TITLE: Adjustment of food textural properties for elderly patients

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Running title: Food texture properties suitable for the elderly

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ABSTRACT:

Over the next twenty years the number of people over 60 years will exceed one billion. Changes associated with ageing have an impact on food texture choices for healthy elders and those used therapeutically for people with swallowing difficulties (dysphagia). The ideal 'swallow-safe' bolus is moist, cohesive and slippery. A general reduction in muscle strength is seen throughout the ageing oropharyngeal musculature, resulting in a reduced ability to safely and efficiently manage hard or fibrous textured foods. Reduced masticatory ability combined with dental loss further compounds the issue. Dry mouth is commonly associated with old age, making it difficult to propel dry or sticky textures through the pharynx, and increases the likelihood of pharyngeal residue. An age related reduction in laryngopharyngeal sensitivity dampens the ability to detect residue, increasing choking risk. Reduced tongue pressure, increases in pharyngeal transit time, valleculae residue, number of clearing swallows and slower and less efficient oesophageal transit occur with aged swallowing. Food textures that are sticky and adhesive will require increased lingual effort to propel them into and through the pharynx. Taken in combination these factors mean that food textures prescribed to the elderly need to be soft and moist and for fibres to be easily broken. To improve moisture content, additional nutrient dense products (e.g. milk, cream or butter) may be required to artificially moisten the bolus. Careful, individualised attention to diet recommendations will result in a diet that is appealing and also provide a variety of textures that are swallow-safe and nutrient dense.

KEY WORDS: choking risk; food textures; elderly; dysphagia; swallowing; dry mouth

PRACTICAL APPLICATION:

Aged related changes in the oral cavity and the oral, pharyngeal and oesophageal phases of swallowing require special thought to the suitability of food textures for the elderly. Foods that are fibrous, hard or dry may be unsuitable due to difficulties with safe particle size reduction and bolus formation for swallowing. Foods that are sticky and adhesive are also problematic and increase risk for both choking and residue. Food texture properties that are ideally suited for the elderly include those that are soft, moist, and easily reduced with minimal chewing effort. Hard food textures that break down and dissolve easily with minimal chewing should be investigated. Increased aroma and flavour may improve appeal lost through reduced variety in food textures. Diet reviews need to consider both textures that can be safely managed and the nutrient density of those textures.

1.0 INTRODUCTION

Compared to fifty years ago, the average person is living 20 years longer, and the World health Organization notes that for the first time, most people can expect to live into their sixties and beyond (World Health Organization, 2015). Changes associated with ageing have an impact on food texture choices for healthy elders and food textures used therapeutically for people with swallowing difficulties (dysphagia). For individuals of any age, there are certain bolus properties that promote safe and efficient swallowing (Loret *et al.* 2011). However, changes associated with aging such as reduction in muscle strength, changes to dentition and salivary flow, and alterations in sensory experiences such as aroma and taste come to effect the type of food elderly people consume (Achem & DeVault 2005). These choices affect nutrient density and can predispose to malnutrition (Popper & Kroll 2003; Taylor & Barr 2006; Charlton *et al.* 2010). This review will describe ideal food properties for safe swallowing. It will then focus on structural and physiological changes that occur with aging and their impact on food texture preferences and swallow safety. It will conclude with specific examples of food texture properties suitable for the elderly.

2.0 THE 'IDEAL' SWALLOW-SAFE BOLUS

For individuals of any age, a bolus is chewed until it is generally of homogenous texture. For hard textured foods, particles are generally reduced to particle sizes of ~1.4-2mm each (Peyron *et al.* 2004; Foster *et al.* 2011). For softer foods (e.g. banana), larger particle sizes are tolerated. The over-arching requirement of oral preparation is to reduce the food to a texture that is swallow-safe and will avoid injury to the mucosa of the oral cavity, pharynx and oesophagus (Prinz & Lucas 1995; Mishellany *et al.* 2006; Foster *et al*. 2011; Peyron *et al.* 2011). In order to achieve this, a moisture content of the final bolus for cereal based foods has been reported to be around 50% (Loret *et al*. 2011). For other foods moisture content is achieved through inherent moisture in the food and supplementation with saliva that is released during chewing and oral preparation. Foods that have a high water content may need very little saliva added, whereas very dry foods (e.g. nuts), will require significantly more saliva and more chewing to moisten the bolus (Mishellany *et al.* 2006). For differing meat textures, moisture content at the point of swallow readiness was found to be the same, despite differences in level of fibre disorganization (Yven *et al.* 2006)The final swallow-safe bolus is soft, homogenous in texture, cohesive and slippery enough to allow ease of swallow initiation and swift transport through the pharynx (Hoebler *et al.* 1998; Loret *et al.* 2011; Motoi *et al.* 2013).

