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Original Article

Role of suprahyoid muscles in the growth pattern of mandible

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Abstract

Background: The facial pattern is broadly classified into three major types -average, horizontal and vertical growth patterns. There are three schools of thought for the factors responsible for these different facial patterns among which multifactorial is the most accepted one. Literature also shows relationship between the orofacial muscles and the facial pattern.

Aim: To explore whether the suprahyoid muscles have any influence on the growth pattern of mandible.

Materials and methods: Electromyographic activities of suprahyoid muscles were evaluated in 30 adults between the age of 18 and 28 years (mean age 23.6 years). Kruskal-Wallis test (p-value<0.05) was applied to compare the mean amplitudes and mean frequencies among three groups during three different activities. The Mann-Whitney 'U' (p-value<0.05) test was performed for multiple comparisons of mean amplitudes and frequencies between the groups for the three activities.

Result: The results of the study shows that the suprahyoid muscles group activities are highest in vertical growers and lowest in horizontal growers, the average growers lying somewhere between the two groups during opening and closing, swallowing and protrusion. The difference in the mean amplitude and the frequency among the three groups are statistically significant.

Conclusion: This study indicates that the suprahyoid muscles group activities may have role in modifying the mandibular growth pattern however further study to explore the cause and effect relationship is suggested.

Key words: Electromyography, Vertical, Horizontal

Introduction

The facial growth pattern is broadly classified into three major types[1-4] – average, horizontal and vertical growth patterns. The factors responsible for these different facial patterns are controversial. There are three schools of thought – hereditary[5], environmental and multifactorial, the last school of thought being the most accepted one. According to Nanda (1988)[6] the facial pattern is already defined in childhood. However, the literature is replete with reports that show relationship between the orofacial muscles and the facial pattern.

The movement of the mandible during various functions like opening and closing of the mouth, mastication, and deglutition is controlled by various elevator and depressor muscles[7]. The role of equilibrium[8-10] in occlusion and malocclusion has been explained by Graber (1963), Weinstein (1963) and Proffit (1978). Several studies related to elevator muscles have been done using electromyography, ultrasonography, transducer and so on to find out the correlation between them and the facial pattern. Most of the studies[11-18] shows that that the EMG activities as well as the biting force are reduced in vertical growers and increased in horizontal growers. Proffit (1983)[19] did not find any difference in biting force of long-face children and normal children and concluded that decrease in the biting force develops during adolescence and is the result of the vertical facial pattern and not the cause of it.

However, only a few studies have been done to evaluate the correlation between the depressor muscles and the facial morphology. Defining possible role of these

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muscles in the growth pattern of the mandible would help us develop definitive preventive as well as corrective strategies that may be employed to achieve a better facial pattern for the needy individual. Hence, this study was undertaken with the following objective:

"To explore whether the suprahyoid muscles have any influence on the growth pattern of mandible" with the following hypotheses:

1. Not only the elevators but also the depressors have some role in the development of the facial pattern.
2. Increased activity of suprahyoid muscles causes downward and backward pull in the anterior part of the mandible causing the mandibular plane to be steeper.

Review of literature

A few studies showing relationship between the suprahyoid muscles and the facial pattern have been reported. According to Tomer and Harvold (1982)[20], elevators along with the ramus of the mandible, and mental region along with the facial and suprahyoid muscles act as independent units. According to Linder-Aronson (1970, 1979, 2000)[21, 22, 23] lowered mandibular posture due to mouth breathing can cause vertical growth pattern and removal of adenoids can bring the normal pattern back. Forsberg et al (1985)[24] and Hiyama et al (2003)[25] showed that extension of head caused by nasal obstruction is associated with increased electromyographic activity. Navarro et al (1995)[26] observed inferior mandibular rotational patterns in masseter resection subjects, superior mandibular rotational pattern in temporalis resection subjects and a less intense superior rotational pattern in the suprahyiod resection group in an experimental study on rats. Van Spronsen (1997)[27] did a study using MRI scanning and cephalometric x-ray and concluded that the orientation of the jaw opening muscles shows significant relationships with vertical craniofacial dimensions. Udea et al (1998)[28] did a surface electrode electromyographic study and reported that the masseter and digastric muscles have significant negative correlation and temporalis muscles have positive correlation with the vertical craniofacial morphology. In a similar study done by Ueda et al (2000)[29] in children and adults, they found similar results with masseter and digastric muscle activities, but did not find any significant correlation with temporalis. Spyropoulos et al (2002)[30] did a study on rats for thirty days to investigate the effect of bilateral suprahyoid muscle myectomy and proved that the absence of the suprahyoid musculature does affect both skeletal growth and orientation of the mandible.

