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Measure for Measure: Pack Performance versus Human Dexterity and Grip Strength

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'Openability' of food and beverage packaging has been shown to be problematic for older consumers. Pressure on resources has seen the use of packaged food and beverages increase in hospitals within the New South Wales region of Australia. Studies at the University of Wollongong have explored the interaction between older people and the types of packages regularly encountered in the delivery of hospital food and nutrition. As these types of packs are commonly found in UK hospitals as well, a series of studies have been undertaken by the University of Wollongong, Australia, and Sheffield Hallam University, UK, to further evaluate the issues surrounding the 'openability' of hospital food and beverage packaging in an attempt to understand in detail the issues leading to difficulty in use.

Current methods of pack 'ease of opening' evaluation rely on hand strength as the core parameter. Our studies examine the role of dexterity in addition to hand strength in pack opening. Water bottles, single portion drink cartons and cheese portions were among the poorest performing packs. Dexterity, rather than strength is found to be a sensitive and reliable method to understand the issues surrounding the poor pack performance, and a repeatable way of comparing different pack formats is presented.

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INTRODUCTION

Society is ageing; in 2011, 16% of UK's population was above 65 years of age[1] and is predicted to rise to 19% in 20 years.[2] However, this is not just a UK phenomenon; the UN predicts the world population of over 65 to rise to over 1.5 billion in 2050 from 486 million in 2006 (UN, 2008)[3]. A society in which a large proportion of its citizens are aged creates a major public health challenge for government, health practitioners, older consumers and other stakeholders. As we age, the likelihood of living with some form of chronic illness is significant. The prevalence of disability from the US Census in 2005 demonstrates that for individuals over 75 years, the proportion of people who need assistance was 55.9% rising to 71% for those 80 years and over.[4]

Health services across the world are under severe pressure because of this increase in longevity and associated likelihood of chronic illness. Older people are, for example, more likely to visit hospital and stay for longer. However, many of the illnesses previously associated with old age have more recently been attributed to poor diets, and there is undisputed evidence that diet and nutrition are directly linked to many of the chronic diseases afflicting older adults.[5]

Researchers have estimated that 40% of UK hospital patients are malnourished,[6] and further studies have shown that older patients are five times more likely to be at risk of malnutrition than younger patients.[7,8]

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A series of researches[6,9,10] have identified inability to access food and beverage packaging as a contributing factor to malnutrition among the older adults and disabled in hospitals. Work by Bell et al.[11] looked at the issue of packaging accessibility in hospitals in the New South Wales (NSW) region of Australia. This work used a patient and staff questionnaire along with pinch and grip strength measurements to assess reasons surrounding inability to access food and beverage products in the hospital environment. A sample meal tray used for the study that offered a range of packaged item types is shown in Figure 1.

An initial study by Bell et al.[11] involved 140 hospital inpatients completing the packaging questionnaire, along with 60 staff. The mean age of the sample was 72 years (±15 years); 46% male and 54% female. The patient interviews in this initial study identified five problematic forms of packaging, with the percentage who could not open each type shown after each pack type: convenience dinners (23%), water bottles (17%), cereal (17%), single portion tetra packages (12%) and condiments (e.g. jam, 10%). The problematic packaging types are shown in Figure 2.

Of those patients who could open the products, approximately 50% of patients had some difficulty opening the convenience meal, the milk and the cereal pack. Nearly 40% of these patients also had difficulty opening the water bottle and tetra packs. All staff reported that patients ask for help opening food and beverage packaging, and 39% of staff reported some difficulty opening certain food and beverage packaging items themselves. Figure 2 shows items that participants were unable to open. The same items had the longest opening time, on occasions when the item could be opened. The work showed that for water bottles, the accessibility issue was likely to be related to some form of hand grip strength or tip pinch strength, whereas for the cereal packages and tetra packs, the issue appeared to be a problem of both dexterity and strength. Hence, it was decided to study the issues surrounding poor 'openability' in further detail and to develop a methodology whereby the authors could determine what pack was affected by which capability the most.

