Hand performance assessment of ten people with Rheumatoid Arthritis when using a range of specified saucepans.

GE Torrens BA, F.R.S.A.*, J Hann **, M Webley M.B., F.R.C.P.**, J Joy **, IA Sutherland PhD ***

* Department of Design and Technology, Loughborough University, Loughborough, Leicestershire, LE11 3TU United Kingdom Tel. +1509 222 664 Fax. +1509 223 999 Email: g.e.torrens@lboro.ac.uk

** Oxford Regional Rheumatic Diseases Research Centre, Stoke Mandeville Hospital NHS Trust, Aylesbury, Bucks. U.K.

*** Brunel Institute for Bioengineering, Brunel University, Uxbridge, Middlesex, U.K.

Keywords *hand performance, rheumatoid arthritis, anthropometrics*

Summary

The aim of the pilot study *was* to provide *information about the design and use of saucepan handles to enable clinicians and designers to specify and provide products that are more appropriate for use by people with Rheumatoid Arthritis (RA)*. *The objectives were:* to evaluate aspects of new handle design for saucepans in terms of their ease of use for people with Rheumatoid Arthritis; document hand grip strength and configuration (grip patterns); *record* relevant anthropometric data to aid the development of new designs and perform an assessment of lifting techniques used in conjunction with perceived optimum handle configuration.

Observation and video footage show that subjects continued to use familiar, but damaging, ways of lifting the saucepan even after extensive joint protection training by Occupational Therapists. Grip strengths recorded using a sphygmomanometer were similar to those found by other studies. The anthropometric measurements taken from the sample group were found to be within available anthropometric surveys of able-bodied people. *However*, hand length within the sample group with RA was longer than the equivalent in surveys of able-bodied subjects. Subjects preferred the narrower handles with some surface texture to the larger and more rounded tapered handles. Large handled saucepans were found not to be viable due to the constraints of UK cooking hob sizes and existing British Standards relating to saucepan specification.

INTRODUCTION

More information is required on sections of the population who have different forms of impairment if designers and ergonomists are to incorporate features into new products that allow a wider range of the population to use them. An example of such a user group is those people who have Rheumatoid Arthritis (RA). Haze (1990) reported that approximately one percent of the population of the United Kingdom was diagnosed with Rheumatoid Arthritis. [1] However, there is little available information about the functional performance of this particular user group that may be applied to the design of new products. Earlier work by the authors [2] identified the need for more data in this area.

The current pilot study was undertaken to allow initial comparisons to be made between anthropometric and functional performance information of people with RA and data based on healthy subjects. *The outcomes of this study will be used to identify specific areas of saucepan handle design that require further investigation. The outcomes will also help to define suitable methods of assessing hand and saucepan handle performance to be used in a larger scale trial.*

Due to the small sample statistical analysis would have been of limited value. However, trends within the data will be used to guide investigators towards areas for more focused larger scale assessments.

Rheumatoid arthritis is a progressively destructive process that results in joint damage and deformity. Soft tissues, such as ligaments supporting joints, may also be involved and damage to these structures in addition leads to joint instability. Thus, with persistent disease, functional capacity is progressively impaired.

SUBJECT SELECTION

The ten subjects were identified from patients attending day clinics at the Rheumatology Unit, Stoke Mandeville Hospital over a period of weeks between the months of August and September. Only female subjects were used as there was a larger sample population from which to choose. *The number of volunteers who could be assessed was restricted due to the limited time each day that was available within the normal routine of the day clinic. Practically, only two or three subjects could be assessed per day. The timing of the assessment period coincided with the main holiday months, which further reduced the number of people being seen within the clinic and so restricting the available sample population. The subjects chosen by a consultant rheumatologist and RA Occupational Therapist displayed a range of severity of the RA condition*. The subjects' condition ranged from those who had moderate joint deformity to one subject who had severe ulna deviation of the fingers from the metacarpophalangeal (MCP) joints. *The deformity common to most of the subjects was some slight ulnar deviation and some limitation of finger flexion. The subject with the severe deformity was the only one who could not produce a prehensile grip in the form of a power grip. The grip strength of each subject further indicated her ability to maintain a prehensile grip.*

The assessment procedure was discussed with the subjects before they were asked to take part in the study. The volunteer subjects were then asked to bring their most used saucepan with them when they next returned for an out patients appointment, arranged by the Rheumatology Unit. Each subject was given a reference number that corresponded to her medical evaluation before the handle assessment.

ASSESSMENT

An assessment was undertaken on all subjects. The aims of the assessment were as follows:

- To evaluate aspects of new handle design for saucepans in terms of their ease of use for people with Arthritis.
- To document handgrip strength, general grip patterns and relevant anthropometric data for the development of the designs.
- To assess the effectiveness of lifting techniques used in conjunction with perceived optimum handle configuration.

Moving the saucepan from one hob to another was the task performed. This part of the overall use of a saucepan was the focus of the study. It required only one grip pattern to be used and no twisting along the axis of the saucepan handle.