3.0 CHANGES TO THE INTEGRITY OF THE CHEWING AND SWALLOWING MECHANISM ASSOCIATED WITH AGING

A general reduction in muscle strength is seen throughout the ageing oropharyngeal musculature resulting in a reduced ability to safely and efficiently manage hard or fibrous textured foods (Kohyama *et al.* 2002; Hall & Wendin 2008). Anterior and posterior tongue strength is reduced as individuals age (Butler *et al.* 2011). The tongue has a key role in manipulation and placement of the bolus between the molar surfaces for chewing, and removal of residue from in and around tooth structures. Following oral preparation of the bolus the tongue shapes and collects the bolus in readiness for swallow initiation and then propels the bolus from the oral cavity to the pharynx. There are also efficiency changes associated with reduced muscle strength in the pharyngeal phase of swallowing. The superior, middle and inferior pharyngeal constrictors have a role in clearing the tail of the bolus through the pharynx and into the oesophagus. Increases in pharyngeal transit time, valleculae residue, and number of clearing swallows are associated with the aged swallow (Donner & Jones, 1991; Dejaeger *et al.*, 1997; Rademaker *et al.* 1998). Finally, reduced oesophageal transit and oesophageal abnormalities such as tertiary contractions and achalasia may also be seen, further impeding flow of the bolus from the oesophagus to the stomach (Shaker & Lang 1994; Dejaeger *et al.* 1997). Certain food textures (e.g. hard, dry, fibrous) become more challenging to manage in the context of ageing swallowing system (Lee & Anderson 2005).

3.1 Dental loss and food texture choices

Whilst it is well known that aging causes systemic changes to skeletal muscles, the effect on the masticatory system is more complex than those of the limb and trunk, for example (Grunheid *et al.* 2009). The jaw muscles have an abundance of hybrid fibres including both slow and fast twitch muscle fibres that contribute to precise modulation of jaw position and force during mastication (Korfage *et al.* 2005). Furthermore there are large individual variations in fibre-type composition. Like limb and trunk muscles there is a reduction in density of cross-sectional masticatory muscle fibres (Korfage *et al.* 2005), however in elderly individuals the proportion of pure Type I fibres decreases while the number of Type II and hybrid fibres increase (Korfage *et al.* 2005). Grunheid *et al.* (2009) reported that muscles have an inherent ability to adapt to changing needs. For example, overloading and increased muscle activity leads to slower, fatigue resistant fibres, whereas unloading and reduced muscle activity leads to transition towards faster, more fatiguable fibre types.

A series of inter-connected elements may drive the changes noted above in human jaw muscles. Firstly, tooth loss is common in the elderly and has prompted initiatives such as the Japanese 8020 campaign for the elderly to retain 20 teeth by 80 years of age (Yamanaka *et al.* 2008). This initiative is supported by studies by Kayser (1981, Kaiser *et al.* 1987) who showed that a minimum of four symmetrical occlusal units and six asymmetrical occusal units were required for adequate masticatory function with an over-riding recommendation for retention of 10 occlusal surfaces (12 front teeth, 8 pre-molars). Loss of occlusal units affects bite force such that those with greater than 20 teeth (10 paired occluscal units) have a bite force of 555 N , in contrast to an exponential decline in bite force with a reduction in remaining teeth; for example 383 N for 10-19 teeth remaining; 180 N for 1-9 teeth remaining and 155 N for edentulous individuals (Yamanaka *et al.* 2008). Korfage *et al.* (2005) noted that removal of all incisors and molars in a monkey model demonstrated a reduction in masticatory muscle mass, a decrease in slow twitch masseter muscle fibres and an increase in masseter fast twitch, fast fatiguable fibres.

