How accurately does a simulation glove reflect function compared to rheumatoid arthritis sufferers?

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ABSTRACT

INTRODUCTION This study assessed the ability of gloves to simulate rheumatoid arthritis of the hand.

SUBJECTS AND METHODS Assessments were made in the dominant hand of 24 healthy volunteers with no glove, glove A (simulating stiffness only) and glove B (simulating stiffness and pain). Results were compared to data held on 23 rheumatoid arthritis patients. Sollerman score was used as a standardised measure of hand function and time taken to complete testing was recorded. Grip strength was also measured in volunteers.

RESULTS Both gloves simulate a reduction in power and prolong time taken to complete Sollerman hand-function testing. The gloves are less able to simulate a matched reduction in function when compared to rheumatoid arthritis sufferers. Sollerman score is 9.7% less in rheumatoid arthritis hands than a healthy volunteer using the glove.

CONCLUSIONS The glove could, therefore, be used to guide future design of tools and aides that accommodate for hand disorders. More work on the usefulness of such disease simulation in the design of tools for such patients is needed.

KEYWORDS

Rheumatoid arthritis – Simulation – Glove – Sollerman hand function

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Rheumatoid arthritis is a chronic, progressive and disabling autoimmune disease with a prevalence of 1%.¹ It affects multiple joints in the body, but especially the small joints of the hand. Such inflammation causes degeneration of the joints which leads to pain and stiffness, particularly during use. The Department of Orthopaedic Surgery in Leicester together with Loughborough University Ergonomics and Safety Research Institute (ESRI) have designed and subsequently evaluated a glove designed to simulate impaired hand function, and thus replicate the effects of a rheumatoid patient's joint stiffness. Such a glove with scientifically based impairment similar to that in rheumatoid arthritis hands would be useful to manufacturers wishing to design products better suited for patients with rheumatoid arthritis.

ESRI was commissioned by Napp Pharmaceuticals Limited to develop a whole-body simulation of arthritis. The simulation included a pair of gloves designed to replicate aspects of impaired function (Figs 1 and 2). Glove A reduces palmar flexion. This is accomplished by incorporating thickened material into the palmar aspect of the glove at the level of the metacarpophalangeal (MCP) joint line of the digits. Glove B also reduced palmar flexion. In addition, it is designed to imitate discomfort across the MCP

and distal interphalangeal (DIP) joints of the digits and the CMC (carpometacarpal) joint of the thumb. This is achieved by the addition of roughened material within the glove to cause moderate discomfort over the volar aspects of joint lines. Both gloves appear identical exteriorly. It was postulated that this impairment of function, by way of stiffness and discomfort, could mimic the difficulties encountered by rheumatoid arthritis sufferers.

The objective of the study was, therefore, to assess scientifically how accurately the gloves simulate rheumatoid arthritis of the hand when compared to known patients suffering rheumatoid arthritis of the hands. We also wished to explore scientifically what aspects of reduced hand function are best matched to rheumatoid arthritis patients. There are currently no other gloves in production designed for such simulation and there are, therefore, no similar comparable studies.

Subjects and Methods

The Nottingham Research Ethics Committee approved the project. The protocol was peer reviewed and funding for the project secured via the MRC IDBA (Inter Disciplinary

Figure 1 Glove A illustrating the thickened material across the MCP joints.

Bridging Awards). Further to this, the glove was tested for health and safety, being approved by the medical physics team at UHL (University Hospitals Leicester).

The project aimed to test how effectively the glove simulates rheumatoid arthritis of the hand by matching it against clinical data held on rheumatoid arthritis sufferers using the Sollerman hand function score as a standardised

Figure 2 Glove A undergoing Sollerman hand-function testing.

test of hand function.² The Sollerman test has been shown to be an accurate and reproducible method of measuring overall hand function.²⁻⁴ Sollerman score assesses 20 activities of daily living using eight grip types (Fig. 3 and Tables 1-5). Each subtest is scored on a 5-point scale (0-4; Table 2), with a maximum score of 80 points for the dominant hand. Of the 20 tasks, 17 are unilateral and three bilateral. As the upper time limit for each activity is 1 min, the test can usually be completed within 20 min.

