A quantitative assessment of the eating capability in the elderly individuals

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ABSTRACT

Ageing process implies physiologically weakened muscles, loss of natural teeth and movement coordination, causing difficulties in eating process. A term “eating capability” has been proposed to measure objectively how capable an elderly individual is in overall food management. Our objectives were to establish feasible methodologies of eating capability assessment, examine correlations between hand and oro-facial muscle strengths and grade elderly subjects into groups based on their eating capabilities. This study was performed with 203 elderly subjects living in UK (n=103, 7 community centres, 2 sheltered accommodation) and Spain (n=100, 3 nursing homes, 1 community centre). Hand gripping force, finger gripping force, biting force, lip sealing pressure, tongue pressing pressure and touching sensitivity were measured for elderly subjects. Measured parameters were normalised and scored between 1 to 5, with 1 being the weakest. Subjects were then grouped into 4 groups based on their eating capability scores, being participants of cluster 1 the weakest group and 4 the strongest. Perception of oral processing difficulty was assessed by showing food images. Hand gripping force showed a strong linear correlation with tongue pressure (UK: 0.35; Spain: 0.326) and biting force (UK :0.351; Spain: 0.427). Biting force was strongly dependent on the denture status. Elderly of the first three groups perceived food products with more hardness and/or fibrous structure as difficult to process orally. The objective measurements of various physiological factors enabled quantitative characterisation of the eating capabilities of elderly people. The observed relationship between hand and oro-facial muscle strengths provides possibility of using non-invasive hand gripping force measurement for eating capability assessment.

KEYWORDS

Elderly; eating capability; hand grip strength; oro-facial muscle; food oral processing

INTRODUCTION

Ageing is a physiological process linked with the gradual deterioration of body's function. The progressive muscle degeneration, loss of natural teeth and gradual decline in motor coordination could make food consumption very difficult. This would not only lead to loss of the quality of life, but might also result in malnutrition. Malnutrition is well recognized disease in the elderlies, and can result in more negative consequence include muscle wasting and impaired immune defences [1]. Furthermore, ageing affects the food enjoyment due to the decrease in the ability to taste and smell, chewing difficulties, the side effects of medications and deterioration in general health [2-4], which might lead to changes in the regulation of appetite and the lack of hunger (also known as "anorexia of ageing") [5].

However, it is worth mentioning that elderly population is significantly diverse in terms of their needs, abilities, difficulties and resources. Even population within the same age group might have different capabilities. For example, independent living elderly are healthier than those who lives in a residential home [6]. Hence, addressing the individuality and designing the perfect food for this heterogeneous group of elderly is a challenge for the food industry and also for the care givers. Despite the fact that food for elderly has attracted great research interests in past few years and some abundant data are available in literature, implication has been limited in both food provision by food manufacturing and service industries and the wellbeing of elderly populations. This was partly due to the poor user connection of these researches and partly due to some fundamental questions on the overall eating process remaining unanswered.

The overall eating actions can be classified into external actions (hand and finger manipulation) and internal actions (food oral processing: first bite, mastication and swallowing). During eating, hands are used in different ways, to lift objects such as lifting and holding glass of water, to manipulate cutlery, to manipulate packaging such as opening a lid of a yogurt and to bring food from the plate to the mouth. An aged individual may find difficulties in carrying out this overall eating process and even an external help might be needed. Those elderlies who suffer from skeletal muscle weakness will have problems in the hand grip precision and hand grip force [7]. Particular pathologies as Parkinson's disease might lead to difficulty in coordination of cutlery on the plate such as cutting or getting hold of the piece of meat as well as transfer it from the plate to the mouth without frequently spilling [8]. Regarding the food oral processing, elderly may have less mastication efficiency than younger population due to a combination of loss of muscle mass, muscle forces and lack of teeth [9]. This fact conditions the elderlies' food choice, making them to consume more frequently softer food such as purees, mashed food [10]. During the mastication and posterior swallowing of the bolus formed, tongue plays an important role in selecting and transferring the food bolus particles and finally initiating the swallowing process [11, 12]. When the whole process (mastication-breathing-swallowing) is not well controlled, individuals could suffer from dysphagia, that unfortunately affects specially the elderly, although the exact effect of ageing on the oropharyngeal swallowing is not yet fully understood [13].

Thus far, assessment of eating capability of an individual has been largely based on subjective measurements, through qualitative interviews or observation protocol during the meal [14, 15]. There are few studies which have characterized some of the individual parameters that influence the eating performance, such as the measurement of hand grip force in elderlies [16, 17], the influence of denture wearers with dentate subjects [18, 19] or the tongue pressure [11] during the swallowing process. However, to our knowledge, there has been no quantitative study that gives objective assessment of all the actions such as lifting objects, manipulating cutlery, taking the food to mouth, chewing, masticating etc. that an individual performs during the overall eating process using objective measurements. In the present study, we propose to measure the actions that are necessary during the eating process, especially those ones where their incapability could affect the eating performance, which could result in loss of their quality of life.