Materials and methods

Electromyographic activities of the suprahyoid muscles were evaluated in 30 adults in this study. With a view of avoiding the radiographic exposure to the subjects, clinical FMA and photographic FMA were proposed as a tool for categorization of the subjects into different growth patterns i.e. average, horizontal and vertical. A pilot study was conducted to test the accuracy of this tool. The result of pilot study showed some variations among the clinical FMA measurements, photographic FMA measurements and the radiographic FMA measurements. Hence, the clinical FMA measurements were used only for the initial categorization of the subjects. Cephalometric evaluation was used for the final categorization.

EMG recording using submental surface electrodes[28,29,31] was done in each individual to evaluate the activities of the Suprahyoid muscle group during opening and closing, swallowing, and protrusion. Mean amplitude and mean frequency was used as parameters to evaluate muscle activities. The material and methods used are discussed under following headings:

- Selection of the subjects
- Electromyographic recordings
- Statistical Methods

- ***Selection of the subjects***

A total of thirty adult volunteers (15 males and 15 females) between the age of 18 and 28 years (mean age 23.6 years) were selected for the present study. Ten of the subjects had average growth pattern, ten had horizontal growth pattern and the remaining ten had vertical growth pattern. None of the subjects had undergone orthodontic treatment.

- ***Initial Selection of the subjects***

Initial selection of the subjects was done by measuring the Frankfort-Mandibular plane angle with "Cephalometric protactor with stencil" (Model No 0913-000, A-Company)

- ***Cephalometric analysis for final categorization of the subjects:***

After initial selection of the subjects by measuring the FMA clinically, the subjects were taken to the Department of Radiology for Cephalometric radiographs. A lateral cephalogram was taken of each subject with the teeth in occlusion using 8"X10" X-ray plate maintaining a distance, from the to the midsagittal plane, of 5 ft and distance, from midsagittal plane to film, of 11.5 cm. The X-ray machine used was "Panex – EC Pantomography (J. Morita Corporation, Japan)". The exposure time used was 2 sec with 18 KVP and 70 mA. (Figures F-II)

Three variables **Ricketts FMA**[2] **(26±4^0), SN-GoGn angle**[1] **(25-30^0),** and **Jarabak's ratio**[31] (Norms = 62-65%) were used to evaluate vertical morphology of the craniofacial skeleton.

- ***Electromyographic Recordings:***

Non-invasive electromyographic recordings were done using surface electrodes[28,29,32] in the right submental area for evaluation of activities of Suprahyoid muscles as follows:

- Recording Venue - The EMG recording was done at University Medical Center (UMC) EMG room.
- EMG Machine – The EMG machine used was “Neuropack Four” model 414K (made in Japan), which had four channels. The channel number 2 was used for recording of EMG of all the subjects. EMG machine was standardized for a gain of 100 µv.
- Bipolar electrodes - Two bipolar electrodes of 1 cm diameter were used for recording EMG. (Fig 1).
- Ground electrode – The ground electrode was placed in the right forearm.
- Electrodes placement procedure:
  1. Cleaning the area - Before placement of the electrodes, electrode site on the skin was rubbed using an alcohol-soaked gauze pad to reduce impedance between skin and electrodes.
  2. Conducting gel used was petroleum jelly.
  3. A point 1 cm lateral to the midpoint of a line from soft tissue Menton to hyoid bone was marked for one of the electrodes. Another point was marked 2.5 cm lateral to the first mark equidistant from the lower border of mandible. One electrode was placed in each of these places maintaining an interelectrode distance of 1.5 cm[28,29] (Fig 1).
  4. The ground electrode was placed in the forearm. The electrodes were fixed firmly with the help of transparent “cello tape”.
- Posture of the patient while recording **-** The patient was asked to sit upright, in a relaxed position, on a stool without support with his Frankfurt-horizontal plane parallel to the floor.
- Standardization of activities and the recordings - The three activities mentioned below were standardized and all the subjects were trained before recordings were taken :
  - i. Opening and closing - This activity was standardized as smooth opening and closing without stoppage, starting from maximal intercuspation and back. This was repeated three times and the mean amplitude and mean frequency were calculated.
  - ii. Swallowing – 10 ml of water was given to the subject and asked to hold in the mouth and wait for command. Upon command “swallow”, the subject was asked to swallow and the recording was made. This was repeated three times and the mean amplitude and mean frequency were calculated.
  - iii. Protrusion and retrusion - The patient was asked to protrude the jaw fully from maximal intercuspation and retrude back smoothly without stopping upon command “protrude” and the recording was done. The action was repeated three times and the mean amplitude and mean frequency were calculated.

- ***Statistical Methods:***

Krushkal-Wallis test was applied to compare the mean amplitudes and mean frequencies among three groups during three different activities.

The Mann-Whitney ‘U’ test was performed for multiple comparisons of mean amplitudes and frequencies between the groups for the three activities.

Results

The results of electromyographic study that included the comparison of mean amplitudes and frequencies and the multiple comparisons between the groups are depicted on Tables 2 to 5. The results of comparison of mean amplitudes and mean frequencies are also presented graphically in Figures 2 to 7.

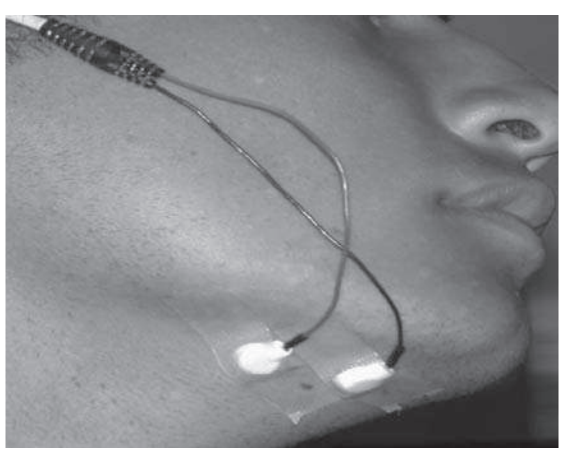

Fig. 1: Taking electromyographic records

Table 1: Categorization of growth patterns

S. No.	Age/Sex	FMA	SN-GoGn	Jarabak's ratio	GP
1	21/F	14H	15H	78.40H	H
2	23/F	20N	18H	68.70H	H
3	18/F	15H	19H	78.00H	H
4	25/F	17N	22H	71.70H	H
5	27/F	22N	25H	70.00H	H
6	21/F	20N	23H	69.40H	H
7	25/M	14H	19H	75.40H	H
8	25/M	16H	23H	75.50H	H
9	21/M	22N	25H	72.00H	H
10	25/M	15H	18H	80.50H	H
11	24/F	25N	29N	67.70H	N
12	23/F	28N	31N	65.90N	N
13	26/F	21N	28N	66.50H	N
14	27/M	22N	28N	68.00H	N
15	24/M	23N	27N	69.50H	N
16	28/M	24N	34N	64.00N	N
17	28/M	20N	28N	68.00H	N
18	28/M	26N	31N	63.90N	N
19	24/M	25N	29N	68.20H	N
20	26/M	28N	35N	65.00N	N
21	18/F	31V	33N	61.70 V	V
22	27/F	31V	37N	60.20V	V
23	20/F	32V	38V	62.50N	V
24	24/F	47V	49V	55.38V	V
25	24/F	36V	40V	58.60V	V
26	19/F	38V	35N	65.40N	V
27	25/M	37V	40V	60.60V	V
28	18/M	34V	44V	60.00V	V
29	23/M	33V	30N	69.20H	V
30	19/M	38V	41V	60.10V	V

