CALIBRATION OF A HAND GRIPPER

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ABSTRACT

The following paper presents a unique method of testing grip strength by using a calibrated hand gripper. Part one of the paper describes the method for calibration of two types of hand grippers. Part two compares the readings obtained from the hand gripper to readings from a dynamometer in 45 hands. Part three compares gripper readings to dynamometer readings in a hand patient population and explores potential clinical application.

CALIBRATION OF A HAND GRIPPER

Hypothesis

In the past, some hand patients have been observed to have poor or inconsistent dynamometer readings, but seem quite able to use their injured hand in more dynamic activities such as squeezing putty or using a gripper hand-exerciser. It became useful then, to report patient's progress by documenting their performance with these devices. Particularly useful was the hand gripper because progressive amounts of resistance could be added to it in the form of rubber bands or steel springs.

Documenting patient performance on a hand gripper could be made much more useful if clinicians knew precisely how many pounds of force were required to move a gripper through its range of motion. By using a calibrated gripper, the patient could be tested without necessarily knowing that he was being tested.

The hypothesis presented by this paper is that there is a correlation between static dynamometer readings and dynamic gripper readings, and that a clinician can predict with a high degree of accuracy the grip strength of the patient from the calibrated gripper alone.

Method

The experiment was divided into three parts:

I. Calibration of two types of hand grippers;

II. Test and comparison of dynamometer and gripper readings on normal subjects;

III. Test and comparison of dynamometer and gripper readings on hand patients.

I. CALIBRATION OF THE HAND EXERCISERS

Two types of hand-exercisers were used. The first was a rubber band gripper, purchaseable at any of a number of suppliers. the gripper was suspended in a vice with one size 64 rubber band attached in the center. (See fig. 1.)

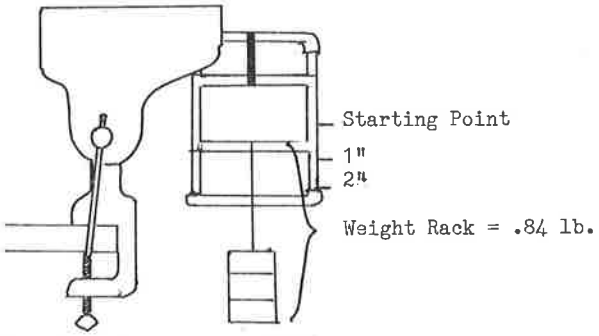


fig. 1 Rubber band gripper

A weight rack weighing .84 lbs. was hung on the movable bar of the gripper, the part normally pulled upon by the human hand. Weights were then attached until:

1. the bar moved 1"
2. the bar moved 2" or the full range of motion of the gripper.

The amount of weight was recorded at the 1" mark and again at the 2" mark. This process was repeated three times. Five size 64 rubber bands were added one at a time in a symmetrical fashion. Each time, three more measurements were taken at the 1" mark and again at the 2" mark. With the addition of four rubber bands, it was necessary to use two loaded weight racks to move the bands through 2". The weight recorded below equals the total weight of the weight rack(s) plus the weights.

1. weight rack = .84 lbs.
2. weight racks = 1.68 lbs.

Calibration of the rubber band exerciser recorded in pounds of force required to pull 1-5 rubber bands a distance of 1" or 2":

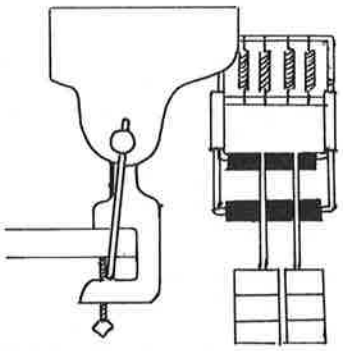
Number of bands:

Trial	1		2		3		4		5	
	1"	2"	1"	2"	1"	2"	1"	2"	1"	2"
1	6.84*	11.84	12.84	21.84	15.84	25.84	24.84	38.68	29.59	47.68
2	6.34	10.84	16.84	23.84	19.84	29.84	21.84	37.68	30.68	45.68
3	4.84	8.84	15.84	20.84	16.84	27.84	24.84	42.68	28.68	44.68
Avg:	5.17	10.51	15.71	22.17	17.17	28.17	23.84	39.68	29.58	45.01

* pounds

The second type of gripper tested was a steel spring gripper purchaseable from G. E. Miller. The experiment was repeated following the same format:

1. three trials for one spring
2. one spring added at a time with three trials for each additional spring



2 Weight Racks = 1.68 lb.

fig. 2 Steel spring gripper

Again, two weight racks were added as the resistance increased. See fig. 2. Following are recordings at 1" and 2" from the starting point for three trials for each spring.

No. springs:

Trial	1		2		3		4	
	1"	2"	1"	2"	1"	2"	1"	2"
1	12.84	17.84	26.84	36.84	39.84	54.68	49.68	72.68
2	12.84	17.84	26.84	36.84	39.84	54.68	49.68	72.68
3	12.84	17.84	26.84	36.84	39.84	54.68	49.68	72.68

One conclusion drawn at this point was that steel springs are more reliable than rubber bands. This is probably due to the manufacturing variance of rubber bands.

II. TEST AND COMPARISON OF DYNAMOMETER AND GRIPPER READINGS ON NORMAL SUBJECTS

The second part of this experiment tested dynamometer and gripper readings on normal subjects. The tests were followed by a comparison of dynamometer and gripper readings to see how well the gripper could predict dynamometer readings.

23 persons were selected at random ranging in age from 23 to 57. There were 15 females and 8 males. A total of 45 hands were tested to obtain the following data:

1. 5 dynamometer readings at the setting is approximately 2" wide and more closely resembles the starting point of the two grippers than any of the other four settings. The following readings were obtained from the dynamometer:
   a. the average or mean score
   b. the range in which the readings fell.
2. The maximum reading from the rubber band exerciser.
3. The maximum reading from the steel spring gripper.

If the subject was able to pull the gripper past the midpoint of 1" but not to the 2" mark, the reading was taken in terms of a range inch-pounds of force required to pull between one and two inches. For example, it requires 12.84 lbs. to pull one spring one inch, and 17.84 lbs. to pull one spring 2 inches. If a person pulled one spring 1.5 inches, we can ascertain that the force required to pull it that distance, was somewhere between 12.84 - 17.84 lbs.

If the subject was able to pull one spring exactly to the 1 inch mark, then the reading recorded was 12.84 lbs. The halfway mark was marked with a magic marker.

If the subject was able to pull one spring 2 full inches, the reading would not be recorded until the subject had tried the gripper with two springs. This way, only the maximum readings were recorded. The subject was considered to have pulled the movable bar the full two inches if either:

a. the movable bar touched the base,
b. the fingers touched the palm and no more motion was possible.

When the rubber band gripper was calibrated, averages of the three trials were calculated. Readings from the rubber band gripper were taken according to these averages. For example, if a subject pulled a rubber band gripper with four bands 1", the reading recorded was the average or 23.84 lbs. If a subject pulled four bands between 1-2", the reading was recorded as a range of the averages (23.84 - 39.68 lbs.).

In the above examples, all readings would have both a lower and upper limit; however, when testing subjects on a gripper with five bands or four steel springs, no upper limit could be set because the grippers were not calibrated beyond this point. In other words, if a subject was able to pull the rubber band gripper with five bands the full two inches, the reading was recorded as greater than (>) 46.01 lbs. If a subject was able to pull the steel spring gripper with four springs the full two inches, the reading was recorded as > 72.68 lbs. Both types of grippers had a maximum range of motion of 2".

Due to space constraints, the actual dynamometer and gripper readings for each of the 45 hands tested could not be included in this paper; however, an addendum is available on request.

To establish the accuracy of the grip strengths predicted from the gripper readings, comparisons were made:

1. between each subject's dynamometer and rubber band gripper readings,
2. between each subject's dynamometer and steel spring gripper readings.

