The Effective Contact Area in Grasp and its Relationship to Quality of Grip, For Persons with Tetraplegia

RY Flynn, TRD Scott, JM Heasman, A Long, V Vare, L Ada, B van Deurzen,
Quadriplegic Hand Research Unit, Royal North Shore Hospital, St Leonards NSW 2065 Australia E-mail: rfly3835@usyd.edu.au

Abstract

A quantitative analysis of physical aspects of grasp and their contribution to its effectiveness was made. By evaluating the influence of these physical parameters to hand grasp, increasingly effective modes of grasp can be determined. This is especially relevant in the creation of an artificial grasp in persons with tetraplegia via interventional techniques [such as electrical stimulation and tendon transfers]. This study examined the sensitivity of grasp to changes in contact area between the skin and the grasped object. The maximum holding force was measured in persons with tetraplegia (ASIA C_5 and C_6). A servomotor applied an increasing force to an object held by the hand until the object was pulled from the hand. The effective skin - object contact area was varied with the application of three types of surfaces to the object. Thereby, a quantitative measure was made of the sensitivity of grasp to this parameter. The effectiveness of the grip was highly sensitive to contact area [4/4 subjects], and the relationship of effective contact area/holding force was evaluated. Further investigation using a functional test supported this.

Keywords*:* 1. Hand grasp 2. Tetraplegia 3. Contact area 4. GRT 5. Holding force

1. Introduction

Modes of hand grasp have been qualitatively classified using varying criteria. Examples of such classifications are those made according to the intended activity to be performed [1] or the influence of the object's shape and size on the grip [2]. The effectiveness of a particular mode of grasp relies on a number of physical factors working in concert. These might include contact at the hand - object interface, range of movement at particular joints and wrist extensor strength.

The aim of this study was to evaluate the contribution of effective contact area to hand grip. The sensitivity of grip to varying contact area has been evaluated to achieve this. Such an investigation will assist in the development of the most effective configurations in electrically stimulated hand grasps in the future.

2. Materials and Methods

Four subjects with tetraplegia at C5 and C6 motor level participated in this study to assess the influence of contact area on hand function. All subjects had some wrist extension, which enabled them to grasp and hold objects by using a tenodesis grasp. Table 1, lists the characteristics of the subjects tested.

Subject	Age	Gender	Injury level	Hand tested
1	51	M	C6	Right
2	21	M	C6	Right
3	29	M	C5	Right
4	29	F	C5	Right

Table 1: Characteristics of subjects

Prior to and at the completion of testing three grip strength measurements were taken with an instrumented cylinder. These measurements were taken to assess the presence of fatigue.

Subjects were positioned in a splint as pictured in Figure 1 after their hands were washed with soap and water and dried thoroughly. Such a protocol ensured to standardise the skin surface between subjects.

The servomotor situated distal to the hand generated force at a rate increasing at 2N/s to the object, which was held by the hand. The servomotor was controlled by custom designed software. The object was a polycarbonate cylinder, which simulated a juice can.

Three types of surfaces were tested on the can which altered the contact area. These included the normal polycarbonate surface, dycen, (which increased the effective contact area) and talc, (which decreased the contact area). The hand was washed between application of different surfaces. The object was similar in dimensions to the one used in the functional test developed by Wuolle et al., [Grasp and Release Test: GRT] but of reduced weight. The surfaces on the can were randomly tested with three to five trials each. In order to reduce fatigue there was a two-minute rest period between trials.

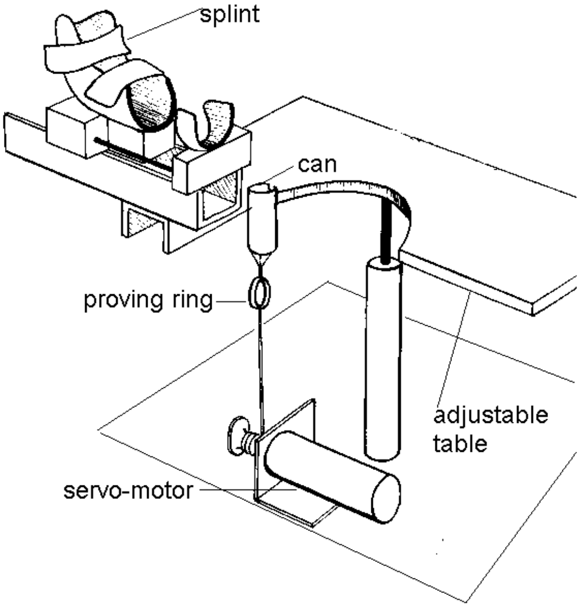


Figure 1. Servomotor set up used to measure effectiveness of grasp

Attached to the can was an instrumented proving ring which measured the motor force as the can was pulled from the hand by the servomotor. The signal measured was passed to an acquisition board (National Instruments PCI-MIO50XE). Data sampling was controlled by LabView software (National Instruments) running on a personal computer (Power Macintosh 9500) and sampled at 250 Hz. The holding force was measured from the proving ring. The maximum holding force was determined as the maximum force generated by the motor before the can slipped out of the hand).