Using the concept of "eating capability" proposed by Laguna and Chen[20], this study aims to measure the overall eating capability using three key components: hand and oral capabilities, and tactile sensitivity. Hand and oral capabilities are essential for food handling and manipulation; tactile sensitivity is a key physiological factor for texture sensation. To measure the selected capabilities different devices have been chose in function of the technique reliability, simplicity of the test to set up and conduct, and the non-requirement of a specialist to assist the test.

It is hoped that through this study, a systematic approach can be established to objectively categorise elderly consumers based on their individual eating capabilities. The hypothesis of this study is that decline in eating capability conditions one's perception of the ease of eating in such a way that food of higher consistencies would be perceived more difficult to consume by individuals with lower eating capability scores.

MATERIALS AND METHODS

Participants and recruitment

United Kingdom. A total of 103 subjects (over 65 years old, 75 women and 28 men) were recruited from seven community centres and two sheltered accommodation through the Neighbourhood Network Scheme in the area of Leeds (Yorkshire, UK).

Spain. A total of 100 subjects (over 65 years old, 62 women and 38 men) were recruited in the area of Baix Emporda (Girona, Spain) from three different nursing homes and one community centre.

The inclusion criteria were: to be above 65 years old and having no acute pain in the upper extremities and oral areas. Participation in the study was voluntary. For the entire experimental procedures, participants did not need to travel but were visited by the researcher either in the community centres, private homes or nursing homes. Ethical approval was obtained from the Faculty Ethics Committee at the University of Leeds (MEEC 13-019) for UK and from the Comitè Ètic d'Investigació Clínica Institut d'Assistència Sanitària, Girona for Spain. All the experimental procedures followed the rules and guidance set by the University of Leeds, UK.

Eating capability components

Eating capability is defined as the physical, physiological, and cognitive capabilities of an individual in handling and consuming food [21]. This work mainly focussed on the hand and oro-facial muscular capability. All measurements were done in triplicate.

Hand capability

Hand gripping force was measured with an adjustable handheld dynamometer (Figure 1a) (JAMAR dynamometer, Patterson Medical Ltd., Nottinghamshire, UK). Participants were asked to squeeze the hand dynamometer with their maximum efforts and maintain that for approximately 3 seconds with both hand alternatively [22]. The intensity of hand gripping was displayed as the maximum force in the digital panel.

Finger gripping force was measured with a modified version of the device designed by previous suthors [23]. It consists of a built-in thin flexible force transducer (see figure 1b) (Tekscan, South Boston, Massachusetts, USA) connected to a multimeter. Two self-adhesive 1cm diameter neoprene discs were attached to the sensor to make the measurement comfortable for participants, as shown in Figure 1b. The multimeter connected to the flexisensor registered the resistance in ohms (the larger the force, the lower the resistance). To convert the registered resistance data into force values, a calibration was conducted. Forces of magnitude from 5 N to 250 N were applied using a Texture analyser (Stable Micro Systems, Godalming, UK) and resistance at each applied force was recorded. A standard curve of the applied force (N) and registered resistance was produced. To perform the maximum finger force, subjects were asked to squeeze the neoprene adhesive with their thumb and index finger and the minimum resistance was recorded.