It was found that in testing normal subjects, one person's dynamometer readings could deviate as much as 7 to 8 lbs. from the mean score. There could be as much as 15 lbs. difference between the lowest and highest score. For this reason, dynamometer readings were compared with gripper readings in terms of their range rather than in terms of a single number.

Figure 3 identifies the total number of grip strengths which were accurately predicted by the rubber band gripper as 39 out of 45(Total of column 1 and 2). This is equal to about 86.6% accuracy. The chart also identifies the number of grip strengths predicted by the gripper that lie within 5, 10, 15, and 20 lbs. of the dynamometer reading as 4 out of 45 or 8.9%.

In this first comparison between dynamometer and rubber band gripper measurements, the gripper predicted that 26 people had grip strengths over 46.01 lbs. This was, in fact, accurate, but the reader should note that in 20 of these cases, the gripper calibration did not predict the upper limit of the range because it had not been calibrated beyond 5 rubber bands. These cases have been indicated in Fig. 3 with an asterisk and placed in columns according to how far beyond 46.01 lbs. the readings fell when compared to the dynamometer.

Figure 4 identifies the total number of grip strengths which were accurately predicted by the steel spring gripper. (Total of column 1 and 2) In this comparison between steel spring gripper readings and dynamometer readings, 35 out of 45 or 77.7% of the cases were accurately predicted by the gripper. Four of these cases were accurately predicted to be above 72.68 lbs. but had no upper limit because the gripper had not been calibrated beyond 4 steel springs.

These cases are identified by asterisks in fig. 4 and placed in columns according to how far beyond 72.68 lbs. they fell when compared to the dynamometer. 10 out of 45 or 22% of the readings were found to be within 5 or 10 lbs. of the dynamometer readings.

III. TEST AND COMPARISON OF DYNAMOMETER READINGS TO BOTH RUBBER BAND AND STEEL SPRING GRIPPER READINGS IN A HAND PATIENT POPULATION

The injured hands of eight subjects were tested in a manner identical to that of the normal subjects.

1. 5 dynamometer readings
   a. mean
   b. range
2. maximum reading from the rubber band gripper
3. maximum reading from the steel spring gripper.

The results of this data are in the addendum which is available on request. Fig. 5 indicates 9 out of 16 or 56.25% of the gripper readings were either accurate of overlapped with the dynamometer readings. 6 out of 16 or 37.5% of the gripper readings fell within 5,10, or 15 lbs. of the dynamometer readings. 1 out of 16 or 6.2% fell in the "over 20 lb. difference" category.

There appears to be a significant difference between the outcome of the gripper-dynamometer comparison on normals versus hand-patients. Some problems which may account for the difference include the following:

a. Size of sample (needs to be larger).
b. Not all the patients had full range of motion. Limited range of motion would prevent a patient from pulling the full two inches regardless of how many rubber bands or springs were attached.
c. The fatigue factor may have been greater in the hand patients. All participants were asked to perform the testing sequence without a break.

It is clear that another study must be completed, taking into consideration the above factors in order for accurate conclusions to be drawn regarding the hand patient population.

Clinical Application and Conclusion

In conclusion, it appears that the rubber band grippers can be calibrated reliably and can be used to predict dynamometer readings with 86.6% accuracy in a normal population. The steel spring gripper can also be calibrated reliably and in this study, predicted dynamometer readings with 77.7% accuracy.

There also appears to be great potential for using this method with hand patients to detect withholding of maximum effort. If, for example, a patient consistently pulls four springs between 1 and 2 inches and has dynamometer readings which are in the 10-20 lb. ranges, one could question whether the patient was exerting maximal voluntary effort on the dynamometer, a device known to the patient as a testing device. The patient is probably more likely to behave more naturally when tested without his knowledge that he is being tested.