Only part of the overall task of using a saucepan during a cooking activity was assessed. The specified task was kept simple to enable the performance of hand and saucepan handle to be assessed more effectively. The set task reduced the effect of variables, such as range of upper limb movement within the task performance and forces acting on the hand through the saucepan handle. This left known variables, such as saucepan handle size, shape and a subject's hand characteristics, to be measured and compared with each other. Moving a saucepan from one hob to another, as described later in the text, enabled the investigators to measure objectively aspects of each subject's performance, such as the time taken to perform a task and, grip patterns used. The objective measurements, when combined with subjective data in the form of subject comments and handle ratings, provided investigators with an indication of the aspects which seemed important when rating ease of use to the subject group.

It is difficult to analyse any one biomaterial without using invasive measurement techniques. The number of biomaterials within the hand and their subtle interaction, with the added complexity of the changing physiological state of each material during

a task, make only an overall assessment possible. Therefore, an overall ergonomic performance of each subject's hands was documented. Each subject's performance with the different saucepans was assessed. Each assessment used non-invasive techniques based mainly on observation. The techniques used were as follows:

- the ability of the subject to achieve a recognisable grip pattern, identified by the experiment operator, from a review of the video recording of each task;
- muscle exertion required to maintain grip, assessed using subject comments, (from a questionnaire and video sound recording), on the ease with which each saucepan was used and muscle strength available to undertake the task, measured using a sphygmomanometer;
- Time taken to undertake the task, measured from the point in time just before the subject moved the saucepan and the ability of the subject's hands to maintain a static grip, assessed through observation of any grip pattern changes during the task performance and subject comments relating to ease of use, (from the same questionnaires and video recording as above).

The forces applied through the saucepan handles were assessed by using a prototype saucepan with mouldable handles. The relative displacement of the mouldable handles on the saucepan was used to compare the forces applied by the hands of each subject. The depth of displacement indicated a greater force being applied by different digits on to the handle. From the mouldable handles, a better understanding of the appropriate shape and potential high pressure points in a handle design could be identified.

The subjects used their own saucepans and a prototype design (prototype One) based on the findings from an earlier study in 1992. [2] The following features were incorporated into the prototype saucepan to reduce the load taken by damaged parts of the hand, based on joint protection principles [3]:

- A second handle diametrically opposite the conventional handle position on to the smallest size of saucepan, reducing the load on the main grip hand by up to half. Currently the majority of manufacturers do not provide a second handle on the smallest saucepan size.
- A pan made of a lightweight material, reducing the proportion of load carried that is not food and water.
- A number of grip options suited to the user's hand dysfunction. The back of the hand, the wrist area and the Thumb/Metacarpal joint area of the index finger combined may be used as alternatives to conventional grip patterns.
- A tapered main handle, allowing the user to choose the location along the axis of the handle where they felt an optimum grip could be achieved. The diameter of the main handle was based on recommendations of Pheasant and O'Neill. [4] The assessment was also used to determine whether the tapered handle does or does not affect the performance of the user.

The dimensions of the secondary handle and tertiary handle, (above the main handle), were made proportional to the anthropometric maximum and minimum of the mainstream wrist dimensions available. [5,6] *The gap between the respective handle shapes allowed the subject the choice of using their wrist to assist in moving the saucepan.*

EQUIPMENT

The equipment used was:

Prototype saucepan One. An aluminium saucepan (Figure 1.), 175 mm internal diameter, and 85 mm deep. The main handle (handle 1) was 160 mm long, overall, with the 40 mm diameter of the handle nearest the saucepan body, reducing to 20 mm over 135 mm. The handle was circular in cross-section and had a ridge of 10 mm at the end of the handle acting as a stop. The tertiary handle, above the main handle,

was of 10 mm thick by 50 mm wide flat section. The section bent from the vertical over the main handle. The secondary handle was also of the same flat section as the tertiary handle. The secondary handle had two bends in the section, one at right angles to the near vertical and one at 25 mm along the near horizontal. The tip of the handle section was 20 mm long.

The handles, and the blocks connecting them to the saucepan base, were to the dimensions specified in British Standard for cookware. [7]