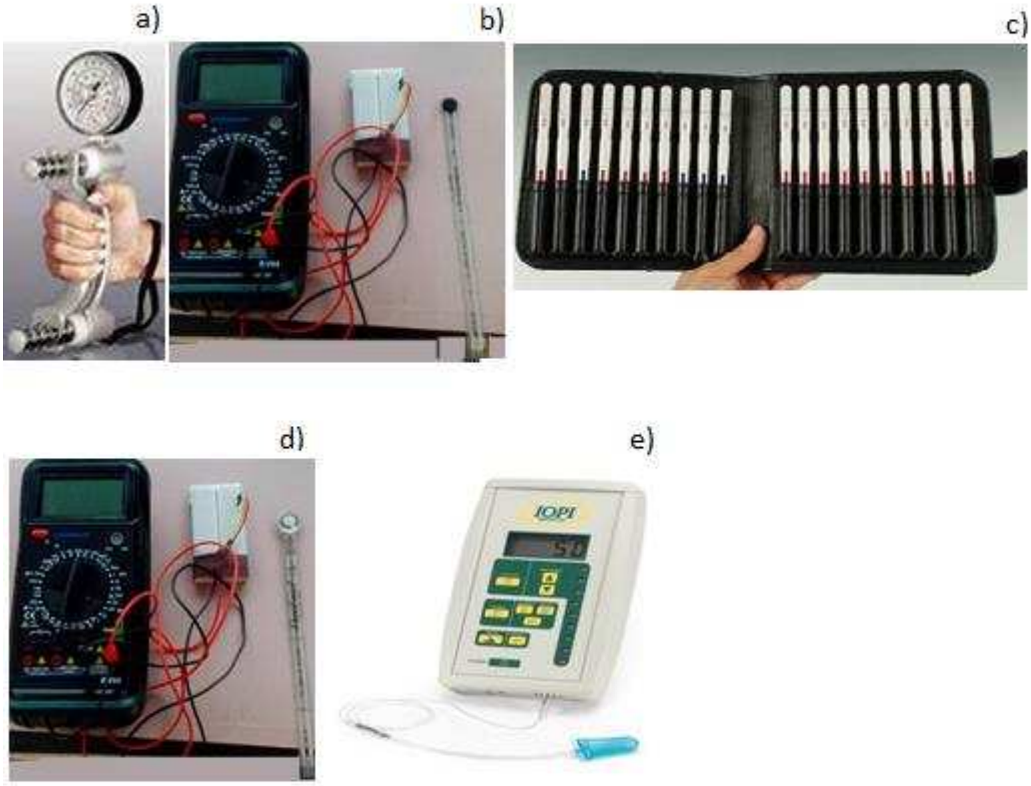

Figure 1. Illustration of the devices used for measuring eating capability components. (a) hand gripping force measuring device (JAMAR dynamometer); (b) finger gripping force measuring device (multimeter and flexisensor with neoprene disc); (c) Semes-Weinstein Monofilament (SWM); (d) biting force measuring device (multimeter and flexisensor with silicon disc) and (e) Iowa oral performance instrument.

Finger-Tactile sensitivity

The chosen technique for touching sensitivity was the Semmes-Weinstein Monofilament (SWM) test (North Coast Medical, Inc., Gilroy, California, USA) (Figure 1c)[24]. A Touch Sense™ monofilament was pressed in perpendicular direction against the skin surface until the filament was bowed for approximately 1.5 seconds and then removed. Tests were begun with the strongest monofilament, which applied a force of 300 g and continued in a descending order down to the weakest filament with only 0.008 g force. Subjects were asked to give a signal when they sensed a touch. If no signal was given after filament pressing, this was taken as a failure by the subject in detecting the touch. The value of the last monofilament that was detected by the participant was recorded as the touching threshold, which is taken as an indication of tactile sensitivity. Results of those participants who were unable to feel the monofilament of 300 g were eliminated.

Oral capability

Denture status

Participants were asked about their denture and were classified into 6 different denture statuses: natural teeth, combination (natural with some crown/bridge), full denture, nothing, just few natural teeth, and bottom or top denture.

Maximum biting force

The designed device used in previous study [23] was used for maximum biting force measurement. Two adhesive silicone disc (diameter: 1.5 cm, thickness: 0.3 cm) were used to sandwich the force sensor (Figure 1d). Participants were asked to bite the flexi sensor with the incisors and hold it for a couple of seconds. The minimum resistance shown by the multimeter was recorded. As a hygienic measure, a new plastic film protector was used for each participant.

Tongue and lip sealing pressure

Tongue pressure was measured using the Iowa Oral Performance Instrument (IOPI®, Medical LLC, Redmond, Washington, USA (Figure 1e), recording the tongue-palate pressure [25]. Participants were asked to locate the bulb into the centre of the oral cavity between the tongue and the hard palate and were asked to press with their maximum ability. The maximum pressure was recorded in kPa.

Lip sealing pressure was also measured using the Iowa Oral Performance Instrument® (IOPI) (Figure 1e). Participants were asked to place the bulb between the two lips and were asked to press lips with their maximum ability. The maximum pressure was also recorded in kPa.

Eating capability score

As in each country studied, the population had different levels of dependence, data has been analysed separately for each country using the same systematic scoring system. Among the measurements carried out, five measurements were chosen for being more repetitive and reproducible to calculate the eating capability score: right hand force, right finger force, finger touch sensitivity, tongue pressure and bite force.

The maximum eating capability score is 5-points having each test measurement contributing to a maximum of 1-point. To calculate the value of each force for every individual, a fraction was generated. The denominator was the maximum value obtained for the test by the strongest participant of that particular country, and the numerator was the participant's value that was going to be studied. To clusters the subjects in each country according to their capability, the eating capability score was used. Participants with eating capability lower than 1 was placed in cluster number one; participants with eating capability lower than 2, was placed in cluster two, and so on.