(V – Vertical, H – Horizontal, N=Normal, GP= growth pattern)

Descriptive Analysis

Table 2: Amplitude

Activities	GP	No of subjects	Mean	Std dev	95% confidence interval for mean		H	P-value (< 0.05)
					Lower Bound	Upper bound		
Opening & Closing	Horizontal	10	172.9	19.27	159.11	186.68	5.69	0.049
	Normal	10	187.3	28.46	166.93	207.66		
	Vertical	10	198.9	25.89	180.37	217.42		
Swallowing	Horizontal	10	132.2	9.21	125.61	138.78	19.74	0.001
	Normal	10	165.4	16.47	153.61	177.18		
	Vertical	10	181.6	6.38	177.03	186.16		
Protrusion	Horizontal	10	148.1	21.39	132.79	163.4	4.604	0.1
	Normal	10	157.4	20.77	142.53	172.26		
	Vertical	10	177.1	38.75	149.37	204.82		

Table 3: Frequency

Activities	GP	No of subjects	Mean	Std dev	95% confidence interval for mean		H	P-value (< 0.05)
					Lower bound	Upper bound		
Opening & Closing	Horizontal	10	127.6	7.1	122.51	132.68	7.412	0.025
	Normal	10	131.6	8.98	125.17	138.02		
	Vertical	10	139.2	10.07	131.99	146.4		
Swallowing	Horizontal	10	127.9	6.24	123.43	132.36	15.11	0.001
	Normal	10	142.7	7.95	137	148.39		
	Vertical	10	144	8.86	137.65	150.34		
Protrusion	Horizontal	10	124.1	5.58	120.1	128.09	5.123	0.077
	Normal	10	127.2	12.3	118.39	136		
	Vertical	10	130.6	13.86	120.68	140.51		

GP: Growth pattern, **H:** Kruskal -Wallis test

Multiple comparisons between groups for three activities (Mann-Whitney 'U" Test)

Table 4: Amplitude

Dependable Variables	Comparision between groups	Mean Difference	P- value	Statistical Significance
1. Opening & Closing	H vs N	-14.400	0.021	Significant
	H vs V	-26.000	0.027	Significant
	N vs V	-11.600	0.306	Not Significant
2. Swallowing	H vs N	-33.220	0.000	Very Highly Significant
	H vs V	-49.400	0.000	Very Highly Significant
	N vs V	-16.200	0.004	Highly Significant
3. Protrusion	H vs N	-9.300	0.468	Not Significant
	H vs V	-29.000	0.030	Significant
	N vs V	-19.700	0.130	Not Significant

Table 5: Amplitude

Dependable Variables	Comparison between groups	Mean Difference	P- value (< 0.05)	Statistical Significance
1. Opening & Closing	H vs N	1.210	0.031	Significant
	H vs V	-11.160	0.007	Highly Significant
	N vs V	-7.610	0.064	Not Significant
2. Swallowing	H vs N	-14.810	0.000	Very Highly Significant
	H vs V	-16.110	0.000	Very highly Significant
	N vs V	-1.310	0.711	Not Significant
3. Protrusion	H vs N	-6.510	0.205	Not Significant
	H vs V	3.110	0.540	Not Significant
	N vs V	-3.410	0.502	Not Significant

Graphical Representation

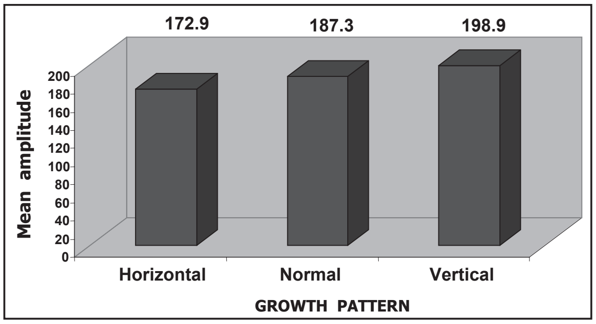

Fig. 2: Comparison of Mean amplitude (Opening and Closing)