Conversely, by using calibrations, a therapist is able to set the gripper at the proper amount of resistance for beginning a graded resistive exercise program to increase grip strength. The patient can then participate in an exercise which is mild enough to be safe for him, yet resistive enough to be therapeutically beneficial.

fig. 3 ACCURACY OF PREDICTION OF RUBBER BAND GRIPPER
(WHEN COMPARED WITH DYNAMOMETER READINGS)

ACCURACY: 86.6%

NORMAL SUBJECTS No. of bands/distance	No. of accurate predictions	Overlap	Within 5 lbs.	Within 10 lbs.	Within 15 lbs.	Within 20 lbs.	Over 20
5 bands/2"	20	5	2 4*	2*	2*	5*	7*
5 bands/1 - 2"	5	10	2		1		
5 bands/1"	1				1		
4 bands/2"							
4 bands/1 - 2"							
4 bands/1"							
3 bands/2"							
3 bands/1 - 2"							
3 bands/1"							
2 bands/2"							
2 bands/1 - 2"							
2 bands/1"							
1 band/2"							
1 band/1 - 2"							
1 band/1"							
TOTALS	26	13	4		2		

Sample consists of 45 hands, 39 out of 45 readings fell into the accurate or some overlap categories. This is equal to 86.6%

* These numbers reflect those cases accurately predicted to be over 46.01 lbs. The upper limit could not be predicted because the gripper was not calibrated past 5

fig. 4 ACCURACY OF PREDICTIONS OF STEEL SPRING GRIPPER
(WHEN COMPARED WITH DYNAMOMETER READINGS)

ACCURACY: 77.7%

NORMAL SUBJECTS No. of springs/distance	No. of accurate predictions	Overlap	Within 5 lbs.	Within 10 lbs.	Within 15 lbs.	Within 20 lbs.	Over 20
4 springs/2"	6	1	1 2*	1*	1*	1*	1*
4 springs/1 - 2"	5	6		1			
4 springs/1"	1		1				
3 springs/2"	1						
3 springs/1 - 2"	5	5	1				
3 springs/1"	3		3	3			
2 springs/2"	1						
2 springs/1 - 2"		2					
2 springs/1"							
1 spring/2"							
1 spring/1 - 2"							
1 spring/1"							
TOTALS	22	13	6	4			

Sample consists of 45 hands. 35 of 45 readings fell into the accurate or overlap categories. This is equal to 77.7%

*Reflect incidence of cases accurately predicted to be over 72.68 lbs. The upper limit could not be predicted because the gripper was not calibrated beyond 4 springs.

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fig. 5 ACCURACY OF PREDICTION OF RUBBER BAND AND STEEL SPRING GRIPPER READINGS (WHEN COMPARED WITH DYNAMOMETER)

HAND PATIENT POPULATION

*+ tested on rubber band gripper
++ tested on steel spring gripper

No. of bands or springs/distance	No. of accurate predictions	Overlap	Within 5 lbs	Within 10 lbs	Within 15 lbs	Within 20 lbs	Over 20 lbs
5/2"	+fx 5th met +fracture	+crush				(*fracture)	
5/1 - 2"				+extensor tendon repair			
5/1"	*amputation		+Dupuytren's				
4/2"							
4/1 - 2"	++fracture	++fx 5th met.					
4/1"							
3/2"							
3/1 - 2"			++extensor tendon repair				
3/1"				++amputation	+thumb crush		
2/2"							
2/1 - 2"	+wrist fx	(borderline) ++Dupuytren's					
2/1"				++crush			
1/2"							
1/1 - 2"		++wrist fx					
1/1"							++thumb
TOTALS	5	4	2	3	1		1

Samples consist of 16 injured hands. 9 of 16 fall into the accurate or overlap categories. (56.25%)
*Represents those cases without an upper limit.

REFERENCE LIST

Matheson, Ph.D., Leonard N. (1984). Work Capacity Evaluation. Anaheim, California: E.R.I.C.

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ADDENDUM

The following data was used to formulate the statistics in the scientific paper "Calibration of a Hand Gripper" presented at the National Forum on Vocational Issues; Dallas, Texas, 1986.

