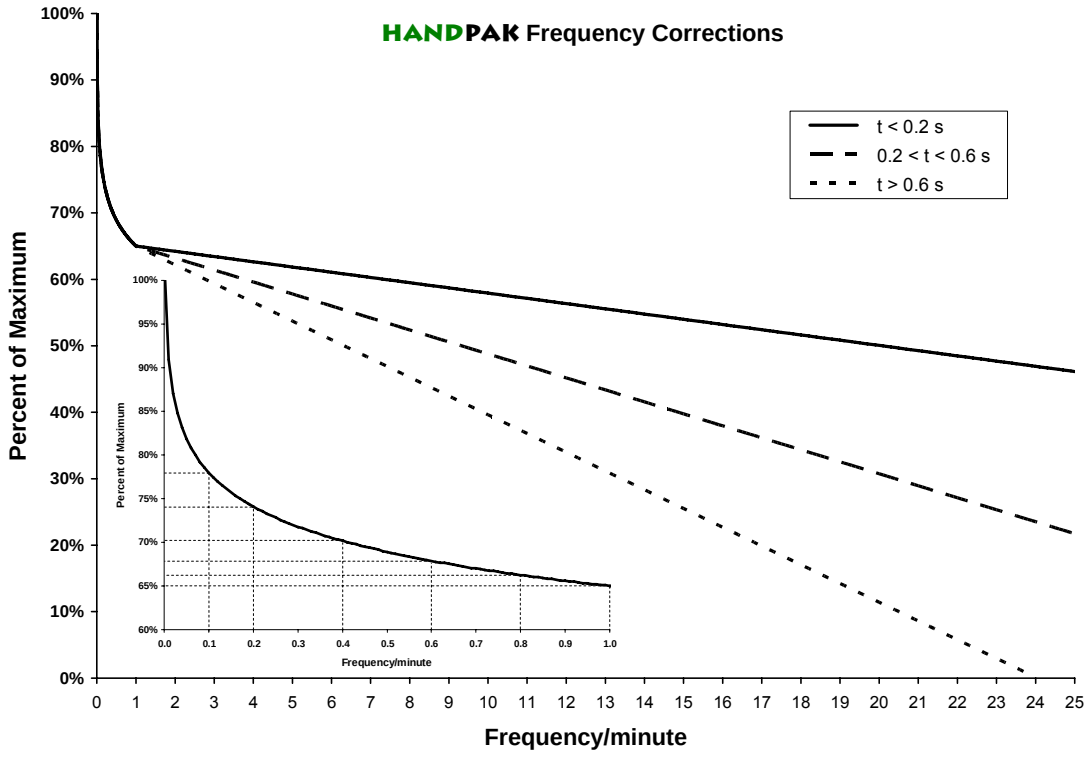


Figure 1: Summary of the frequency corrections for efforts less than 0.2 s (blue), greater than 0.6 s (red) and between those durations (green). The logarithmic decrease in acceptable force with frequencies between 0 and 1/min is inset.

REFERENCES

Andrews, D., Potvin, J.R., Calder, I,C., Cort, J.A., Loree, H., Agnew, M., Stephens, A. (2005) Acceptable peak forces and impulses during manual hose insertions. Proceeding of the International Society of Biomechanics, Cleveland, Ohio.

Ciriello,V.M., Webster,B.S., Dempsey,P.G. (2002) Maximal acceptable torques of highly repetitive screw driving, unlar deviation, and handgrip tasks for 7-hour workdays. *American Industrial Hygiene Association Journal*. 63, 594-604.

Cort, J.A., Stephens, A., Potvin, J.R. (2006). Maximum finger pull forces. *Proceedings of International Society of Ergonomics 2006 Congress*. Edited by R.N. Pikaar, E.A.P. Koningsveld and P.J.M. Settels. Elsevier Ltd.

DiDomenico, A., Nussbaum, M.A. (2003) Measurement and prediction of single and multi-digit finger strength. *Ergonomics*, 46(15), 1531-1548.