CURRENT METHODS TO MEASURE PACK 'OPENABILITY'

Packaging manufacturers as well as bulk purchasers (such as a hospital) would benefit from a comprehensive method to assess 'openability' of food and beverage packaging. Several initiatives have been established to assist, such as the 'User-friendly packaging – Guideline for the Industry'[12]; the

Figure 1. Typical meal tray in the study by Bell et al.[13]

Figure 2. Problematic packaging types.

European Committee for Standardization technical specification for ease of opening[13]; the guidelines put forward by the Arthritis organizations in conjunction with Georgia Tech[14] and tender guidelines developed by NSW HealthShare.[15] These guidelines are useful but not exhaustive – their focus is primarily on hand strength, usability guidelines (colour, contrast, text size, etc.) and/or user satisfaction. Additionally, much of the previous work is based on the data for strength such as that by the DTI, Berns or Voorbij and Steenbekkers[16–18] and is largely concerned with jar opening forces. While packaging of this type has been identified in these studies as a significant problem, it is not a packaging type that is used in a hospital environment, and the studies have typically measured people in a standing environment, again not particularly relevant to a hospital environment. Rodriguez Falcon and Yoxall[19] have investigated the role of dexterity in opening medical packaging and found that it is a useful indicator and predictor of 'openability'. Other work by Bell et al.[20,21] has used time as a measure of 'openability', correlating it with grip, pinch and dexterity scores. The purpose of this paper is to demonstrate that dexterity is the more relevant aspect of hand function for assessing packaging 'openability' than strength (with the exception of twist top containers) and to present a method to rank pack ease of opening using a dexterity 'accessibility score'.

WELL OLDER ADULTS AND HOSPITAL FOOD AND BEVERAGE PRODUCTS

A total of 34 people [11 men (32%), 23 women (68%)] responded to an invitation to participate in this study in the Nursing Simulation Laboratory at the University of Wollongong, NSW, Australia. All participants were over 65 years of age, independently living in the community and considered to be well. Each participant was tested and seated in a chair for meals in hospital. Grip strength, pinch strength and dexterity were measured using validated testing procedures as well as the time taken to open a selection of hospital food and beverage items. Subjects' hands were filmed opening the items using the facility's in situ cameras (Figure 3).

Figure 3. University of Wollongong testing suite.

Grip and Pinch Strength Testing: Well Older Adults in a Hospital Environment

Grip strength was measured using a Jamar dynamometer (Lafayette Instrument Company, Lafayette, IN, USA).[22] Participants were tested on their dominant hand first for both the grip and pinch strength measurements. Pinch strength was tested with a Jamar hydraulic pinch gauge[22] using three different tests; tip pinch, three point pinch and a lateral pinch. Both instruments were calibrated for the testing days.

Dexterity Testing: Well Older Adults in a Hospital Environment

Dexterity of participants was analysed using the Purdue Pegboard test first proposed by Tiffin in 1948.[23] The Purdue Pegboard test can be used for numerous purposes including testing for the presence and/or extent of brain damage, learning disabilities and dyslexia. There are four individual tests that are carried out when using the Purdue Pegboard. Normally, for all of these tests, the participant sits at a table that is at comfortable height, and all standard data 'norms' such as those provided by Lafayette Instruments[22] and Desrosiers[24] have previously been measured in this way. An example of a participant undergoing testing is shown in Figure 4.

Participants were then asked to open seven of nine differing pack formats sourced from the local hospital (specific items and number varied due to availability from hospital kitchen). The pack items are shown in Figure 5. Both the time to open the packs and the number of attempts were later determined from the recordings of the subject/pack interactions.

Figure 4. Participant undergoing testing.

Figure 5. Differing packaging formats.

Yoxall et al.[25] in a previous study identified a total of seven key grip types to open packaging. However, in this study, only four grip types were measured (overall grip strength, tip grip strength, three-point pinch (or chuck grip) and lateral pinch strength) because of the nature of the packaging being studied, with the non-measured grip types not being generally used to access packaging of this type. Examples of a tip, three-point pinch (or chuck grip) and a lateral grip are shown in Figure 6.