In addition to tooth loss, the effect of food hardness may have an effect on the composition of jaw muscle fibres. Although there are no human studies reported, animal studies indicate that provision of a soft diet in a rabbit model results in a reduction in Type I (slow twitch) fibres and an increase in Type II (fast twitch) fibres (Korfage *et al.* 2005). This discussion highlights a clear inter-relationship between number of occlusal units, bite force, and muscle changes adapting to reduced usage. Consequently diet becomes both an impact on and an outcome of dental status in the elderly. Note also, the link between dental status and choking risk. There is a high correlation between absent teeth, ill-fitting dentures, dental disease and sudden choking deaths (Berzlanovich *et al.* 2005; Wick *et al.* 2006). Pereira *et al.* (2006) and Okamoto *et al.* (2012) have found that individuals with dentures have only 25% of the chewing effectiveness of dentate people and produce a coarser bolus that has larger particles. Fibrous foods (meat), hard food (raw fruit and vegetables), and mixed consistency textures become more challenging with age (e.g. soups with noodles, meat, vegetables, chicken or fish with bones) (Lee & Anderson 2005; Hall & Wendin 2008). Softer, easy-to-chew options are more likely to be chosen.

3.2 Food texture modification for safety

Healthy elders will typically choose soft textured food by preference. Individuals with swallowing difficulties as a result of stroke, neurological conditions, head and neck cancer or other conditions require a range of degrees of food texture modification (Wright *et al.* 2005; Germain *et al.* 2006). There are typically three levels of food texture modification plus regular food. These often include foods that are (a) soft, (b) minced and moist or mashed, and (c) pureed or ground (Cichero et al., 2013). Most recently, the International Dysphagia Diet Standardisation Initiative (IDDSI) released international descriptors for food texture modification for individuals with swallowing difficulties (IDDSI 2015). The IDDSI framework is a continuum of eight levels (0-8) addressing both food and drink texture modification on a single continuum (IDDSI 2015). For foods, as with all published national terminologies, each category of food texture modification requires the bolus to be soft and moist (Cichero et al., 2013; IDDSI 2015). Degrees of modification then largely reflect homogeneity of particles and particle size. Soft food textures can be mashed with a fork but may have disparate particle sizes, whilst pureed or ground food has very small particles that are homogenous in texture and size. The recommendations regarding food texture features, including size and shape are informed by autopsy results and non-fatal choking incidents (Rimmel *et al.* 1995; Berzlanovich *et al.* 1999; Centre for Disease Control and Prevention 2002; Morely et al 2004; Food Safety Commission Japan 2010; Chapin *et al.* 2013; Siddell *et al.* 2013; Kennedy *et al.* 2014). Whilst more people choke in the community or at home, choking still occurs in hospital settings (69% and 9.5-27% respectively) (Berzlanovich *et al.* 2005). The types of food individuals choke on includes sausages, sandwiches, meat, vegetables, noodles, and the less intuitive puree, ground meat and mashed fruit (Cichero 2015). In addition to food textures or shapes that increase choking risk, person-features must also be considered. Individuals with cognitive impairment, oral phase impairment and those with an intellectual disability are at higher risk of choking (Samuels *et al.* 2007). Individuals with missing or compromised teeth are at increased risk of choking (Berzlanovich *et al.* 1999, 2005; Wick *et al.* 2006); and individuals with reduced bite force and chewing ability are likewise at increased risk of choking (Chen, 2009).

3.3 Hard food, fibrous food and 'dissolvable' hard food textures

For individuals who experience fatigue during chewing, but have otherwise good control of the bolus, it may be sufficient to cut hard textured food to smaller 'bite-sized pieces' to reduce the masticatory load. Indeed a recommendation from a systematic review of choking deaths considers small particle size recommended management to reduce choking risk (Kennedy *et al.* 2014). The human thumbnail measuring about 1.5cm, provides a reasonable reference point for a particle size that is large enough to chew, yet small enough to require fewer chewing actions (Murdan 2011). Indeed this size is often used in sensory testing, and has been reported in published national terminologies (National Dysphagia Diet Task Force 2002; Kohyama *et al.* 2002; Mishellany *et al.* 2006; Atherton *et al.* 2007; National Patient Safety Agency UK 2011; Duan *et al.* 2014).