Food perception difficulty

Images of selected foods and meals in a wide range of texture (from liquid to semi solid and hard solid) printed in colour in polish-coated papers were presented to subjects. Foods of different consistencies were selected by researchers taken into account previous published works [18, 26, 27]. After, different food images were chosen with a focus group in each country with participants over 65 years old. Images were shown in a random order and subjects were asked if they had any difficulty in manipulating these food items in the plate, transferring them to the mouth, biting (1st bite), masticating, as well as swallowing them. Participants self-reported the difficulties (or not difficulty) perceived by each food item. The food items that were perceived difficult to process orally were recorded together with the associated comments after a brief discussion with each participant in both UK and Spain.

Data analysis

The calculation of the mean values and the standard deviation (SD) were done using Microsoft Office Excel 2010. One-way analysis of variance (ANOVA) to study the difference among the population in function of denture status and two-way ANOVA to study the difference due to age and gender factors was applied to the physical probes. The significant differences were calculated by Tukey's test ($p < 0.05$). Pearson's correlation was done to study the relationship between different parameters; this analysis was performed using XLSTAT 2009.4.03 statistical software (Microsoft, Mountain View, CA).

RESULTS

Eating capability components and age influence

We will discuss the results by studying first separately the different capabilities of the participants in UK and Spain. Followed by the correlations among the different parameters and finally the eating capability scores will be built up and discussed.

Hand capability.

Hand gripping forces for both countries showed similar values for the same age group. With the age increment, these values showed a decrement (non-significant for Spanish population, $p>0.05$) especially for the age above 90 years (table 1). Previous studies have reported a linear correlation between the age and the hand force for healthy adults [28]. However, in the population studied in this manuscript not significant correlation with the hand force was found, probability due to the numerous pathologies suffer by the participants (data not shown) and the high variability among them (sd >5.05 Kg for all of the age groups).

Similar tendency than hand values was found for finger forces. In table 1 it can be observed that values were also similar (at $p>0.05$) between countries with high standard deviation suggesting high variability among the individuals. Also, it does exist a tendency of finger force to decrease with the age increment (table 1), not statistically significant for Spanish population ($p>0.05$), however, correlating both finger force population against the age, there a significant negative correlation (at $p>0.01$ level) (table2).

Oral capability.

Lip pressure did not correlate with age increment in either of the countries (Table 2). However, we observed lower lip pressure values in old elderly group than in young elderly group (Table 1). Tongue pressure values were significantly different for the different age groups in both UK and Spain due to the normal muscular decline with age ($p < 0.05$) (Table 1).

Table 1. Characteristics of subjects in UK and Spain for the eating capability components measurements.

Age of participants (years)		65-69	70-74	75-79	80-84	85-89	90-94
Number of participants	UK	14	20	28	12	14	14
	Spain	13	7	16	24	25	18
Hand force (R) (kg)	UK	18.17[ab] (10.62)	20.86[a] (7.6)	21.65[a] (8.42)	19.09[ab] (7.90)	17.89[ab] (9.66)	10.51[b] (5.05)
	Spain	17.83[a] (11.01)	20.26[a] (17.07)	18.46[a] (7.64)	14.86[a] (8.88)	11.46[a] (7.11)	13.55[a] (6.73)
Hand force (L) (kg)	UK	19.58[a] (13.36)	17.81[ab] (8.14)	18.9[a] (8.33)	17.39[ab] (8.42)	14.87[ab] (8.77)	8.91[b] (4.48)
	Spain	13.52[ab] (10.52)	20.42[a] (16.09)	16.73[ab] (10.17)	14.19[ab] (7.01)	10.62 (7.22)	12.66[a] (7.17)
Finger force (R) (kg)	UK	1.77[a] (2.02)	1.01[ab] (0.45)	0.9[a] (0.42)	0.9[ab] (0.64)	0.79[ab] (0.33)	0.7[b] (0.23)
	Spain	0.99[a] (0.56)	1.35[a] (0.76)	1.1[a] (0.6)	0.91[ab] (0.60)	0.76[a] (0.30)	0.95[a] (0.49)
Finger force (L) (kg)	UK	1.46[a] (1.52)	1.17[ab] (0.84)	1.2[ab] (1.57)	0.84 (0.42)	0.99[ab] (0.72)	0.65[b] (0.11)
	Spain	0.83[a] (0.39)	1.1[b] (0.73)	1.39[a] (1.96)	0.83[a] (0.47)	0.72[a] (0.27)	0.91[a] (0.46)
Touch sensitivity threshold (g)	UK	0.22[a] (0.44)	0.22[a] (0.46)	0.09[a] (0.1)	0.16[a] (0.17)	0.21[a] (0.33)	0.45[a] (0.45)
	Spain	0.52[a] (1.19)	0.55[a] (0.57)	0.88[a] (2.55)	1.94[a] (6.27)	6.49[a] (24.94)	0.37[a] (0.47)
Lip sealing pressure (kPa)	UK	20.37[a] (9.95)	23.47[a] (10.72)	23.61[a] (9.10)	22.16[a] (8.17)	21.83[a] (9.52)	18.32[a] (8.88)
	Spain	21.92[a] (11.36)	15.5[a] (3.39)	19.47[a] (9.06)	18.81[a] (8.28)	17.45[a] (11.21)	19.22[a] (10.12)
Tongue pressure (kPa)	UK	34.07[a] (14.97)	33.62[a] (12.94)	33.59[a] (13.04)	30.62[a] (12.24)	29.39[a] (13.08)	21.88[a] (9.68)
	Spain	30.69[a] (19.49)	32.86[a] (22.33)	25.79[a] (11.08)	26.9[a] (14.38)	21.17[a] (11.18)	25.31[a] (12.21)
Bite force (kg)	UK	4.92[ab] (5.22)	5.42[a] (4.02)	5.17[a] (4.46)	2.83[ab] (2.89)	3.96[ab] (4.47)	1.33[b] (0.99)
	Spain	7.64[a] (9.05)	4.4[a] (8.54)	4.77[a] (5.65)	2.28[a] (3.69)	2.44[a] (4.16)	2.32[a] (3.16)