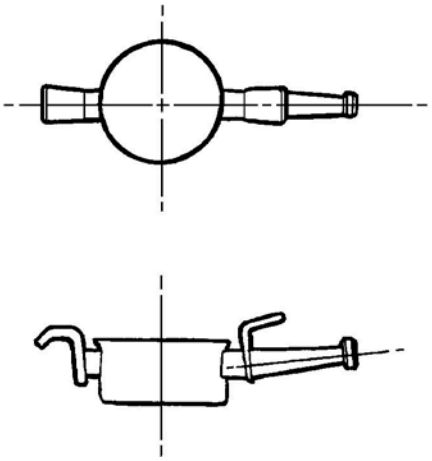


Figure 1 Prototype saucepan One

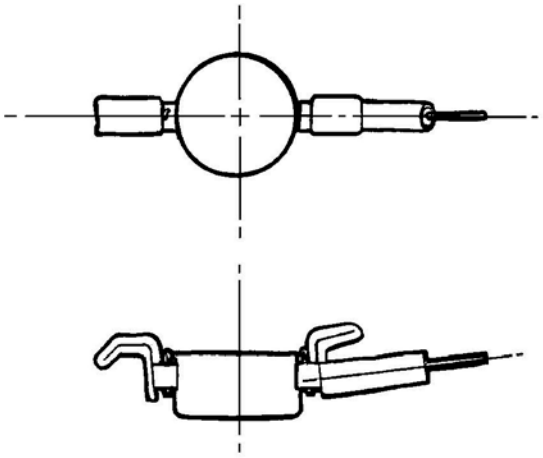


Figure 2 Prototype saucepan Two

Prototype saucepan Two. The same base specification as saucepan One. The handles were detachable from one of two rectangular aluminium blocks attached to the saucepan base (diametrically opposed) that supported an aluminium rod on which a sleeve of soft moulding material of specified dimensions was applied (see Figure 2). The moulding material used was "Soft Stuff", a commercially available flour, gelatine and water mix (produced by the Early Learning Centre, Swindon, SN3 4TJ, U.K.). The

material was considered neutral in contact with the subjects skin as it conformed to B.S.5665:1979, *Safety of Toys.* [8] The material was chosen from trial usage of moulding materials, including plasticine, clay, modelling clay, and putty. The authors made a subjective evaluation that "Soft Stuff" had the correct density to be easily moulded by a weak hand grip, while staying attached to the handle supporting rod. *The supporting rod ran through the centre of the moulded material, during saucepan lifting.* The main handle was 50 mm in diameter and 160 mm long. The secondary and tertiary handles were 25 mm thick by 50 mm wide in section.

250 ml of water, (approximately 1/2 pint), was placed into each saucepan during the assessment. Testing of the assessment methodology had shown that water in the saucepan encouraged the subjects to use the same lifting technique during the assessment as when cooking at home.

Saucepan handles. Whilst filling in the questionnaire the subjects were asked to choose from a range of handle designs that best suited their needs. There were six handles from which to choose:

- Handle one was a round section, 20mm diameter by 160mm long.
- Handle two was a round section, 40mm diameter by 160mm long, tapering away from the body of the saucepan to a diameter of 20mm.
- Handle three was a round section, 40mm diameter by 160mm long, tapering towards the body of the saucepan to a diameter of 20mm.
- Handle four was a round section 20mm diameter by 160mm long.
- Handle five was an oval section 40mm across the horizontal axis, 20mm across the vertical axis and parallel in section throughout its length of 160mm.
- Handle six was injection moulded, with a 25mm square section that tapered from the underside of the handle to a section of 15mm thick by 25mm wide. The underside of the handle had four grooves (finger grips) approximately 15mm across by 7mm deep set nearest to the saucepan body. The underside of the handle was hollow; the wall

thickness of the handle shell was approximately 5mm thick, with exposed edges being rounded.

METHOD

Following a medical assessment, the evaluation procedure was as follows:

A range of anthropometric measurements for the study group was taken based on measurements by Garrett. [6] These included hand length, thickness and breadth and wrist breadth and thickness. The anthropometric measurements were used to help specify the main handle grip dimensions. The scale of the hand size determines the overall size of the handle design. Measurements were taken using callipers or a flexible tape where the subjects' hand would not fully extend. The span between first and second digits was measured from a tracing of the profile of the digits and hand made on a flat surface. Comparisons were made between some of the measurements that were available from the Peoplesize™ database and are shown later in the results. Grip strength was measured using a sphygmomanometer and the resulting pressure noted from the Mercury scale was converted to Newtons for ease of comparison with other studies.

Figure 3 Sketch of image captured from video taped assessment showing movement of the subject's own saucepan from one hob to another

Figure 4 Sketch of image captured from video taped assessment showing prototype saucepan about to lifted by subject.

Figure 5 Sketch of image from video taped assessment as subject lifts saucepan 2. with handles made of moulding material.

The subjects were asked by the Occupational Therapist to lift their own saucepan from one hob to another, left to right in the way the subject would normally perform this task. (See Figure 3.) The centre line of the saucepan handle was placed in line with the midline of the subject's body, to avoid suggesting a preferred hand to use. The actions were video taped for further evaluation, as shown in Figure 4. The Therapist asked each subject to freely comment what they felt as they used the pan. Their comments were noted by the Therapist and supplemented with comments noted from the video.

The subject was asked to lift prototype saucepan One and its contents from one hob to another, left to right. The procedure, recording of the subject's actions and comments followed the convention stated for the subjects' own saucepan.