Fibrous foods are complex food textures for oral preparation and are often identified on autopsy studies as choking risks (Berzlanovich *et al.* 1999, 2005; Wick *et al.* 2006;

Food Safety Commission Japan 2010). Safe chewing and swallowing of fibrous foods requires an ability to break the fibrous framework and then reduce the particles to a size and form that is swallow safe. Rotary chewing using the molar teeth and sufficient stamina is required for this process. For meat products, cutting across the grain makes fibres shorter and therefore easier to chew (Purslow 2005).

Anecdotally and from clinical experience, individuals who require soft, minced or pureed food textures often miss the 'crunch' and textural variety offered with hard textured foods. There is a class of hard food textures referred to clinically as 'dissolvable' or 'melt-in-the-mouth' textures that have a regular hard texture appearance, but with the addition of moisture and little chewing are easily broken down to a swallow-safe bolus (Gisel 1991; Dovey *et al.* 2013). These foods have been used clinically most often with the paediatric or disability populations to teach chewing skills (Dovey *et al.* 2013). However, they could be used effectively for the elderly who wish to experience the sensory qualities that hard textured food provides with the benefit that little chewing strength or stamina and minimal saliva is needed for oral preparation. Some examples include potato crisps, wafers, and prawn crackers or crisps (Gisel 1991; Dovey *et al.* 2013; Duan *et al.* 2014). 'Dissolvable' foods have also been described in the International Dysphagia Diet Standardisation Initiative framework in the 'transitional foods' section (IDDSI 2015).

3.4 Sticky and adhesive foods

As noted above, there is a reduction in tongue strength associated with aging (Butler *et al.* 2011). Sticky and adhesive foods such as nut butters, sticky rice and festive sticky rice cakes have been associated with increased choking risk (Wick *et al.* 2006; Food Safety Commission Japan 2010). The tongue force required to initiate movement of this type of food texture, resistance offered to movement and potential to stick to structures such as the hard palate or gingiva with unexpected or uncontrolled release once sufficiently softened with saliva increases choking risk. Sticky and adhesive food textures should be avoided in frail elders and individuals with swallowing difficulties (Berzlanovich *et al.* 2005; Kennedy *et al.* 2014).

3.5 Boost aroma and flavor to compensate

Where food texture modification is essential for safe swallowing and to reduce choking risk, alternatives to texture are required to increase the appeal of the food. Chewing releases flavor volatiles as particle mix with saliva throughout the oral phase, whereas foods that require little or no chewing results in retronasal flavor appreciation that occurs after the swallow (Foster *et al.* 2011). Boosting flavor and aroma provides one way to increase the sensory experience, although both of these sensory areas are somewhat degraded with aging (Popper & Kroll 2003). There are studies, however, that have shown that the ability to appreciate particular food flavours are preserved and have been shown to provide a statistically significant increasing in food appeal. For example the inclusion of oyster sauce, ginger, and garlic along with judicious use of foods that excite the intact trigeminal system (e.g. heat of chili, pungency of mustard) have been shown to increase food intake in the elderly (Henry *et al.* 2003; Delahunty *et al.* 2004).

4.0 INTEGRITY OF THE BOLUS PATHWAY

The discussion above has focused on the integrity of the chewing mechanism and food textures properties that help to create a swallow-safe bolus. However, attention must also be paid to integrity of the bolus pathway. Even a slippery, cohesive bolus will travel more slowly and require greater effort to propel if the bolus pathway (i.e.

oral, pharyngeal and/or oesophageal mucosa) is dry. Healthy saliva production is essential to the slippery texture of the final bolus in addition to the integrity of the oropharynegal and oesophageal mucosa. Both watery and viscous saliva are produced (Humphrey & Williamson 2001). Mucins within saliva help to provide the 'slippery' quality that lubricates and assists with bolus transport (Bongaerts *et al.* 2007). Saliva has a role in dissolving tastants during chewing which enhances flavor perception, and also offers a role in temperature regulation of the bolus. Saliva includes enzymes that help initiate carbohydrate digestion (e.g. amylase and lipase), whilst also providing an acid-base balance to manage reflux and bacteriostatic and bactericidal function to protect the oral cavity (Humphrey & Williamson 2001). Thus saliva has a key role in keeping the oropharynx and oesophagus moist and in good condition. A slippery bolus will travel far more effectively along a pathway that is also moist and lubricated, reducing the likelihood of residue or the need for multiple clearing swallows.