Values in parentheses are standard deviations. Means in the same raw with the same letter do not differ significantly ($p>0.05$) according to Tukey's test
Abbreviations: kg, kilograms; R, right; L, Left

Table 2. Correlation matrix (Pearson) with the measured eating capability components and age in UK and Spain

	Age	Right hand force (kg)	Left hand force (kg)	Finger right hand force (kg)	Finger left hand force (kg)	Touch sensitivity threshold (g)	Lip sealing pressure (kPa)	Tongue pressure (kPa)	Bite force (kg)
Age (years)	1	-0.305	-0.271	-.202**	-0.186**	0.115	-0.085	-0.234**	-0.293**
Right hand force (kg)	-0.305	1	0.809**	0.576**	0.544**	-0.151*	0.244**	0.390**	0.421**
Left hand force(kg)	-0.271	0.809**	1	0.564**	0.537**	-0.134	0.285**	0.454**	0.288**
Finger right handforce (kg)	-0.202	0.576**	0.564**	1	0.673**	-0.075	0.059	0.270**	0.297**
Finger left hand force (kg)	-0.186	0.544**	0.537**	0.673**	1	-0.104	0.025	0.210**	0.315**
Touch sensitivity threshold (g)	0.115	-0.151	-0.134	-0.075	-0.104	1	-0.166*	-0.116	-0.104
Lip sealing pressure (kPa)	-0.085	0.244**	0.285**	0.059	0.025	-0.166*	1	0.396**	0.167*
Tongue pressure (kPa)	-0.234	0.390**	0.454**	0.270**	0.210**	-0.116	0.396**	1	0.180*
Bite force (kg)	-0.293	0.421**	0.288**	0.297**	0.315**	-0.104	0.167*	0.180*	1

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Biting force exhibited for UK participants a decrement with the age (table 1), however, for Spanish population, even there is a trend to decrease the bite force with the age, it is not statistically significant. As table 3 shows the majority of the participants were denture wearers, but there is not a clear trend between the dental status and the age increment. Following previous procedure [19], measuring biting force as a function of denture status showed (table 3) that highest values were recorded for participants who had natural teeth (bite force = 6.00 kg) followed by combination (5.48 kg), denture (2.34 kg), nothing (1.3 kg) just a few (0.81kg), or top or low jaw (0.061kg). Previous researchers [9, 29, 30] underlined the importance of the oral health condition with the elderly nutrition status. In this study we used the hand gripping force as an indicator [31] for the nutritional state, as it can be observed in table 3, there was no statistically significant difference (at p>0.05) for the different dental status, again due to the high variability among participants. However, it should be mentioned that although it is not statistically significant, participants without any teeth or denture (described in the table as nothing) were the weakest executing the hand grip force (9.27 kg), meaning that this participants are in risk of malnutrition.

