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Relationships between masticatory rhythmicity, body mass and cephalometrically-determined aesthetic and functional variables during development in humans

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ABSTRACT

Objective: We studied the relationship between chewing rhythmicity, craniomandibular morphology, and age in humans.

Design: Sixty subjects (10 M:10F/group × three age groups, viz., 4–8, 10–14, and 17–21 years) participated. Subjects chewed gum for 2 min while jaw movements in the frontal plane were videorecorded. Mean and variation in mean chewing cycle duration (T_C) were quantified using maximum opening to maximum opening as cycle boundaries. Five "aesthetic" cephalometric variables (e.g., ANB) and seven "functional" variables (e.g., jaw length) were quantified from subjects' lateral cephalographs. Simple linear regression models and several multivariate analyses were used in comparisons.

Results: Mean T_C increased and variation in T_C decreased significantly with age. Body mass correlated with age, height, T_C, all seven "functional" variables and only two "aesthetic" variables. Mean T_C was correlated significantly with jaw length, distance from condylion to first molar point, distance from gonion to zygomatic arch, and distance from hyoid to menton.

Conclusions: T_C appeared to adapt with age. Although T_C scaled most significantly with age, it is more likely that T_C is mechanistically linked to jaw length or size. The decrease in T_C variation with age suggests improved efficiency. T_C did not scale with "aesthetic" variables, suggesting that these do not impact chewing rate; however, clinical procedures that impact jaw length may. The negative allometric scaling of T_C with "functional" variables may reflect the pedomorphic jaw and face of humans. Further human studies will provide insights into the nature of scaling and adaptation of rhythmic chewing during development.

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1. Introduction

Mastication is among the most important functions of the mammalian orofacial system. Mammals have been particularly successful due in part to unique and diverse dental, glossal and oral traits (reviewed in[1]). Although definitions vary, there is general consensus that true mastication is characterized by relatively rhythmic jaw opening and closing movements, a precise inter-occlusal bite and unique sensory adaptations, which likely play a key role in maintaining masticatory rhythmicity.[2]

The periodicity of rhythmic behaviours such as mastication has been variously modelled or described. For instance, based on Poincaré maps and spatial statistical methods, rhythmicity in brainstem neural circuitry generating mammalian respiration has been identified as manifesting simple periodic limit cycle activity with noise, mixed-mode oscillatory behaviour, quasiperiodic oscillatory behaviour, or high-dimensional chaotic (aperiodic) behaviour with increased neural excitability.[3] Other investigators have attempted to calculate the fractal dimension of human mastication.[4] Further dynamical systems analyses will be informative regarding the rhythmic nature of mastication. For purposes of this paper, we will define rhythmicity in relatively simple terms using the uncorrected coefficient of variation (CV, cf.[5] for an example of use of the corrected CV), defined as the ratio of the standard deviation (SD) and mean masticatory cycle duration, T_C, or its inverse, mean masticatory cycle frequency F_C, calculated from samples of continuous masticatory sequences.

Although mastication involves reduction of food, studies of masticatory rhythm in humans have often used chewing gum. An advantage of using chewing gum is that it provides a means of sampling long, continuous sequences of rhythmic masticatory-like activity, which is ideal for studies of motor rhythmicity. For instance, Plesh et al. used a metronome to evaluate jaw movement timing and kinematics and masticatory electromyography (EMG) associated with gum chewing.[6] As rate increased above each subject's preferred chewing rate, it became increasingly difficult for subjects to follow the metronome, and several changes in kinematics and EMG activity were noted. According to the authors, the results suggested that chewing performance was tied to a preferred chewing rate. On the other hand, no subjects were able to follow metronomes perfectly, i.e., CV was about 10–17% at slow and fast rates (calculated from Table 1 in the paper), and when subjects were allowed to chew gum at a preferred rate, the CV was very similar to that reported in other mammals, viz., 22%. This suggests that both T_C and CV are important properties of mastication that can be identified in human studies that use chewing gum.

Various factors may affect mean and variation in T_C. These factors include but are not limited to jaw kinematics,[7,8] tongue kinematics,[9] jaw length,[10,11] length and force of the chewing stroke[12,13] and, to a lesser extent, the physical properties of

Table 1 – Demographics and descriptive statistics of subjects by group and sex.