Between assessments using the saucepans, each subject was asked to fill in a questionnaire about all aspects of the performance of their own saucepan compared

with the prototype pan. They were also asked to make a number of choices about their preferred handle shape, size and overall size of saucepan. The subjects were asked to indicate which aspects of using a saucepan they found difficult and how many saucepans they used during cooking. The were also asked if they would like a saucepan that enabled them to cook a number of different foods together to reduce the number of pans used and how much they would wish to pay for a new saucepan. The questionnaire was used to give the subject a rest period before performing the set task again with prototype saucepan Two.

Each subject was asked to lift prototype saucepan Two in the same manner as she had lifted the prototype saucepan One. The handles of prototype saucepan Two were in the same position as those fitted to prototype saucepan One (see Figure 5)

The Therapist changed the handles on prototype saucepan Two and marked the mouldings with a reference code. The code corresponded to the subject's identification code and the hand used as the main holding grip and the secondary, supporting grip (e.g. right for main handle, left for secondary handle). The main grip used was identified as the hand trying to form a power grip, rather than a hook or pinch grip as used on handle Two or Three. The types of grip identified are based on descriptions given by Napier. [9]

PROCESSING OF INFORMATION.

The moulds from the handle grips on prototype saucepan Two were documented by drawing a number of orthographic views of the discrepancies from the originally moulded handle shapes. The drawings allowed the authors to try to define the optimum shapes for aspects of clinically diagnosed hand dysfunction, as defined by the Consultant Rheumatologist and Occupational Therapist.

A number of methods were explored to compare the defined shapes from the evaluation. Lofting of the three dimensional handle shapes into orthographic drawings and surface scanning were considered. Lofting is the slicing of an object at set intervals to be able to dimension the complex shape within three dimensions, X, Y, and Z axis. No comparison could easily be made because there was no anatomical reference point that could be identified on the moulded handles. It was found that careful study of the moulded grips by a designer was the only efficient way to identify shapes that occurred in a number of moulded handle grips.

A video tape recording of the subjects using a saucepan was studied to relate the diagnosed dysfunction of each subject to their task performance. This involved identifying notable body movements or posture considered abnormal. Handgrip types were identified and each task performance timed. The timing of each task performance was taken from the moment of hand contact with the handle to the point at which the hand/s were removed from the handle/s. *Where the subject repeated the task, an average time was calculated.*

RESULTS

Anthropometric survey. *Data collected from the subject group was compared with UK anthropometric data available using Peoplesize[10] , an anthropometric database. The measurements taken from the subject group fell within the documented range of the UK female population.* There were noticeable discrepancies in three of the nine subject measurements available to review (see Table 1). Hand length in forced extension, in a flat plane, might reasonably be expected to produce a longer dimension than a hand in a rested, neutral position in the same plane. However, forced extension measurements of three subjects (subject numbers 7 right hand, 8 right hand and 9 left hand) were found to be shorter than those taken with the hand

in a more curled rest position. There are a number of reasons that may be suggested for the discrepancies:

- operator error when measuring to the anatomical points defined for the specified measurement, or reading of the measurement scale;
- deformities within the subject's hand, producing an abnormal extension movement of the hand and;
- Digits when forced into a flat position.

Further evaluation is required to define the cause of the dimensional discrepancies. It should be noted that individual dimensions taken did not always relate proportionally to the subject's general size. An example is that subject three had the smallest handbreadth measured but the largest hand thickness, suggesting those anthropometric irregularities might be condition related. The irregularities may also have been exaggerated due to the small sample size. A much larger sample would need to be surveyed to support the suggestion that irregularities are condition related.

Grip strength. The average grip strength of the ten subjects ranged from 20.72 N (50 mm Hg) to 70.03N (137.33 mm Hg) as shown in Table 2. The findings correspond to other studies [11,12] that show results within the same range of forces generated by females with rheumatoid arthritis.

Questionnaire. The questionnaire results are shown in Tables 3 and 4. The subjects all found the prototype saucepan easier to use and the majority found their own pan difficult to use.