Table 3. Mean of age and bite force by dental status

Dental status	Number of participants	Age (Years)	Bite force (Kg)	Non dominant hand force (kg)
Natural	54	77.59^{ab} (7.82)	6.00^{a} (5.64)	17.51^{a} (10.79)
Combination	43	78.33^{ab} (8.17)	5.48^{ab} (6.27)	14.97^{a} (9.18)
Denture	77	82.31^{ab} (8.52)	2.32^{ab} (2.93)	14.69^{a} (9.38)
Nothing	13	83.77^{ab} (8.36)	1.37^{ab} (1.64)	9.27^{a} (5.08)
Just a few natural teeth	11	85.09^{b} (7.23)	0.81^{ab} (0.65)	15.57^{a} (8.48)
Top or low jaw with denture	4	75.50^{a} (6.35)	0.61^{b} (0.05)	15.56^{a} (4.38)

Values in parentheses are standard deviations. Means in the same column with the same letter do not differ significantly (p>0.05) according to Tukey's test. Abbreviations: kg, kilograms

Tactile sensitivity

Tactile or touching sensitivity is shown in Table 1. Although there exists a general increment of touching threshold (in other words, subjects were less sensitive) with age, no significant correlation was observed (Table 2).

Correlation between hand and orofacial muscle strengths

As shown in Table 2, significant correlation (at p>0.01) between hand gripping force and tongue pressure (for the right hand= 0.390; left hand=0.454) were observed. Hand force and biting force also showed a strong correlation (for the right hand= 0.421; left hand=0.288). In UK, a consistent linear relationship between hand grip and oro-facial muscle force (biting force, tongue pressure) was recorded (R = 0.72-0.89) (curve fitting not shown). In Spain, a weak polynomial relation could be established between the aforementioned forces (R= 0.35-0.68). The touching sensitivity threshold for showed an inverse relationship (at p>0.05) with the right hand gripping force (-0.151).

Eating capability group characteristics and relation with the food perception difficulty

Table 4 shows the values of eating capability scores. Each raw of table four correspond to a one single participant, the food rejected and the rejection reason explained by the participant. The maximum score to obtain was 5-points. However, none of the participants obtained the maximum score implying that no single subject could give the strongest performance in all of the capabilities measured. The strongest group of participants studied were allocated in group 4, where the maximum force values and the minimum sensitivity threshold were recorded. The group 1 corresponds to the most debilitated group of individuals.

Table 5 presents the eating capability scores for subjects in both UK and Spain along with the food rejected and the reasons for rejection, each row corresponded to one participants, meaning that from the 200 interviewed subjects, 37 participants found troublesome to eat some food product. Food products with increased level of hardness (e.g. biscuits) and fibrous structure (e.g. apple, peanut) were perceived by elderly of eating capability group 1, 2 and 3 as difficult foods to process orally.

Table 4. Group **segregation in function of eating capability described by individual objective behaviour**

	Eating Capability Score		Age (Years)		Force at non-dominant hand		Finger force non-dominant hand		Touch sensitivity threshold		Tongue pressure (Kpa)		Bite force (Kg)		Number of particpants	
	Spain	UK	Spain	UK	Spain	UK	Spain	UK	Spain	UK	Spain	UK	Spain	UK	Spain	UK
Group 1	1.34^{a} (1.52)	0.73^{a} (0.17)	83.29^{a} (8.09)	84.96^{a} (8.79)	8.89^{a} (4.85)	9.04^{a} (2.70)	0.67^{a} (0.19)	0.62^{a} (0.03)	84.71^{a} (133.77)	30.12^{a} (86.08)	19.56^{a} (9.90)	17.78^{a} (6.52)	1.16^{a} (1.41)	1.34^{a} (1.52)	55	23
Group 2	3.88^{b} (3.13)	1.39^{b} (0.26)	79.71^{ab} (7.53)	77.49^{b} (6.93)	17.67^{a} (6.78)	16.32^{b} (6.50)	0.95^{a} (0.47)	0.92^{a} (0.55)	34.85^{a} (96.65)	5.80^{a} (41.19)	32.89^{a} (13.90)	31.42^{b} (10.81)	4.70^{ab} (5.98)	3.88^{ab} (3.13)	35	53
Group 3	6.64^{c} (3.99)	2.08^{c} (0.45)	75.86^{ab} (6.69)	79.71^{ab} (7.53)	27.02^{b} (7.64)	22.07^{c} (7.33)	1.87^{b} (1.18)	1.30^{a} (0.83)	0.29^{a} (0.51)	0.06^{a} (0.05)	31.36^{a} (22.81)	39.59^{bc} (9.80)	8.58^{b} (7.68)	6.64^{b} (3.99)	7	15
Group 4	9.95^{d} (7.08)	3.19^{d} (0.14)	70.00^{b} (1.41)	73.56^{b} (4.36)	37.33^{c} (2.86)	31.27^{c} (5.26)	2.05^{b} (0.13)	3.10^{b} (2.64)	0.04^{a} (0.00)	0.28^{a} (0.65)	53.00^{b} (9.90)	47.57^{c} (9.22)	22.99^{c} (0.87)	9.95^{c} 7.08)	2	9

Values in parentheses are standard deviation.