Liedberg & Owall (1991) investigated the effect of saliva loss on chewing and capacity for oral food perception. Healthy individuals received intramuscular injections of 0.5 mL of methylscopolamine nitrate to temporarily restrict saliva flow during the chewing experiments. The authors noted when compared to normal saliva function, that a chemically induced reduction in saliva resulted in a lack of perception of food particles in the oral cavity, difficulty collecting and forming a bolus and difficultly initiating the swallow reflex. Hydrophilic foods that particulate (e.g. nuts, crackers, cookies) pose a particular problem in this regard, compromising swallowing safety. A reduction in saliva occurs as a natural part of the ageing process and is exacerbated by medication side effects that cause dry mouth. (Cassolato & Turnbull 2003). Xerostomia, or dry mouth, thus affects the ability to form a swallow-safe bolus with sufficient moisture content and also increases the dryness of the bolus pathway, thereby increasing risk for residue and need of multiple swallows to clear the bolus (Lee & Anderson 2005). Both of these features increase choking risk. Hard, dry, sticky and adhesive foods require large amounts of saliva, also making these textures unsuitable for individuals with dry mouth conditions. Further compounding these effects, there is an age related reduction in laryngopharyngeal sensitivity that dampens the ability to detect residue (Martin *et al.* 1994). Residue may be inhaled after the swallow, increasing choking risk.

5.0 FOOD TEXTURE MODIFICATION AFFECTS NUTRIENT DENSITY

Although elderly people are less active than younger people, their need for most nutrients does not change (WHO 2015). Consequently malnutrition is a concern for the elderly (WHO 2015). The need to avoid entire classes of food texture such as hard, dry, fibrous, sticky and adhesive foods impacts on whole food groups necessary for adequate nutrition. For example, the need to avoid these types of textures affects the ability to consume iron-rich protein (meat, poultry, fish, nuts, seeds etc.), foods containing vitamins and minerals (raw fruits and vegetables) and foods containing dietary fibre (fruits and vegetables). Texture modification such as puree requires the addition of liquid to ensure the final product is moist. Nutrient dilution can occur if food is pureed with water. Nutrient-rich alternatives such as milk, butter, cream, cheese, gravy, creamy soup or sour cream could be used to add moisture to pureed food instead. Some individuals may safely manage a small amount of regular textured food but benefit from nutrient-rich, high calorie supplements to meet their nutritional needs.

The consequences of inadequate nutrition are sobering. Malnutrition results in reduced muscle mass that often results in reduced functional ability, thereby increasing dependence on others. Increased risk of infection and poor wound healing (e.g. pressure sores) are also associated with malnutrition (Litchford *et al.* 2014). Eating smaller amounts also results in gut atrophy. Attention is needed to both nutritional content and swallow-safe food textures that can deliver these needs to elderly people.

6.0 CONCLUSION

Food textures prescribed to the elderly need to be soft or for fibres to be easily broken. The bolus needs to be moist and lubricated to overcome issues associated with passage of the bolus over dry oropharyngeal mucosa. This may mean that additional nutrient dense moisture (e.g. milk, cream or butter) is required to artificially moisten the bolus. Hard, dry foods should generally be avoided, with the exception of 'dissolvable' solids. Careful, individualised attention to food textures will result in a diet that provides a variety of textures, that is swallow-safe and able to meet the person's nutritional needs.

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ETHICAL REVIEW: This review does not involve human or animal testing.

REFERENCES

ACHEM, S.R. and deVAULT, K.R. 2005. Dysphagia in aging. J Clin Gastroenterol 39, 357-371.

BERZLANOVICH, A.M., FAZENY-DORNER, B., WALDHOER, T., and FASCHING, P. 2005. 'Foreign body asphyxia: A preventable cause of death in the elderly. American Journal of Preventive Medicine 28: 65-69.