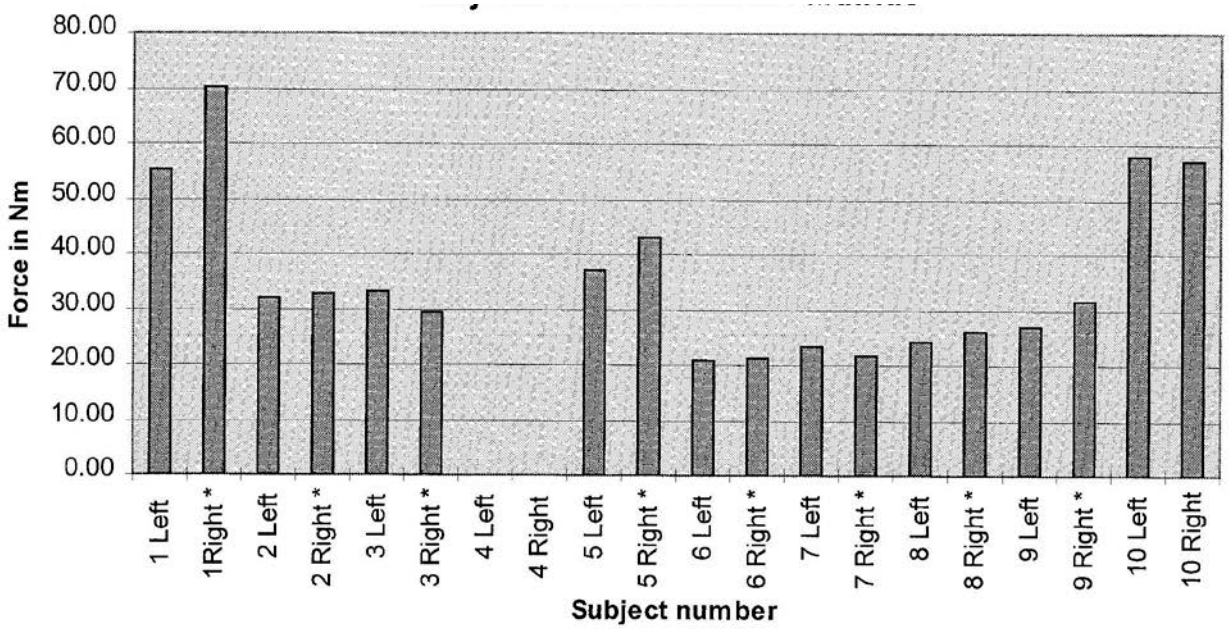
Nine subjects found their own saucepans to be heavy or very heavy, where only one subject found the prototype pan (prototype One) to be heavy. Four found their own saucepan unstable, while only one subject found the prototype pan unstable. Four subjects found their own saucepan a little unsafe to use, with nine subjects finding the prototype pan safe or very safe. The majority of subjects found the handle sizes to be just right on the prototype and each subject's own saucepan. Nine subjects wanted a rough surface to their handle. The handle shape did not give any clear indication as to the type of handle preferred, however, none of the subjects chose an oval sectioned handle or a handle that tapered away from the saucepan body. Nine subjects found it an advantage to have a saucepan with two handles.

It can be seen in the results shown in Table 4 that that majority of the ten subjects had difficulty with lifting, carrying and tipping of a saucepan.

Table 1 Results of comparison the assessment results with corresponding values from the Peoplesize™ database

Subject/ Measurement	*Hand breadth across knuckles*	*Wrist breadth*	*Forearm breadth 75 mm from wrist*	*Forearm thickness 75 mm from wrist*	*Wrist thickness*	*Hand thickness*	*Hand length at rest (surface)*	*Land length, forced extension*	*Thumb web span, max*
1 Left	80	59	60	51	40	26	190	195	38
1 Right*	80	55	63	57	46	26	190	195	30
2 Left	75	55	46	49	41	26	190	194	30
2 Right*	74	57	48	44	35	27	190	190	39
3 Left	68	61	47	51	46	29	178	182	13
3 Right*	70	60	49	47	41	29	179	179	28
4 Left									
4 Right									
5 Left	70	64	59	62	45	26	165	174	18
5 Right*	71	62	66	61	45	25	178	178	25
6 Left	72	54	49	46	34	28	174	170	26
6 Right*	72	55	49	51	34	29	162	170	22
7 Left	72	56	56	41	34	24	185	185	24
7 Right*	73	52	56	45	32	21	188	180	21
8 Left	77	57	68	65	48	25	175	175	39
8 Right*	77	62	77	67	47	28	167	166	29
9 Left	80	55	53	55	40	26	200	192	26
9 Right*	81	54	53	53	39	26	196	194	28
10 Left	77	59	60	60	40	24	179	178	47
10 Right	77	58	63	60	40	26	180	180	35
Avg	74.8	57.5	56.8	53.6	40.4	26.2	181.4	182.1	28.8
stdev	4.0	3.3	8.5	7.7	5.0	2.0	10.6	9.4	8.4
95th	82.6	64.0	73.2	68.5	50.2	30.1	201.9	200.3	45.0
5th	67.0	51.0	40.3	38.7	30.6	22.2	161.0	163.8	12.5
PSz 50th	77.0	54.0				27.0	173.0	173.0	
PSz %ile	33	87				40	83	84	
Co-efficient of Variance (CV)	5.4	5.8	14.9	14.3	12.5	7.8	5.8	5.2	29.1

Table 2 Graph showing right and left hand grip strength measurements of nine female subjects with Rheumatoid arthritis. Note that grip strength for subject Four was not recorded



Five subjects did not favour a saucepan that cooked a number of foods together. The number of pans normally used by six subjects was three. Nine subjects preferred to cook with the medium sized pan (188 mm diameter) and estimates for the price the subjects would pay for a new pan ranged from £15.00 to £25.00.