Means in the same column with the same letter do not differ significantly ($p>0.05$) according to Tukey's test

Table 5. Eating capability scores in UK and Spain and food rejection due to oral processing difficulty

Eating capability score	Food rejected	Reasons
UK		
0.645	peanuts	not able to chew
0.677	biscuit	not able to chew
0.837	apple	not able to chew, is too hard, fragile teeth
1.112	hard candies	too hard
1.196	apple	too hard
1.233	apple, beaf, biscuit, peanuts, seed bread, tomato	not able to eat: seed bread under gums, are difficult to manipulate and hard to chew
1.558	apple	too hard
1.778	apple	apple: too hard
1.807	beef, biscuit, hard candies, lettuce, peanuts	too hard
1.892	hard candies, peanuts	peanuts: painful at mouth, hard candies: difficult to eat
1.903	Biscuit, peanuts	not able to chew
1.906	apple	not in big pieces
2.082	peanuts	not able to chew
2.569	peanuts, apple	not able to chew
2.752	peanuts, seed bread	peanuts: not able to chew; seed bread: seeds under gum
Spain		
0.36	meat	not able to chew
0.69	peanuts	not able to chew
0.79	peanuts, biscuits	not able to chew
0.89	peanuts, fres vegetables	not able to chew
1.03	meat	not able to chew
1.03	meat	not able to chew
1.04	fresh vegetables	not able to chew
1.15	apple, meat	not able to chew
1.21	apple	not able to chew
1.4	peanuts	not able to chew
1.48	apple	not able to chew
1.54	fresh vegetables	not able to chew
1.56	apple, meat, peanuts	not able to eat nothing hard
1.64	meat	get exhausted eating meat
1.65	apple,peanuts	not able to chew
1.69	apple,peanuts	not able to chew
1.71	meat	not able to chew

1.73	apple,peanuts	not able to chew
1.75	meat	not able to chew
1.93	bread and meat	not able to chew
2.16	meat	is too difficult to manipulate
2.48	apple, bread, meat	not able to chew

Note: Food that has been elicited as not able to digest, produce migraine and not consumed as prescribed by doctor has been eliminated

DISCUSSION

The main findings of the present study underline the evidence that "eating capability" concept enables going beyond age consideration and takes into account the individuals' physical capabilities.

As the result showed, for population with health issues and dependency, measured forces were not always correlated with age. For example, for hand gripping force, individuals with different health disorders, such as cerebral stroke [32], peripheral nerve [33] or hand osteoarthritis [34] cannot perform hand grip movements adequately. In case of Spanish subjects, the lower correlation values of hand gripping force with age can be explained by the debilitated of the subjects living in nursing homes. Previous authors have reported that the hand gripping strength can be related with general muscle strength [28, 31] and posterior tongue strength [35]. We also observed that hand and oro-facial muscular forces are significantly correlated despite the variability among subjects (as denture status or stroke). This indicates that hand force coul be used as predictor of oro-facial muscle strength for elderly subjects who have no sensory motor illness, however more study is needed to find a model for this relation. Assessing multiple parameters for eating capability is a necessary undertaking considering the fact that each capability measurement gives different information.

Finger gripping measurement had the highest variability among subjects, as this precision measurement picks up even minor variability in subjects suffering from traumas [36]. Although finger and hand gripping forces were significantly correlated (see Table 2), it is worth noting that these measurements provide different information about one's physiological status. Hand force indicates overall muscle strength [16] and general health status [31], but finger gripping force indicates the integrity of sensorimotor system such as damage in Parkinson's disease or Huntington's disease [32]. The decline in general strength (measured as hand gripping force) or coordination (measured as finger gripping force) could add difficulties to do common tasks of food handling such as opening a package or lifting food from the plate to the mouth. To perform these actions, touch sense is needed. The loss of sensation is related with predisposition to mechanical, thermal or chemical injury [37]. For Spanish participants, touching sensitivity did not show any relationship with other measurements; whilst in UK it was negatively correlated with hand forces.