Determining Pack Performance

Two methods (statistical and visual) are used to assess pack performance in this paper. First, correlations between time taken to open packs and aspects of hand function (grip and pinch strength,

Figure 6. Tip,three-point (chuck) and lateral pinch grips.

dexterity) were calculated using Spearman's rank order correlation coefficient for the non-dominant grip and non-dominant lateral pinch grip as well as dexterity measures as these elements of hand function were not normally distributed. Pearson's product-moment correlation was used for all other grip and pinch measures. Work by Cohen (1988)[26] showed that a small correlation value is between 0.10 and 0.29, a medium correlation between 0.30 and 0.49 and a large correlation between 0.50 and 1.0. The correlation can, however, be either positive or negative.

Second, time and hand function data were plotted and trend lines placed through the data to provide a visual demonstration of the pack performance. This method provides opportunity to visualize emerging trends of pack performance showing differences between the packs for the measured cohort. Packs that are influenced by any of the strength and dexterity measures should show trend lines that are not horizontal, since a horizontal line would indicate that opening time is not influenced by the other measured variable. Further, plotting the data provide richer detail than performing a purely statistical approach, which was limited in this research due to the sample size and mixture of normal and abnormal data distribution. Examples of data plots are shown in Figures 7 through to 10. In these Figures, some data is omitted for clarity.

RESULTS AND DISCUSSION

Grip and pinch strength testing

The mean grip and pinch scores (with standard deviation) are shown below in Table 1. No significant correlations were found for either grip or pinch strength and time to open the packs.

This finding is confirmed by plotting grip and pinch strength versus time and fitting trendlines through the data, allowing us to visualize the performance of the packs relative to each other and to assess the influence of grip strength on the efficiency of opening a pack.

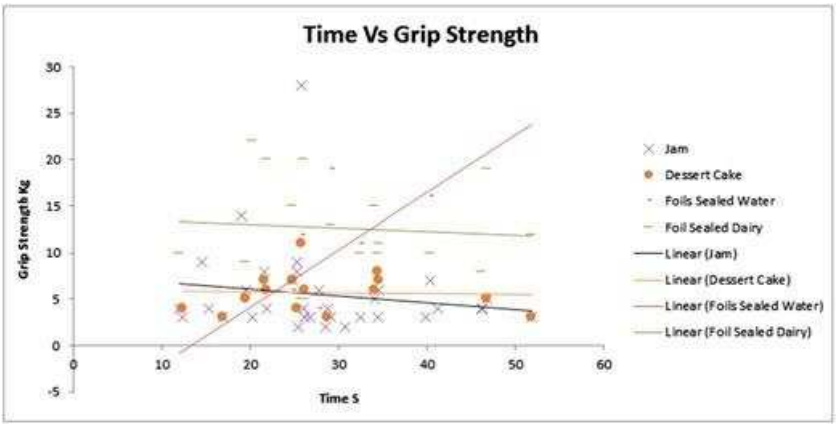

Figure 7. Time versus grip strength for various packaging formats.

Table 1. Grip and pinch strength data (kg/f), (n = 34).

–	Gross grip		Tip		Three-point pinch		Lateral pinch	
–	Dom	Non-dom	Dom	Non-dom	Dom	Non-dom	Dom	Non-dom
Mean	28.58	27.56	4.31	4.16	6.21	5.88	7.25	6.66
SD	10.29	10.85	1.32	1.3	2.07	1.85	2.28	2.52

This approach to examining the data is shown in Figure 7. Here, the relative 'flatness' of the dessert cake packaging format can be readily seen as opposed to the results for the jam, foil-sealed dairy and foil-sealed water, indicating that the latter packaged items were influenced more by grip strength than the dessert cake. Of interest, the foil-sealed water is seen to have a positive slope indicating increasing strength relates to a corresponding increase in time to open this particular product.

Tip pinch, three-point pinch strength and time data for various products are shown in Figures 8 and 9. Much of the data appears to be relatively flat indicating little correlation with tip or pinch strength; however, the figures again shows foil-sealed water to have a strong relationship to three-point pinch strength and tip pinch strength.