Variable[a]	Child			Adolescent			Adult		
	Female	Male	Total	Female	Male	Total	Female	Male	Total
N	10	10	20	10	10	20	9	9	18
Age	6.0 (1.2)	6.1 (1.1)	6.0 (1.2)	11.6 (1.1)	11.7 (1.4)	11.6 (1.2)	19.4 (0.9)	19.2 (0.8)	19.3 (0.8)
Ethnicity	0:1:9:0:0	1:0:9:0:0	1:1:18:0:0	0:0:9:0:1	1:2:7:0:0	1:2:16:0:1	0:0:8:1:0	0:0:8:0:1	0:0:16:1:1
Ht	115 (14)	113 (10)	114 (12)	148 (10)	149 (13)	149 (12)	163 (8)	180 (6)	172 (11)
Wt	22 (4)	23 (6)	23 (5)	39 (11)	45 (12)	42 (12)	59 (6)	76 (7)	67 (11)
T_C	656 (92)	584 (74)	620 (89)	709 (114)	819 (74)	764 (109)	779 (82)	842 (85)	811 (87)
CV_C	0.20 (0.04)	0.17 (0.04)	0.19 (0.04)	0.17 (0.04)	0.16 (0.03)	0.17 (0.03)	0.14 (0.04)	0.16 (0.02)	0.15 (0.03)
N_C	62 (8)	64 (3)	63 (6)	60 (5)	60 (5)	60 (5)	58 (4)	60 (6)	59 (5)
Co-Cr	26.9 (5.3)[b]	27.9 (2.4)	27.4 (3.9)[b]	30.5 (2.8)	29.5 (4.0)	30.0 (3.4)	31.2 (3.8)	32.8 (5.6)	32.0 (4.7)
Co-Gn	87.4 (5.2)[b]	89.7 (3.2)	88.6 (4.3)[b]	100.2 (6.8)	102.8 (6.4)	101.5 (6.6)	111.2 (5.2)	119.2 (5.1)	115.2 (6.5)
Co-Ma	21.7 (1.1)[b]	23.1 (1.8)	22.4 (1.7)[b]	24.1 (4.0)	24.6 (2.8)	24.4 (3.4)	25.6 (2.6)	27.4 (3.5)	26.5 (3.1)
Go-Zp	42.6 (5.7)[b]	44.4 (3.2)	43.5 (4.5)[b]	49.6 (5.3)	50.4 (6.1)	50.0 (5.5)	54.9 (4.9)	65.8 (2.8)	60.3 (6.8)
Go-Za	46.3 (5.4)[b]	47.6 (3.2)	47.0 (4.3)[b]	53.5 (4.3)	54.8 (4.8)	54.1 (4.5)	58.2 (5.6)	68.6 (3.2)	63.4 (6.9)
H-Me	32.8 (5.6)[b]	33.2 (4.7)	33.0 (5.0)[b]	45.0 (5.8)[b]	45.4 (6.2)[b]	45.2 (5.8)[c]	44.7 (3.4)	50.5 (6.4)	47.6 (5.8)
Co-M_1	51.4 (3.4)[b]	55.5 (3.7)	53.5 (4.0)[b]	59.6 (6.1)	61.0 (4.6)	60.3 (5.3)	69.5 (3.9)	73.0 (5.3)	71.3 (4.8)
SNA	80.2 (3.9)	81.1 (3.3)	80.7 (3.6)	81.8 (3.1)	81.5 (4.4)	81.6 (3.7)	80.3 (2.4)	80.0 (3.3)	80.2 (2.8)
SNB	76.6 (2.8)	76.2 (2.4)	76.4 (2.5)	77.0 (2.6)	78.5 (3.7)	77.8 (3.2)	77.6 (2.8)	79.1 (2.8)	78.3 (2.8)
ANB	3.6 (1.7)	5.0 (2.3)	4.3 (2.1)	4.8 (3.6)	2.9 (2.5)	3.9 (3.1)	2.8 (1.8)	0.9 (1.8)	1.8 (2.0)
FMA	27.2 (4.5)	29.0 (3.5)	28.1 (4.0)	28.1 (5.7)	26.6 (6.4)	27.3 (6.0)	30.5 (4.3)	21.8 (4.9)	26.2 (6.3)
LAFH	53.5 (1.6)	56.0 (2.9)	54.7 (2.6)	53.9 (1.8)	53.6 (2.0)	53.8 (1.9)	54.6 (2.2)	53.5 (2.9)	54.0 (2.5)

[a] Variable key: N, number of subjects; Age, in decimal years; Ethnicity, ordered as African-American: Asian or Asian-American: Caucasian: Indian: Middle-Eastern; Ht, height (cm); Wt, weight (kg); T_C, chewing cycle duration (ms) calculated from mean T_C of individual subjects; CV_C, coefficient of variation of T_C (proportion), calculated from CV_C of individual subjects; N_C, mean number of chewing cycles used in calculating T_C and CV_C for each subject; Co-Cr, temporalis lever arm length (mm); Co-Gn, mandibular length (mm); Co-Ma, masseter lever arm length (mm); Go-Zp, distance from gonion to estimated origin of masseter on posterior zygomatic arch (mm); Go-Za, distance from gonion to estimated origin of masseter on anterior zygomatic arch(mm); H-Me, length of anterior digastric (mm); SNA, SNB, ANB, FMA are angle measurements (°) as shown in Fig. 1; LAFH, lower anterior face height (mm).

[b] Data unavailable for one subject.

[c] Data unavailable for two subjects.