Biting force is known to be not directly associated with the loss of masticatory performance [38], but indirectly influences food oral processing because of the loss of dents [39] or decline in salivary flow [40]. It was clear that the dental status strongly influenced the biting force values. Lesser number of teeth and consequently loss in biting force might lead to reduced efficiency of food particle size reduction and bolus formation. Subjects with incomplete dentition tend to swallow larger food particles[41]. The formation of swallow-able food bolus depends on the tongue movement and coordination. Tongue disorders might result in difficulties in swallowing [42], which is a common problem encountered in elderly population[43, 44] due to its relationship with subclinical aspiration[35] and dysphagia[45]. Clinically, swallowing disorders are diagnosed through videofluography [46], that allows to give complete information about the whole swallowing process and its possible functional abnormalities in each phase. In the present work, authors have chosen IOPI device because lingual function is a key contributor to food transportation during the swallowing process, and IOPI provides the capability of the tongue to execute this force for the swallowing initation (in KPa).Tongue pressure obtained using IOPI device is generally scattered among individuals [11]. However, the average maximum tongue pressure for older age group (35 ± 11 kPa) has been reported to be significantly lower than that for younger adults group (48 ± 10 kPa).[27] The average age and the number of participants used in this previous study were considerably lower. In our study, young elderly had a tongue pressure ranging from 30 to 34 kPa (for both countries), which confirms the results of previous qualitative study.
There has been no literature study about the lip pressure dependence on age. Most of the previous studies report the evaluation of lip sealing functions and its changes after orthodontic therapy/surgery [47, 48]. Lip sealing pressure showed high variability and little age dependence. High variability may be difficult to explain, but one may think that one's health status may play more important role than age. For instance, the occurrence of stroke is not necessarily age dependent but has huge consequence on lip sealing capability.

It must be recognized that aging population is extremely diverse. The quantitative measurement of the eating capability could help caregivers to assess a broader understanding of needs of elderly individuals. This study attempted to evaluate the relationship of physical difficulty of elderlies with their eating difficulty. Individuals were characterised for their physiological capabilities in the whole process of eating and assessed if subjects of the same cluster experienced similar eating problems. With four clusters categorised based on their capability scores, it was expected that individuals belonging to the same cluster would have similar eating difficulties. Also, subjects in cluster 1 would elicit more food eating difficulties than those of the successive clusters. However, against our expectation, clusters 1, 2 and 3 showed no clear difference in the perception of oral processing difficulties for either of the countries. Participants in all three clusters found foods with increased hardness or fibrous structure such as biscuits, apples, peanuts as difficult to eat, with "difficult to chew", "painful at mouth" , "too hard to bite" being the most common commentaries. This suggests that the current clustering system is probably not fine enough to distinguish delicate differences of eating problems among elderly populations. Further research is needed for better classification of eating capability.

In previous works researchers [49] used the Geriatric Oral Health Assessment Index, where a questionnaire regarding the functional dimension, the pain and the discomfort and the psychosocial dimension was used to evaluate problems related with food ingestion. In the present work, authors tried to summarise the entire GOHAI questionnaire to avoid participant's fatigue, we think that there is still pendent to find an objective measurement of the food difficulty. However, due to the few participants who affirmed to have problems (<18.5%), we think that in the perceived eating difficulty; psychology and social factors played an important role. For instance, many elderly with functional problems found almost impossible to eat without spilling the food and this was seen as a matter of shame. It was also obvious during the study that many elderly had fear from being judged, as has been reported by some other researchers [15, 50].

Further considerations regarding outcome measures

Research with debilitated elderlies is a challenging task due to the potential health issue implications, which might occur when the elderlies are made to eat, swallow or exert certain movement depending upon the type of food provided as a part of their study. However, authors realized that for some cases, elderly eating perception was based on social and psychological biases and may not correlate with their real difficulties of eating. According to our understanding, this is one of the causes of the lack of distinct differences between food oral difficulty perceptions as a function of different eating capability scores. Other cause might be that the willingness to eat certain food products overshadows the eating difficulty. Although further psychological approach based research is needed, authors realise that the willingness to eat certain foods even of higher hardness by the elderlies can compensate the effort (time and force needed) to do it. For example, during the course of the study, some endotelous participants affirmed to eat meat or peanuts; however, they admitted that it took them much longer time than that of eating pureed food. We believe that a different approach to measure the difficulty should be taken in future researchers, using already existing questionnaires (GOHAI) and relating these responses with the physical time needed to perform the whole eating process for different food products.

CONCLUSION

This work investigated reduced physiological capabilities of eating for elderly populations. Instrumental measurements of the hand and oro-facial muscle strengths gave quantitative reflection of one's capability of overall food management. Statistical analysis revealed important correlations among these physiological capabilities and age. Despite the investigation is still preliminary, results suggest that the positive correlation between hand and orofacial muscle strengths in elderly might lead to the possible use of non-invasive method (hand force) for eating capability assessments. However, assessing multiple parameters for eating capability is a necessary undertaking. To study the relationship between eating capability score and perceived difficulty of food oral manipulation in details, future studies are planned to examine real food oral processing with elderly using objective measurements such as measuring chewing cycles, number of chews, bolus-swallowing time, characterization of bolus and we plan to take into consideration to avoid psychological and social bias.

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