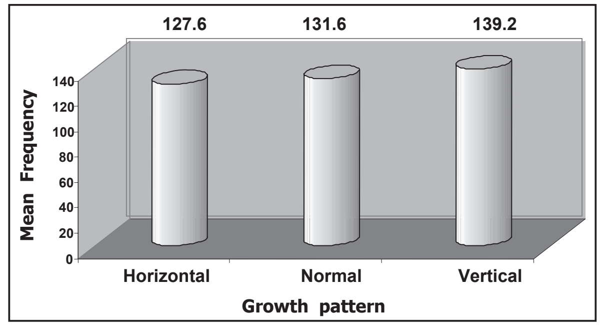

Fig. 3: Comparison of Mean Frequency (Opening and Closing)

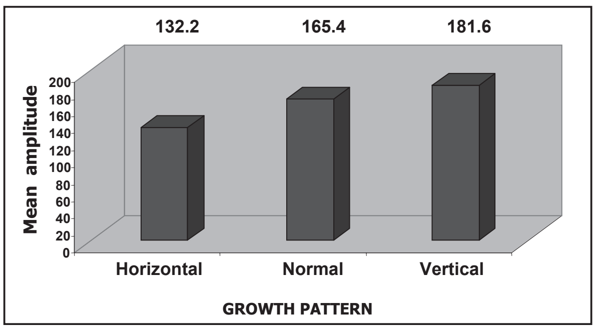

Fig. 4: Comparison of Mean amplitude (Swallowing)

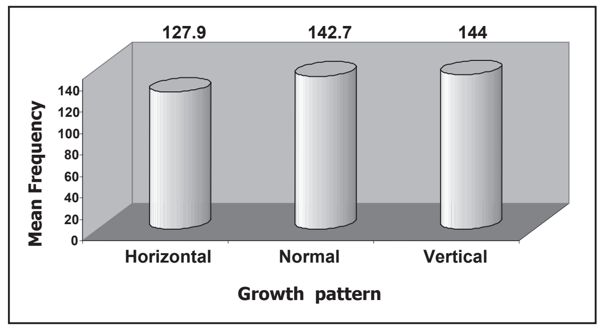

Fig. 5: Comparison of Mean frequency (Swallowing)

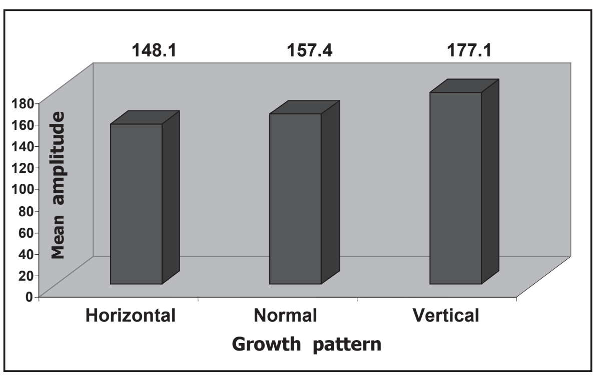

Fig. 6: Comparison of Mean amplitude (Protrusion)

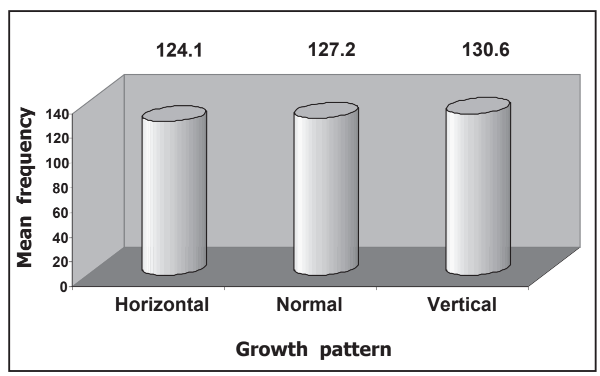

Fig. 7: Comparison of Mean frequency (Protrusion)

Discussion

The suprahyoid muscles[7] include digastric, stylohyoid, mylohyoid and geniohyoid muscles. Theses muscles are directly or indirectly involved with different functions like opening of jaws, mastication of food, respiration, speech and protrusion of the mandible. They act in antagonism with the elevator muscles such as the temporalis, medial pterygoid and masseter.