Table 1 The 20 activities of daily living assessed via the Sollerman hand-function tests and the grips used

TASK	GRIP TESTED
1 Turn key	Pulp and lateral pinch
2 Pick up coins and put in purse	Pulp pinch
3 Open and close purse zip	Pulp and lateral pinch
4 Pick up coins from purse	Pulp pinch
5 Pick up wooden blocks	Five finger pinch
6 Lift iron from box	Transverse volar, hand pronated
7 Turn screw with screwdriver	Diagonal volar grip
8 Pick up nuts and put on bolts	Pulp, lateral and tripod pinch
9 Unscrew jar lids	Spherical volar grip
10 Do up buttons on clothing	Pulp and lateral pinch
11 Cut plasticine	Tripod and diagonal volar
12 Put Tubi-Grip stocking on the other hand	Lateral and five finger pinch
13 Write with a pen	Tripod pinch
14 Fold paper and put in envelope	Five finger and lateral pinch
15 Attach paper clips to envelope	Pulp and lateral pinch
16 Pick up telephone and put to ear	Diagonal volar grip
17 Turn handle	Transverse volar grip
18 Pour water into jug	Five finger pinch
19 Pour water from jug to cup	Transverse volar grip
20 Pour water from cup	Pulp and lateral pinch

Table 2 Methods of score allocation to the Sollerman hand-function test (applies to all tasks)

4 points	No difficulty, within 20 s, correct grip
3 points	Slight difficulty or 20-40 s or slight divergence from normal grip
2 points	Completed but with great difficulty or 40-60 s or not correct grip
1 points	Partially performed within 60 s
0 points	Task cannot be performed at all

Table 3 Grip types tested by task

Grip type	Task numbers assessing that grip
Pulp pinch	1, 3, 4, 8, 10, 15, 20
Tripod pinch	8, 11, 13
Spherical volar grip	9
Diagonal volar grip	7, 11, 16
Lateral pinch	2, 3, 8, 10, 12, 14, 15
Five finger pinch	5, 12, 14, 18
Transverse volar grip	6, 17, 19
Hand in pronation	6

Based on a previous study,⁵ we performed a power calculation which indicated that to see 15% change in Sollerman score, at least 14 patients were required in each group.

Twenty-four healthy adult volunteers were recruited, of whom six were men and 18 women. Their mean age was

37.7 ± 12.7 years (range, 21–60 years). Twenty-three were right handed and one was ambidextrous. One volunteer, with recent trigger finger release, was excluded from the study with a pre-existing hand disorder.

The volunteers took the Sollerman test of hand function. The test was administered by the same occupational therapist for all subjects. We measured the time in seconds to complete each individual task. The grip strength in kilograms was assessed using a single calibrated Jamar dynamometer. Results were obtained from volunteers wearing no glove, glove A and glove B using their dominant hand. To prevent learning bias, each volunteer underwent hand-function assessment in a random order, starting testing either with or without a glove.

The data collected on the 23 known rheumatoid arthritis patients comprised Sollerman hand-function score and demographics. Unfortunately, grip strength and total time data were not available as the dynamometer did not allow a record of weak hands. The mean age for this group was 56.4 ± 9.7 years (range, 42–74 years). There were five men and 18 women. Of these, 19 were right handed, two left handed and two ambidextrous.

We acknowledge that rheumatoid arthritis patients are significantly older than volunteers. We addressed this by performing a separate analysis and found no statistical difference in Sollerman hand function score ($P = 0.8$) or total time taken ($P = 0.7$) when data are compared to volunteers over ($n = 16$) and those below ($n = 8$) 45 years of age.

Initial comparisons were made amongst the volunteers with and without each glove to assess the degree of impairment caused. Subsequent analysis compared function of each glove with that of the rheumatoid arthritis sufferers, to assess the accuracy of simulation. Data were parametric and so paired and unpaired t -tests were used.

Results

Comparison of the glove with normal hands

The results show that normal hand grip strength was reduced when either glove was used, particularly glove B (mean reduction 41% to a mean of 19.3 ± 7.3 kg; $P < 0.005$; Table 4).

Table 4 Sollerman test results and grip strength

	No glove	Glove A	Glove B	Rheumatoid arthritis patients
Mean score (SD)	99 (1)	93 (3)	92 (4)	82 (16)
Mean seconds (SD)	150 (41)	245 (70)	279 (72)	Not applicable
Mean grip strength kg (SD)	32.8 (9.5)	20.1 (6.8)	19.3 (7.3)	Not applicable

Table 5 Sollerman grip type

Grip type	No glove	Glove B		Rheumatoid arthritis		<i>P</i> ^b
	Mean	Mean	<i>P</i> ^a	Mean	Difference ^c	
Pulp pinch	3.9	3.4	NS	3.2	0.3	NS
Tripod pinch	3.7	3.1	NS	2.9	0.2	NS
Spherical volar grip	4.0	3.4	< 0.05	2.8	0.6	NS
Diagonal volar grip	3.8	3.5	NS	3.2	0.3	NS
Lateral pinch	3.9	3.6	NS	3.3	0.3	NS
Five finger pinch	4.0	3.9	NS	3.5	0.4	< 0.05
Transverse volar grip	4.0	4.0	NS	3.5	0.5	< 0.05
Hand in pronation	4.0	4.0	NS	3.4	0.6	< 0.05

All data items were analysed using a *t*-test. Only statistically significant *P*-values are given. NS, not significant.