SAMPLE: 45 normal hands
8 injured hands

DATA TAKEN:

1. Five dynamometer readings (pounds/force)
2. Average dynamometer reading (pounds/force)
3. Range of Dynamometer readings (pounds/force)
4. Maximum rubber band gripper reading (pounds/force)
5. Maximum steel spring gripper reading (pounds/force)

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NORMAL SUBJECTS

Subject No. 1:

Five Dynamometer Readings: 65,50,58,58,58 (lbs.)

Average Grip Strength: 57.8 (lbs.)

Range of Dynamometer Readings: 50 - 65 (lbs.)

No. of rubber bands/distance/force required: 5/2" > 46.01 (lbs.)

No. of steel springs/distance/force required: 3/2" 54.68 (lbs.)

(Subject No.) 2: 80,66,69,70,75

68

66 - 80

5/2" > 46.01

4/1 - 2" 49.68 - 72.68

3: 44,46,40,36,40

41.2

36 - 46

5/2" > 46.01

3/1 - 2" 39.84 - 49.68

4: 55,60,59,56,50

56

50 - 60

5/2" > 46.01

4/ 1 - 2" 49.68 - 72.68

5: 35,40,37,40,40

38.4

35 - 40

5/1 - 2" 29.68 - 46.01

3/1" 39.84

6: 45,50,50,54,50
49.8
45 - 54
5/2" > 46.01
3/1 - 2" 39.84 - 54.68

7: 86,85,81,74,76
80.4
74 - 86
5/2" > 46.01
4/2" > 72.68

8: 98,110,100,98,92
99.6
92 - 110
5/2" > 46.01
4/2" > 72.68

9: 45,55,50,45,50
49
45 - 55
5/1 - 2" 29.68 - 46.01
3/1" 39.84

10: 50,35,55,40,35
43
35 - 55
5/1 - 2" 29.68 - 46.01
3/1 - 2" 39.84 - 54.68

11: 55,52,50,55,44
51
44 - 55
5/2" > 46.01
3/1" 39.84

12: 48,35,40,42,40
41
35 - 48
5/1 - 2" 29.68 - 46.01
3/1" 39.84

13: 100,85,85,75,78
84.6
75 - 100
5/2" > 46.01
4/2" > 72.68

14: 115,95,95,105,100
102
95 - 115
5/2" > 46.01
4/2" > 72.68

15: 45,38,38,32,30
36.6
30 - 45
5/2" >46.01
3/1 - 2" 39.84 - 54.68

16: 45,45,52,47,45
46.8
45 - 52
5/2" > 46.01
4/1" 49.68

17: 80,80,93,95,95
88
80 - 95
5/2" > 46.01
4/2" > 72.68

18: 86,100,95,110,98
97.8
86 - 110
5/2" > 46.01
4/2" > 72.68

19: 54,47,45,50,48,20
48.8
45 - 54
5/1 - 2" 29.68 - 46.01
3/1 - 2" 39.84 - 54.68

20: 57,55,45,49,48
50.8
45 - 57
5/1 - 2" 29.68 - 46.01
3/1" 39.84

21: 35,41,39,44,41
40
35 - 44
5/1 - 2" 29.68 - 46.01
2/1 - 2" 26.84 - 36.84

22: 47,46,47,45,48
46.6
45 - 48
5/1 - 2" 29.68 - 46.01
3/1 - 2" 39.84 - 54.68

23: 36,40,40,46,41
40.6
36 - 46
5/1 - 2" 29.68 - 46.01
2/1 - 2" 26.84 - 36.84

24: 47,50,54,48,46
49
46 - 54
5/1 - 2" 29.68 - 46.01
3/1 - 2" 39.84 - 54.68

25: 46,51,50,46,41
46.8
41 - 50
5/1 - 2" 29.68 - 46.01
3/1 - 2" 39.84 - 54.68

26: 60,63,59,59,53
58.8