Dexterity Testing

Using the instrumentation and the methods described in Section 2.3, the results for dexterity scores as well as the correlation between dexterity and time taken to open a package were determined (Table 2). For all products except the foil-sealed dairy, there was an inverse correlation between dexterity and time taken to open the products, indicating that all packs (except foil-sealed dairy) were more easily opened when the subjects had better dexterity scores.

Of particular concern is the finding for tetra packs [$r = -0.45$, $n = 32$, $p = 0.010$], as these packs are used in hospitals to provide high energy, high protein supplements for patients with reduced appetites, who are malnourished or are at risk of becoming malnourished. A previous study by Wilton et al.[24] also identified tetra packs as the most problematic type of packaging for patients to open.

This relationship between dexterity and time to open the packs is visually represented, which depicts the dexterity measure 'Right Left Both' from the Purdue Pegboard test plotted against time for each product. The steep trend lines for the Custard, Honey and Tetra packs show the strong relationship found in the correlations in Table 2.

Products and Hand Function

The data show the different aspects of hand function and their relationship to the time taken to open the products. Figures 7–10 show that accessibility is not as simple as strength; however, the data

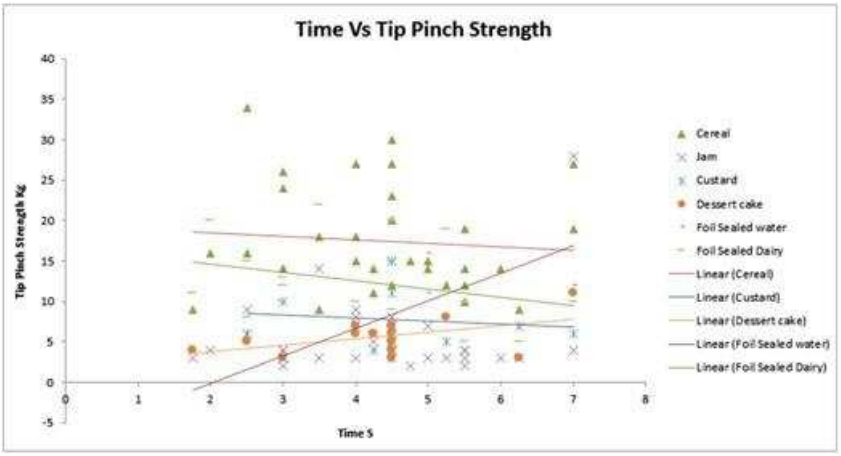

Figure 8. Time versus tip pinch strength for various packaging formats.

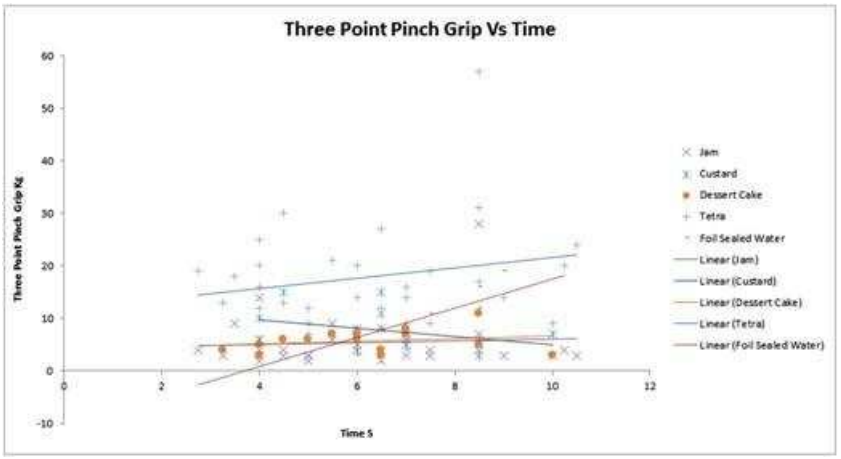

Figure 9. Time versus three-point pinch strength for various packaging formats.

Table 2. Significant negative correlations between dexterity (RLBoth) and time to open packs.