Forces measured through handle moulds. The results of documenting the moulded handle shapes were inconclusive. The grip loading from the subjects was so low that no prominent features were noted. This suggests an appropriate surface texture may be more significant in optimising grip than overall shape.

Recognising Grip Pattern. The video showed a number of subjects trying to use a power grip, as identified by Napier, [8] when lifting their own pan. A power grip occurs

when the thumb is in the plane of the palm, its metacarpophalangeal and carpometacarpal joints are adducted. The fingers are flexed, laterally rotated, and inclined towards the ulnar side of the hand. The fingers are flexed in opposition to the palm. The wrist is in ulnar deviation, neutral between extension and flexion.

Table 3 Results of the questionnaire answered by ten female subjects 1 to 4

Question/subject number	1	2	3	4	5	6	7	8	9	10	Total
1 Comfort. *Do you find your own pan to be*:											
Very comfortable				1							1
Comfortable	1	1	1			1				1	5
Uncomfortable					1		1		1		3
Very uncomfortable								1			1
1 Comfort. *Do you find the prototype pan to be*:											
Very comfortable	1			1						1	3
Comfortable		1	1		1	1	1	1	1		7
Uncomfortable											0
Very uncomfortable											0
2 Ease of use. *Was your pan*:											
Very easy to use	1	1									2
Easy to use			1			1					2
Difficult to use				1	1		1		1	1	5
Very difficult to use								1			1
2 Ease of use. *Was the prototype pan*:											
Very easy to use	1			1	1						3
Easy to use		1	1			1	1	1	1	1	7
Difficult to use											0
Very difficult to use											0
3 Safety. *Did you find the prototype pan*:											
Very safe		1		1		1				1	4
Safe	1		1		1		1		1		5
A little unsafe								1			1
Very Unsafe											0
3 Safety. *Did you find your own pan*:											
Very safe											0
Safe	1	1	1	1		1		1			6
A little unsafe					1		1		1	1	4
Very Unsafe											0
4 Weight. *Did you find your own pan*:											
Too heavy								1			1
Heavy	1	1	1	1	1		1		1	1	8
Just Right						1					1
Light											0
Very light											0
4 Weight. *Did you find the prototype pan*:											
Too heavy											0
Heavy			1								1
Just Right				1	1	1			1	1	4
Light	1						1	1			3
Very light		1									1

Table 4 Results of the questionnaire answered by ten female subjects 5 to 14

Question/subject number	1	2	3	4	5	6	7	8	9	10	Total
5 Stability. *Did you find your own pan to be*:											
Stable	1	1		1		1		1			5
Unstable			1		1		1		1	1	5
5 Stability. *Did you find the prototype pan to be*:											
Stable	1	1	1	1	1	1	1	1	0	1	9
Unstable											0
6 Size. *Was the handle size on the prototype pan*:											
Handle 1											
Too big	1									1	2
Just right		1		1	1	1	1	1	1		7
Too small											0
Handle 2											
Too big	1										1
Just right					1					1	2
Too small		1									1
Handle 3											
Too big			1								1
Just right	1	1		1		1	1	1	1	1	8
Too small											0
7 Surface. *Did you find your own pan*:											
Very Rough											0
Rough	1	1	1		1	1	1	1	1	1	9
Smooth				1							1
Very smooth											0
8 Handle shape. *Which shaped grip did you prefer to use*?											
1 Round section											0
2 Round tapering towards pan											0
3 Round tapering away from pan						1			1	1	3
4 Parallel handle section	1			1							2
5 Oval section with largest width in the vertical axis											0
6 Straight top with rough underside		1	1		1		1	1			5
9 *Did you find using 2 handles an advantage*?											
Yes	1	1		1	1	1	1	1	1	1	9
No			1								1
10 *How much would you expect to pay for a saucepan*?*	£20	£10	£25	A	£15	B	£25	£15	£10	£15	
11 *How many saucepans would you normally use for cooking*?											
1											0
2					1	1	1				3
3	1		1	1				1	1	1	6
4		1									1
12 *Would you find a pan enabling the cooking of different foods together useful to cut down on the number used*?											
Yes					1		1		1	1	4
No	1	1	1	1		1		1			6
13 *Do you have any problems with the following*?											
a Lifting	1	1	1		1	1	1	1	1	1	9
b Carrying	1		1		1	1	1	1	1	1	8
c Removing lids				1				1			2
d Tipping	1	1	1		1	1	1	1	1	1	9
e Straining	1	1	1		1	1	1	1		1	8
14 *Of the following pans which size(s) would you prefer to use*?											
A (110 mm Dia.)				1				1			2
B (165 mm Dia.)	1	1	1		1	1	1	1	1	1	9
C (210 mm Dia.)							1				1

* Question 10 answer A: A lot for the right pan
Question 10 answer B: No idea

Table 5 shows the timed performance results in full. The two-handled prototype pan was seen to be more confidently moved than the original pan. Timings of the task show six of the subjects took the same time or less to move the saucepan when using the prototype saucepan than when using their own pan. Results for two subjects (3 and 5) are missing due to recording over those results with later assessments. The task timings ranged between 1.98 s to 6.75 s when using the subject's saucepan and 1.78 s to 3.17 s when the subjects used the prototype pan.