^aNo glove tested against glove B.

^bGlove B tested against rheumatoid arthritis patient data.

^cDifference in reduction compared to volunteers with glove B.

Both gloves also demonstrated a reduction in Sollerman hand function, and an increased time to complete the tasks. Again, this was most pronounced with glove B, in which there was an 8% reduction when compared to no glove ($P < 0.005$). The total time required to complete the entire test was increased, with glove B, taking a mean 87% longer ($P < 0.005$).

Certain functions were impaired more than others with the gloves, and this was illustrated by analysis of each Sollerman sub-test. The grip types most significantly reduced were the pulp-pinch, tripod-pinch and spherical volar grip. For example, task 4, which involved placing coins in a purse and reflects pulp pinch grip (see Fig. 3 and Table 1), took a mean 152% longer time to complete with glove B, with an average 36% reduction in Sollerman hand function ($P < 0.005$) when compared to normal ungloved volunteers. The most significant reduction in function arose with task 9, which involved turning jar lids and reflects spherical volar grip. Sollerman score was reduced by mean 15% ($P < 0.005$) in this subtest and time taken increased by mean 213% ($P < 0.005$). Also highly significant was subtest 8, which involved turning nuts on a bolt and reflects pulp pinch, lateral pinch and tripod pinch grip. Here, Sollerman score was reduced by mean 33% ($P < 0.005$) and time taken was increased by mean 150% ($P < 0.005$).

Comparison of the glove with rheumatoid arthritis

Rheumatoid arthritis patients had a mean Sollerman score of 82 ± 15.6 ; ($P < 0.05$). These patients have the greatest reduction in functions using pulp pinch, tripod grip and spherical grip. This is illustrated by the fact that rheumatoid patients had the most difficulty in tasks 8–11; combined, these reflect tripod pinch and pulp pinch grip (Table 5).

In comparison with glove B, rheumatoid patients had a lower mean Sollerman score (82 vs 92). Both had the greatest level of impairment with pulp pinch, tripod pinch and spherical volar grip. The glove does not impair function to the same extent as in rheumatoid arthritis patients (Table 2).

There was some variability in the way glove B reflected rheumatoid arthritis function. The data show that the glove is good in reflecting tripod, diagonal volar and lateral pinch grip with little difference in mean score for these functions (Table 5). Functions where the glove less accurately reflects rheumatoid arthritis patients include hand in pronation, transverse volar and spherical grip.

Discussion

The results demonstrate that hand function is reduced with both gloves. Time taken to complete the test is prolonged with both gloves compared to normal and grip strength is significantly reduced. However, when the glove is compared to rheumatoid arthritis patients, the reduced function is not a fully accurate match, especially with subtests involving pulp pinch grip. Sollerman score is 9.7% less in rheumatoid arthritis hands than a healthy volunteer using the glove.

The glove most effectively reduces subtests requiring fine touch such as picking up coins (task 4) and turning screws (task 8). It is unclear how much of this is contributed to by the reduced sensation caused by wearing the gloves. Perhaps future glove designs could leave the finger pulps free of material to reduce this sensory inhibition. The study did not account for sensory or proprioceptive disability encountered by patients suffering from rheumatoid arthritis.

In one study by van Tuiji *et al.*,⁵ mean test score in the arms of patients lacking sensation was significantly lower than in those with normal tactile gnosis ($P < 0.001$).

The glove also fails to simulate reduced movement at the elbow and wrist and this weakness could contribute to subsets of the Sollerman test becoming confounded. The aforementioned difference in age of the volunteers when compared to rheumatoid arthritis patients could also have been significant; however, the glove has been produced to be used by designers, who would tend to be of an age under 50 years.

The glove does successfully and significantly reduce hand function when compared to a normal hand with no glove; however, more work on the usefulness of such disease simulation in the design of tools for such patients is needed. In its current form, it is perhaps best suited to those tools requiring predominantly grips of lateral pinch, diagonal volar and tripod pinch as it these that the glove best reflects rheumatoid arthritis of the hand.

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