BERZLANOVICH, A.M., MUHM, M., SIM, E., and BAUER, G. 1999. Foreign body asphyxiation – an autopsy study. American Journal of Medicine 107: 351-355.

BONGAERTS, J.H.H., ROSETTI, D. and STOKES, J.R. 2007. The lubricating properties of human whole saliva. Tribo Lett 27: 277-287. DOI 10.1007/s11249-007-9232-y

BUTLER, S.G., STUART, A., LENG, X., WILHELM, E., REES C., WILLIAMSON, J., KRITCHEVSKY S.B. 2011. The relationship of aspiration status with tongue and handgrip strength in healthy older adults. J Gerontol A Biol Sci Med Sci 66: 452-458. doi:10.1093/gerona/glq234

CASSOLATO, S.F. and TURNBULL, R.S. 2003. Xerostomia: clinical aspects and treatment. Gerodontology 20: 64-77.

CENTRE FOR DISEASE CONTROL AND PREVENTION. 2002. Non-fatal choking related episodes among children, United States 2001. Morb Mortal Wkly Rep 51: 945-948.

CICHERO, J.A.Y., STEELE, C., DUIVESTEIN. J., CLAVE. P., CHEN. J., KAYASHITA. J., DANTAS. R., LECKO. C., SPEYER. R., LAM. P. and MURRAY

J. 2013. The need for international terminology and definitions for texture-modified food and thickened liquids used in dysphagia management: Foundations of a global initiative. Current Physical Medicine and Rehabilitation Reports 1: 280-291.

CICHERO J.A.Y. 2015. Texture-modified meals for hospital patients. In J Chen & A Rosenthal, Modifying Food Texture (Volume 2): Sensory analysis, consumer requirements and preferences. Elsevier Ltd. Cambridge, U.K.

CHAPIN, M.M., ROCHETTE, L.M., ABNNEST, J.L., HAILEYESUS, T., CONNOR, K.A. and SMITH, G.A. 2013. Nonfatal choking on food among children 14 years or younger in the United States, 2001-2009. Pediatrics: 132: 275-281

CHARLTON, K.E., NICHOLS, C., BOWDEN, S., LAMBERT, L., BARONE, L., MASON, M. and MILOSAVLJEVIC, M. 2010. Older rehabilitation patients are at high risk of malnutrition: Evidence from a large Australian database. J of Nutr, Health & Aging 14: 622-628.

CHEN, J. 2009. Food oral processing – A review. Food Hydrocolloids 23: 1-25.

DEJAEGER, E., PELEMANS, W., PONETTE, E, and JOOSTEN, E. 1997. Mechanisms involved in postdeglutition retention in the elderly. Dysphagia 12: 63–7.

DELAHUNTY, C.M. 2004. How do age related changes in sensory physiology influence food liking and food intake? Food Quality & Preference 15: 907-911.

DONNER M. and JONES, B. 1991 Ageing and neurological disease. In Jones B, Donner MW (Eds) Normal and Abnormal Swallowing: Imaging in Diagnosis and Therapy. Springer-Verlag, New York.

DOVEY, T.M., ALDRIDGE, V.K. and Martin, C.L. 2013. Measuring oral sensitivity in clinical practice : A quick and reliable behavioural method. Dysphagia 28:501-510.

DUAN, H., Gu, S. ZHAO, L. and LU, D. 2014. Establishment of fracturability standard reference scale by instrumental and sensory analysis of Chinese food. J Texture Studies 45: 148-154. doi:10.1111/jtxs.12059.

FOOD SAFETY COMMISSION JAPAN. 2010. Risk Assessment Report: Choking accidents caused by foods. *www.fsc.go.jp/english/topics/choking_accidents_caused_by_foods.pdf (accessed April 2014).*

FOSTER, K.D., GRIGOR, J.M.V., NE CHEONG, J., YOO, M.J.Y., BRONLUND, J.E. and MORGENSTERN, M.P. 2011. The role of oral processing in dynamic sensory perception. Journal of Food Science 76: R49-R61.

GERMAIN, I., DUFRESNE, T., and GRAY-DONALD, K. 2006. A novel dysphagia diet improves the nutrient intake of institutionalized elders. Journal of the American Dietetic Association. 106: 1614-1623.