Table 5 Time taken to undertake task by nine female subjects. One subject recording was unavailable for review.

Time/subject number	*1*	*2*	*3*	*4*	*Average*
Own pan					
1	2.36	2.22	2.93	2.35	1.98
2	2.02				2.02
3					
4	6.75				6.75
5					
6	5.69	3.36			4.48
7	3.94				3.94
8	2.75	2.18			2.47
9	1.99	2.75			2.37
10	3.79	2.26			3.03
Prototype one					
1	2.01	2.01	1.92		1.98
2	1.99	3.28			2.64
3					
4	2.24	2.2			2.22
5					
6	2.58	2.81			2.83
7	3.17				3.17
8	1.57	2.84			2.21
9	3.12	2.81	2.71		2.88
10	1.7	1.69	1.65	2.09	1.789

Two handles were found to be the most used configuration with a form of power grip applied using the thumb and fingers with limited flexion at the distal ends. Handle One and Two were mainly used, as shown in Figures 3,4 and 5. There was less flexion of the fingers of subjects with more severe levels of RA. The subjects still tried to form

a power grip. When prehension could not be achieved or maintained, prehension was achieved on the saucepan by the subjects using their arms to apply pressure on to the two side handles using virtual fingers. Using all the fingers at the same time as a virtual, or single, finger is based on a description given by MacKenzie and Iberall. [13]

Figure 6 Prototype saucepan with handles for ease of use

DISCUSSION

The results of the grip strength measurements indicate that people with RA have approximately half to one-third the grip strength of an able bodied adult. A similar reduction was found by Jones, Unsworth and Haslock.[12] The lack of pressure applied by the subjects to the task handle resulted in the subjects relying upon the biomechanical properties of the hands structure to support the handle and stop rotational instability along the axis of the main handle during transfer of the pan.

Edin, Westling and Johansson [14] observed that during a static holding task a subject would reduce the finger force used to hold an object until it reached the point at which the object would slip. This indicates people apply a form of energy efficiency rule to their actions during grip. Although grip strength is important to the force being

applied to the object, the biomaterials of the hand also have a large part to play in maintenance of grip. From other studies undertaken by one of the authors [15, 16] the biomechanical characteristics of the skin and underlying tissues of the hand, that interact with the surface of the object, have been shown to play a part in grip. Furthermore, one of the studies indicated a course-featured surface with asperities over five millimetres deep on a pitch of ten millimetres was the optimum for use with young adults. [16] During the assessment documented here nine of the ten subjects requested a rough surface on the handles via the questionnaire. Four subjects choose a handle with a coarse featured surface.

Measuring the mechanical performance characteristics of a hand becomes a more significant part of predicting the hand performance of a given subject if a concept of energy efficiency is followed innately by everyone during the performance of a task. A rough surfaced handle may be considered useful during grip. A specification for a featured surface that may optimise grip for people with RA requires further investigation. More study is required into the role played by skin, soft tissues of the glabrous surface of the hand, joint capsules and surrounding connective tissues during grip performance of people with RA to enable a handle specification to be proposed.

Large handles, as shown in Figure 6, would greatly assist the subjects to move the saucepan safely and without applying damaging loads to the hands. However, the size, shape and position of saucepan handles are constrained by British Standards relating to the design and production of saucepans. The larger handles shown in Figure 6 would not be considered within BS 7643:1988. [7] Results from the study indicate even a small handle opposite the main handle on a saucepan diameter of 110 millimetres would help people with RA continue to use pans as a means of food preparation.

Thin handles of 20 mm diameter or smaller were more acceptable than large diameter versions that were over 20 mm diameter. This may be due to the limited movement of those subjects with more severe RA. *A flat, slightly oval sectioned handle that is parallel along its length may enable the user to slide their hand on to the grip of handle One.* It may also assist in reducing the grip force required to stop rotation about the axis of handle One. However, the oval section offered within this study was not seen as useful by the ten subjects. The reason for the lack of interest in the oval handle may have been that it was too large in section. Further study is required to identify the priorities of people with RA when considering the purchase of a saucepan and particularly the handle performance.

CONCLUSION

The evaluation of the results has shown there is more to grip performance than the force that may exerted through strength alone. The biomechanical characteristics of the skin, underlying tissues, joint capsules and bones seem to have a significant role to play in grip beyond muscle exertion alone.

Based upon the findings the following recommendations can be made regarding saucepan design:

- a textured handle provides a better grip interface than a smooth finished handle;
- a coarse featured surface on the underside of the handle will be perceived to provide a better grip;
- the overall shape of a conventionally positioned handle should be straight along its length, with a diameter of less than 20mm;
- A second handle on the smallest size of saucepan would enable people with even severe forms of arthritis an opportunity to move the saucepan more safely and with less effort.