Food/beverage item	Sample size (n)	Sig (two-tailed)	r
Custard	13	0.001	−0.80
Tetra pack	32	0.010	−0.45
Condiments	34	0.015	−0.41
Honey sachet	34	0.000	−0.65

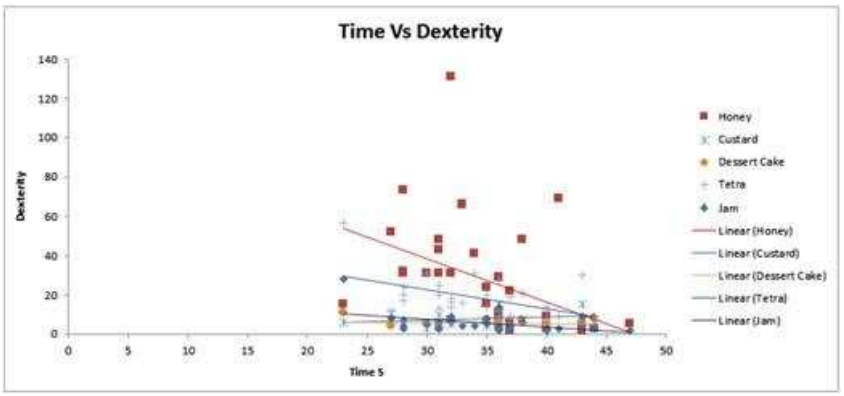

Figure 10. Time versus dexterity for various packaging formats.

demonstrate that having a strong gross or pinch grip does not necessarily lead to efficient pack opening. No statistical significance was detected for grip or pinch strength and efficient pack opening. Dexterity, however, demonstrated a significant relationship to efficient pack opening for five packaged products: custard, honey sachet, tetra pack, condiments and the inner bag of the cereal box. Figures 7–10 demonstrate a visual representation of accessibility for various packaging types based on the gradient of the trend line. These trend lines allow a visual representation of relative pack performance for the measured cohort.

It can be seen that the gradients allow for the relative visual comparison of each pack type against a particular variable, e.g. the honey portion is more affected by dexterity than the dessert cake. The data show that foil-sealed dairy is affected by pinch strength more than the jam or the custard (though no statistical significance is reached). In this way, the graphs provide a richer description of the elements of hand function involved for efficient pack opening than a purely statistical approach in this study.

CONCLUSIONS

The use of a Perdue Pegboard to measure dexterity provides a cheap and reliable dexterity measure that is backed up with substantive normative data. From this method, dexterity is seen to effect the time to open packs more than strength in general (where packs could be opened). A combination of statistical analyses and graphical analyses enables stakeholders (pack designers, hospital catering suppliers, brand owners, etc.) to make comparison between different packs and alternate designs of packs.

In measuring dexterity and strength and plotting those outcomes against time to access a pack, we are able to make visual comparisons of relative pack performance and understand which packs are more problematic than others. From these trend lines, we can give a 'score' to the pack, which will give a useful, repeatable, valid and reliable method of assessing the relative pack performance that can be used by designers, manufacturers and marketers. It is anticipated that in using this method, the attributes of packs that perform well can be observed and compared with those that perform badly and aid in pack redesign.

In this study, custard, honey, tetra packs, condiments and foil-sealed water were all seen to be worst performing packs than the dessert cake pack. This is likely to be a combination of the number and complexity of tasks involved (for example, the number of steps required to open a tetra pack). For the other packs, a combination of strength is needed to overcome the seal and also the ability to grip and maintain the grip on the pack.

To understand the human pack interaction requires a multifaceted evaluation approach that has been demonstrated here through observation of participants and statistical and graphical visualization of pack performance. From this, were are able to evaluate both good and poorly performing packs. Further research with larger sample sizes and including user satisfaction measures is indicated.

Clearly, some packs perform better than others, which lead to the following recommendations:

- Where possible, hospital food should be served in pack formats that have been identified as easily accessible.
- If the aforementioned is not possible, concentrated effort should be made on the packaging supply chain to produce packs that are less susceptible to issues surrounding capability loss and in particular dexterity.
- As part of the aforementioned process, any new packs should be analysed using the type of techniques discussed in this paper to facilitate comparison with current practice.

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