GISEL, E.G. 1991. Effect of food texture on the development of chewing of children between six months and two years of age. Dev Med Child Neurol. 33: 69–79.

HALL, G. and WENDIN, K. 2008. Sensory design of foods for the elderly. Ann Nutr Metab., 52, 25-28. DOI: 10.1159/000115344

GRUNHEID, T., Langenbach G.E.J., Korfage, J.A.M., Zenter, A., and van Eijden T.M.G.J. 2009 'The adaptive response of jaw muscles to varying functional demands. Eur J Orthodont, 31, 596-612. DOI: 10.1093/ejo/cjp093.

HENRY, C.J.K., WOO, J., LIGHTOWLER, H.J., YIP, R., LEE, R., HUI, E., SHING, S., and SEYOUM T.A. 2003. 'Use of natural food flavours to increase food and nutrient intakes in hospitalized elderly in Hong Kong', International Journal of Food Sciences and Nutrition. 54: 321-327.

HOEBLER, C., KARINTHI, A., DEVAUX, M-F., GUILLON, F., GALLANT, D.J.G., BOUCHET, B., MELEGARI, C. and BARRY, J-L. 1998. Physical and chemical transformations of cereal food during oral digestion in human subjects, British Journal of Nutrition 80: 429-436.

HUMPHREY, S.P. and WILLIAMSON, R.T. 2001. A review of saliva: normal composition, flow and function. J of Pros Dent, 85, 162-169.

INTERNATIONAL DYSPHAGIA DIET STANDARDISATION INITIATIVE. 2015. Detailed descriptions, testing methods and evidence: Food Levels 4-7. www.http://iddsi.org/resources/ Accessed 24 November 2015.

KENNEDY, B., IBRAHIM, J.E., BUGEJA, L. and RANSON, D. 2014. Causes of death determined in medicolegal investigations in residents of nursing homes: A systematic review. Journal of the American Geriatrics Society 62: 1513-1526.

KAYSER, A.F. 1981. Shorted dental arches and oral function. J Oral Rehab, 8, 457-462.

KAYSER, A.F., Witter, D.J. and Spanauf, A.J. 1987 'Overtreatment with removable partial dentures in shortedn dental arches. Aus Dent J, 32, 178-82.

KORFAGE, J.A.M., Koolstra, J.H., Langenbach, G.E.J, and van Eijden T.M.G.J. 2005. Fiber-type composition of the human jaw muscles (part 2) – Role of hybrid fibers and factors responsible for inter-individual variation. J Dent Res, 84, 784-793.

KOHYAMA, K., MIOCHE, L. and MARTIN, J-F. 2002. Chewing patterns of various texture foods studied by electromyography in young and elderly populations. J. Texture Studies 33, 269-283.

Lee, J. and Anderson, R. (2005) 'Effervescent agents for oesophageal food bolus impaction', Emergency Med J, 23, 123-124.

LIEDBERG, B. and OWALL, B. 1991. Masticatory ability in experimentally induced xerostomia. Dysphagia 6: 211-213.

LITCHFORD M.D., Dorner B. & POSTHAUER M.E. 2014. Malnutrition as a precursor of pressure sores. Advances in Wound Care 3: 54-63. DOI: 10.1089/wound.2012.0385

LORET, C., WALTER, M., PINEAU, N., PEYRON, M.A., HARTMANN, C., and MARTIN, N. 2011. 'Physical and related sensory properties of a swallowable bolus' Physiol & Behav, 104, 855-864.

MARTIN, J.H., DIAMOND, B., AVIV, J.E., JONES, M.E., KEEN, M.S., WEE, T.A. and Blitzer A. 1994. Age-related changes in pharyngeal and supraglotic sensation. Ann Otol Rhinol Laryngol. 103: 749-752.

MISHELLANY, A., WODA, A., LABAS, R. and PEYRON, M-A. 2006. The challenge of mastication: Preparing a bolus suitable for deglutition. Dysphagia 21: 87-94.

MOTOI L., MORGENSTERN, M.P., DUNCAN I., WILSON, A.J. and BALITA, S. 2013. Bolus moisture content of solid foods during mastication. J Texture Studies, 44, 468-479.