Subsequently, subjects were tested using the GRT functional test with the can. The subjects were tested in a similar manner to the GRT testing protocol except the surface on the can was again modified. The three surfaces were again;

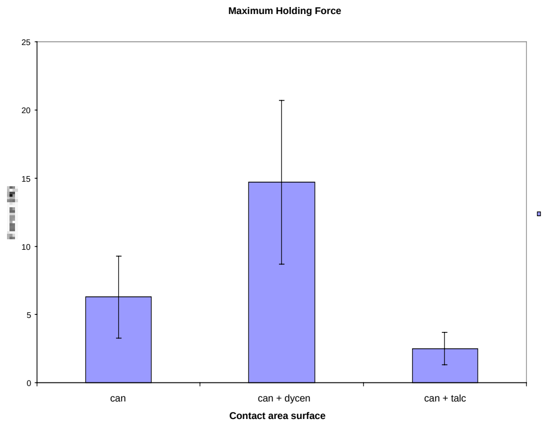
-the normal polycarbonate can
-dycen to increase the effective contact area
-and talc to decrease the effective contact area on the can.

In the GRT, subjects are required to move the can as many times as possible (in a thirty second period), from a starting position on the board to another specified position. The can must also remain in an upright position.

3. Results

All results are expressed as mean ± standard error with n = number of tests. Student T-Test was used for significance testing with $p<0.05$ indicating significance unless otherwise stated.

In all 4 subjects there was a significant increase in the maximum holding force when the contact area was increased with the use of dycen in comparison to talc and normal surface.



Graph 1: Maximum holding force with changes in contact area

With the increase in effective contact area on the can by the application of dycen the maximum holding force increased significantly [$P(T\leq t)<0.006$] from (6.3N ± 3 n=21) to (14.2N ± 6 n=20). With the decrease in effective contact area, using talc, the maximum holding force decreased significantly [$P(T\leq t)<0.02$] from (6.3N ± 3 n=21) to (2.5N ± 1.2 n=19).

In the GRT with subjects using the can from the test kit, only subject 1 was able to perform the test [at a 75% success rate]. With the application of the dycen to the can Subject 2 & 3 achieved a 100% success rate. Using the light can object from the previously described experiments, Subject 4 was unable to lift and place the can at all. Yet, with the application of dycen to increase the contact area this subject achieved a 100% success rate.

4. Discussion

Using increased effective contact area to improve hand grasp may enable people with tetraplegia to increase their hand function. Electrical configurations that improve contact area without actually increasing grasp force may be beneficial. If the muscles can be stimulated at a lesser force this may reduce the risk of grasp failure due to muscle fatigue.

By quantifying the relationship of contact area and its contributions to effective hand grip, modifications to the grasp can be objectively analysed and validated.

As such, improvements in contact area and the consequent grasp will be identified more easily and enable other physical parameters [such as joint range of movement and wrist extensor strength] of grip to be investigated and manipulated.

5. Conclusion

The quantitative analysis of contact at the object hand interface in people with tetraplegia clearly demonstrated that increased contact area significantly improved the maximum holding force of the grasp. This was also verified in the functional test [using the GRT].

6. References

[1] Napier JR, (1956) The prehensile movements of the human hand. *J Bone Joint Surg.* 38 - B pp. 902 - 913

[2] Landsmeer JMF, (1962) Power grip and precision handling, *Ann Rheum Dis.* pp. 164 - 170

[3] Wuolle KS, Van Doren CL, Thrope GB, Keith MW, Peckham PH. (1994) Development of a quantitative hand grasp and release test for patients with tetraplegia using hand neuroprosthesis. *The Jour of Hand Sur.* pp. 209 -217.

Acknowledgments: The authors would like to acknowledge the support of the Motor Accidents Authority of NSW, the Movement Disorder Foundation, The Spinal Research Foundation, the Cecilia Kilkeary Foundation and the Northern Sydney Area Health Service Research Grants Scheme. Special thanks also to Mr Kevin Brigden.