53 - 63
5/2" > 46.01
4/1 - 2" 49.68 - 72.68

27: 66,71,73,68,66
68.8
66 - 73
5/2" > 46.01
4/1 - 2" 49.68 - 72.68

28: 86,79,84,83,80
82.4
79 - 86
5/2" > 46.01
4/1 - 2" 49.68 - 72.68

29: 70,58,50,55,55
57
50 - 70
5/2" > 46.01
4/1 - 2" 49.68 - 72.68

30: 85,79,65,60,50
66.5
50 - 85
5/2" > 460.1
4/1 - 2" 49.68 - 72.68

31: 45,40,40,40,40
41
40 - 45
5/1 - 2" 29.68 - 46.01
3/1 - 2" 39.84 - 54.68

32: 55,45,40,45,40
45
40 - 45
5/1 - 2" 29.68 - 46.01
3/1" 39.84

33: 70,60,70,55,58
62.6
55 - 70
5/2" > 46.01
4/2" > 72.68

34: 65,70,78,77,77
73.4
65 - 78
5/2" > 46.01
4/2" > 72.68

35: 55,55,54,50,48
52.4
48 - 55
5/1 - 2" 29.68 - 46.01
3/1 - 2" 39.84 - 54.68

36: 65,60,60,60,58
60.5
58 - 65
5/1 - 2" 29.68 - 46.01
3/1 - 2" 39.84 - 54.68

37: 46,45,38,35,45
41.8
35 - 46
5/1 - 2" 29.68 - 46.01
2/2" 36.84

38: 54,50,48,45,45
48.4
45 - 54
5/1 - 2" 29.68 - 46.01
3/1" 39.84

39: 70,65,55,60,50
60
50 - 70
5/1 - 2" 29.68 - 46.01
4/1" 49.68

40: 80,65,58,74,72
69.8
58 - 80
5/2" > 46.01
4/1 - 2" 49.68 - 72.68

41: 45,28,45,35,48
40.2
28 - 48
5/1" 29.68
3/1" 39.84

42: 50,45,55,40,45
47
40 - 55
5/1" 29.68
3/1" 39.84

43: 68,65,70,68,70
68.2
65 - 70
5/2" > 46.01
4/1 - 2" 49.68 - 72.68

44: 68,70,65,68,65
66
65 - 70
5/2" > 46.01
4/1 - 2" 49.68 - 72.68

45: 60,70,72,77,70
69.8
60 - 77
5/2" > 46.01
4/1 - 2" 49.68 - 72.68

1. Dupuytren's Contracture: 10,16,18,24,26

   Average Grip Strength: 18.8 (lbs.)

   Range of Dynamometer Readings: 10 - 26 (lbs.)

   No. or rubber bands/distance/force required: 5/1" 29.68

   No. of steel springsdistance/force required: 2/1 - 2" 26.84 - 36.84

2. Amputations digits 3,4 to PIP: 30,30,28,33,30,34

   30.8

   28 - 34

   5/1" 29.68

   3/1" 39.84

3. Comminuted finger fx (index): 65,65,65,70,64

   65.8

   64 - 70

   5/2" > 46.01

   4/1 - 2" 49.68 - 72.68

4. Crush injury: 60,55,55,45,35

   50

   35 - 60

   5/2" > 46.01

   2/1" 26.84

5. Stiff right index secondary to extensor tendon repair: 55,64,64,69,68

   64

   55 - 69

   5/1 - 2" 29.68 - 46.01

   3/1 - 2" 39.84 - 54.68

6. Left thumb crush injury:	40,31,37,35,35
	35.6
	31 - 40
	3/1" 17.17
	1/ < 1" < 12.84
7. Left comminuted wrist fracture:	21,24,20,16,16
	19.4
	16 - 21
	2/1 - 2" 15.17 - 22.17
	1/1 - 2" 12.84 - 17.84
8. Fracture 5th metacarpal:	84,88,70,87,94
	84.3
	70 - 94
	5/2" > 46.01
	4/1 - 2" 49.68 - 72.68