MURDAN S. 2011. Transverse fingernail curvature in adults: a quantitative evaluation and the influence of gender, age and hand size and dominance. Int J Cosmet Sci, 33:509-513.

NATIONAL DYSPHAGIA DIET TASK FORCE. 2002. National dysphagia diet: standardization for optimal care. American Dietetic Association, Chicago.

NATIONAL PATIENT SAFETY AGENCY, ROYAL COLLEGE SPEECH AND LANGUAGE THERAPISTS, BRITISH DIETETIC ASSOCIATION, NATIONAL NURSES NUTRITION GROUP, HOSPITAL CATERERS ASSOCIATION. 2011. Dysphagia diet food texture descriptions. http://www.ndr-uk.org/Generalnews/dysphagia-diet-food-texture-descriptors.html. Accessed 29 Apr 2011.

OKAMOTO, N., Tomioka, K., Saeki, K., Iwamoto, J., Morikawa, M., Harano, A., and Kurumatani N. 2012. 'Relationship between swallowing problems and tooth loss in community-dwelling independent elderly adults: the Fujiwara-Kyo study', J Am Geriatr Soc., 60, 849–53.

PEREIRA, L.J., GAVIAO, M.B.D. and VAN DER BILT, A. 2006. Influence of oral characteristics and food products on masticatory performance. Acta Odontologica Scandinavica. 64: 193-201.

PEYRON, M-A., GYERCZYNSKI, I., HARTMANN, C., LORET, C., DARDEVET, D., MARTIN, N and WODA, A. 2011. Role of physical bolus properties as sensory inputs in the trigger of swallowing. *PLoS ONE* 6: e21167.

PEYRON, M-A., MISHELLANY, A and WODA A. 2004. Particle size distribution of food boluses after mastication of six natural foods. J Dent Res, 83, 548-582. DOI: 10.1177/154405910408300713

POPPER R. and KROLL, B.J. 2003. Food preference and consumption among the elderly. Food Technology 57: 32-40.

PRINZ, J.F., and LUCAS, P.W. 1995. Swallow thresholds in human mastication. Archives of Oral Biology 40: 401-403.

PURSLOW, P.P. 2005. Intramuscular connective tissue and its role in mean quality. Meat Science 70: 435-447.

RADEMAKER, A.W., PAULOSKI, B.R., COLANGELO, L.A. and LOGEMANN, J.A. (1998) Age and volume effects on liquid swallowing function in normal women. Journal of Speech Language and Hearing Research 41: 275–84.

RIMMELL, F. THOME, A., STOOL S., REILLY, J.S., RIDER, G., STOOL, D. and WILSON, C.L. 1995 Characteristics of objects that cause choking in children. JAMA 274: 1763-1766.

SAMUELS, R., and CHADWICK, D.D. 2006. Predictors of asphyxiation risk in adults with intellectual disabilities and dysphagia. Journal of Intellectual Disability Research 50: 362-370.

SHAKER, R. and LANG, I.M. 1994. Effect of ageing on the deglutitive oral, pharyngeal, and esophageal motor function. Dysphagia 9: 221–8.

SIDDEL, D.R., KIM, I.A., COKER. T.R., MORENO, C. and SHAPIRO, N.L. 2013. Food choking hazards in children. Int J Ped Otorhinolaryngol 77: 1940-1946.

WICK, R., GILBERT, J.D., and BYARD, R.W. 2006 Café coronary syndrome-fatal choking on food: An autopsy approach. Journal of Clinical Forensic Medicine 13: 135-138.

WORLD HEALTH ORGANIZATION. 2015. World Report on Ageing and Health, WHO Press, Geneva, Switzerland.

YAMANAKA K., Nakagaki, H., Morita, I., Suzaki, H., Mashimoto, M., and Sakai T. 2008. Comparison of the health condition between the 8020 achievers and the 8020 non-achievers. Int Dent J, 58, 146-150.

YVEN, C., Bonnet, L., Cormier, D., Monier, S., and Mioche, L. 2006. Impaired mastication modifies the dynamics of bolus formation. Eur J Oral Sci, 114, 184-190.