Current performance assessments used in clinical practice, such as the Jebsen Hand Test,[17] may be augmented with some of the following recommendations to help clinicians to relate direct measurements of the hand to the achievable performance outcome of the patient. Range of movement (ROM), grip strength and incorporating the following recommendations into assessment of hand performance can enhance the effectiveness of specifying a suitable product for the client, in this example a saucepan:

- anthropometric measurements of the hand offer some guide to overall clearance dimensions that are required for the accurate specification of product handles;
- the measurement of the span between digit one and two is important in specifying a handle of an appropriate diameter when distal parts of the digits have restricted movement, it also has a bearing the cross-sectional of the handle shape that might fit into the space created between the span of digit one and two;
- because of the small forces applied by people with RA to a saucepan handle taking a hand moulding to assess pressure applied by parts of the hand is inappropriate;
- Timing a task performance is a good indicator of a patient's ability, the time taken could be compared with that of an able bodied standard time to undertake the task or a previously recorded timing. The addition of this method to existing activity of daily living (ADL) assessment methodologies would enhance the available data when evaluating medical intervention.

The study described here offers clinicians an opportunity to use techniques commonly used in human factors performance measurement. The measurements described are quantifiable and so offer a basis for more complex evaluations of the psychological profile of the patient. The measurements described may be used to augment current practices not replace them.

ACKNOWLEDGEMENTS

The authors would like to thank Mr Nigel Robertson, Open Ergonomics for his help in evaluating the anthropometric data in relation to data from Peoplesize™. This project was supported by the Tools For Living programme grant (1988-1993), from Action Research, and funding from The Stoke Mandeville Hospital Trust.

REFERENCES

1 Hazes JM, Silman AJ. Review of U.K. data on the Rheumatic Diseases-2, Rheumatoid Arthritis, British Journal of Rheumatology, 1990; **29**, 310-312

2 Brown F.R., Torrens G.E., Wright D.K. Research into optimising Hand and Body function for tasks in everyday living: The development of a range of "easy use" saucepan handles. *VI Mediterranean conference on Medical and Biological Engineering*, Capri, Italy, 5-10 July 1992; **2**, 549-553.

3 Goodwill CJ. *Rehabilitation of the physically disabled adult*, ISBN 0 7099 3874 8

4 Pheasant ST, O'Neill D. Performance in gripping and turning-a study in hand/handle effectiveness, *Applied Ergonomics,*1975; **Dec**, 205-208

5 Pheasant ST, Athropometric estimates for British civilian adults, *Ergonomics*, **25**, 993-1001

6 Garret JW, The adult human hand: some anthropometric and biomechanical considerations, *Human Factors*, 1971; **13**, (2), 117-131

7 British Standards Institution 7643: 1988 British Standard Specification for the Performance of handles and handle assemblies attached to cookware, *HMSO*, London, 1988

8 British Standards Institution 5665: 1979. British Standard Specification for the Performance of Toys, *HSMO,* London, 1979.

9 Napier JR. The prehensile movements of the human hand, *Journal of Bone and Joint Surgery*, 1956; **38B**, 902-913

10 Open Ergonomics Ltd, Peoplesize, 1990

11 Helliwell P, Howe A, Wright V, Functional assessment of the hand: reproducibility, acceptability, and utility of a new system for measuring strength, *Annals of rheumatic diseases*, 1987; 46, 203-208

12 Jones AR, Unsworth A, Haslock I. Functional measurements in the hands of patients with rheumatoid arthritis, *International Journal of Rehabilitation Research*, 1987; **10**, 62-72

13 MacKenzie CL and Iberall T. In: Stelmach G.E. and Vroon P.A. (ed) *The grasping hand; Advances in psychology*, 1994; **104** (North-Holland, Amsterdam) 222-235.

14 Edin B, Westling G, and Johansson R.S. Independent control of human finger-tip forces at individual digits during precision lifting, *Journal of physiology*, 1992; **450**, 547-564

15 Torrens GE. A contribution to the understanding of the role of digital pulp in hand grip performance, In: Robertson SA(ed), *Contemporary Ergonomics,* Annual Conference of the Ergonomics society, April 1996, Taylor Francis, London 1996; 75-80 ISBN 07484 05496

16 Torrens GE. What is the optimum surface feature? A comparison of five surface features when measuring the digit coefficient of friction of ten subjects, In: Robertson SA (ed), *Contemporary Ergonomics,* Annual Conference of the Ergonomics society, April 1997, Taylor Francis, London, 1997, 314-325, ISBN 0 7484 0677 8

17 Spaulding SJ, Mc Pherson JJ, Strachota E. Jebson hand function test: performance of the uninvolved hand in hemiplegia and of the right-handed, right and left hemiplegic persons, *Archives of Physical Medicine & Rehabilitation*, 1988; **69**, 419-422