Fernandez, J.E., Dahalan, J.B., Halpern, C.A., Fredericks, T.K.,(1992). The effect of deviated wrist posture on pinch strength for females. In: *Advances in Industrial Ergonomics and Safety, vol. IV*, Taylor and Francis, London, pp. 693-700.

Greig, M., Wells, R. (2004) Measurement of prehensile grasp capabilities by a force and moment wrench: Methodological development and assessment of manual workers. *Ergonomics*. 47(1), 41–58.

Imrhan, S.N., (1991). The infuence of wrist position on different types of pinch strength. *Applied Ergonomics* 22, 379-384.

Imrhan, S.N., Loo, C.H., (1991). The influence of wrist position on different types of pinch strength. *Applied Ergonomics*, 22 (6), 379-384.

Imrhan, S.N., Rehman, R., (1995). The effects of pinch width on pinch strengths of adult males using realistic pinch-handle coupling. *International Journal of Industrial Ergonomics* 16, 123-134.

Kattel, B.P., Fredericks, T.K., Fernandez, J.E., Lee, D.C., (1996). The effect of upper-extremity posture on maximum grip strength. *International Journal of Industrial Ergonomics*, 18, 423-429.

Longo, N., Potvin, J.R., Stephens, A. (2002). A psychophysical analysis to determine acceptable forces for repetitive thumb insertions. *Proceedings of the Association of Canadian Ergonomists*.

Mathiowetz, V., Kashman, N., Volland, G., Weber, K., Dowe, M., Rogers, S., (1985*). Grip and pinch strength: normative data for adults. Archives* of Physical Medicine and Rehabilitation, 66, 69-74.

Mital, A., Kumar, S., (1998) Human muscle strength definitions, measurement, and usage: Part I - Guidelines for the practitioner. *International Journal of Industrial Ergonomics* 22 , 101-121.

O'Sullivan,L.W. and Gallwey,T.J. (2002) Upper-limb surface electro-myography at maximum supination and pronation torques: the effect of elbow and forearm angle. *Journal of Electromyography and Kinesiology*, 12, 275-285.

Peebles,l. and Norris B (2003) Filling in 'gaps' in strength data for design. *Applied Ergonomics*. 34, 73-88.

Potvin, J.R., Calder, I.C., Cort, J.A. (2005) Maximum forces with lateral pinch, pulp pinch, oblique grasp, medial grasp and finger tips in flexed and neutral wrist postures. *Unpublished*.

Potvin, J.R. Calder, I.C., Cort, J.A, Agnew, M.J., Stephens, A. (2006) Maximal acceptable forces for manual insertions using a pulp pinch, oblique grasp and finger press. *International Journal of Industrial Ergonomics*, 36, 779–787.

Snook, S.H., Ciriello, V.M., (1991). The design of manual handling tasks: revised tables of maximum acceptable weights and forces. *Ergonomics* 34(9), 1197-1213.

Snook,S.H., Vaillancourt,D.R., Ciriello,V.M., Webster,B.S. (1995) Psychophysical studies of repetitive wrist flexion and extension. *Ergonomics*, 38, 1488-1507.

Snook,S.H., Vaillancourt,D.R., Ciriello,V.M., and Webster,B.S. (1997) Maximum acceptable forces for repetitive ulnar deviation of the wrist. *American Industrial Hygiene Association Journal*, 58, 509-517.

Snook,S.H., Ciriello,V.M., Webster,B.S. (1999) Maximum acceptable forces for repetitive wrist extension with a pinch grip. *International Journal of Industrial Ergonomics*. 24, 579-590.

Teigrob, K., Cort, J.A., Stephens, A., Potvin, J.R. (2006) Maximum hose installations forces. *Proceedings of International Society of Ergonomics 2006 Congress*. Edited by R.N. Pikaar, E.A.P. Koningsveld and P.J.M. Settels. Elsevier Ltd.