The suprahyoid muscles[30] are depressors of the mandible and play a secondary role to the lateral pterygoids. However, the point of action of lateral pterygoids is at the condyle whereas the point of action of suprahyoid muscles is at the anterior part of the lower border of the mandible. They open the mandible by pulling the anterior part of the mandible downward and backward. According to Hiiemae and Crompton (1985)[33], "*the mechanics of jaw opening have been classically described as based on a downward and forward pull on the condyle, coupled with a downward and backward pull on the anterior part of the mandible from the lateral pterygoid and the digastric, respectively".*

When infrahyoid muscles act as a stabilizer of the hyoid bone, the suprahyoid muscles depress the mandible when the masseter muscle stabilizes the mandible in intercuspal position; they elevate and protract the tongue and suprahyoid complex, as in the second phase of deglutition. In both of these situations, the force is exerted on the anterior part of the mandible. The digastric has a maximum force capability to produce the torque necessary to open the jaw. Total postdigastric tenotomy torque would be 50% of its total pretenotomy torque, but the digastric muscles do not play a major part in the control of the transverse movements of the mandible[34].

Most of the studies[10-15] related to biting force, muscle size and facial morphology have shown that increased biting force is related to increased muscle size and increased muscle size is correlated to horizontal growth pattern characterized by small gonial angle and less steep mandibular plane angle. Similarly, relationship between decreased biting force due to muscle weakness and steep mandibular plane angle has been shown[35,36]. Now the question arises what role do the suprahyoid muscles play, if any? Do the suprahyoid muscles have some role to play as suggested by Kreiborg et al[35]?

In the present study, increased suprahyoid muscles activity was observed in individuals with vertical growth-pattern and decreased activity in individuals with horizontal growth pattern as compared to individual with normal growth pattern suggesting that suprahyoid muscles are comparatively hyperactive in individuals with vertical growth pattern and less active in individuals with horizontal growth pattern.

Van Vlierberghe et al (1986)[37], experimenting with digastric muscle shortening, did not find any obvious growth inhibition of the mandible. According to their working hypothesis, shortening of the anterior belly of the digastric muscles should restrain the anterior growth of the mandible; but there were no indications of the development of a retrognathic mandible. The result of this study is in contradiction to their observation because according to the result of this study the increased suprahyoid muscles activity should contribute to the vertical growth pattern.

However, Navarro et al (1995)[26] found an upward mandibular rotation pattern after suprahyoid muscle resection in rats. Similarly, Spyropoulos et al (2002)[30] found the occurrence of decreased mandibular growth in a group of 12 rats in which bilateral excision of suprahyoid muscles was performed. The present findings support the results of these two studies.

Studies related to the posture and craniofacial morphology[20,22-23] indicate that forward and downward posturing of mandible may contribute to the vertical growth pattern. According to Solow (1984)[38] a large head extension is followed by backward displacement of TMJ, decreased growth in mandibular length, reduced facial prognathism, and less-than-average true forward rotation of the mandible. On the other hand, head extension is followed by opposite facial development. In relation to this, the report of Hellsing et al (1987)[39] is worth mentioning that the suprahyoid muscle activity increases when head is extended. This increased activity may play definitive role in causing vertical growth pattern. But the question arises why the suprahyoid muscles should be hyperactive in individuals other than mouth breathers, which cannot be explained on the basis of present study alone. Further study is needed to answer this question.

This study also showed less suprahyoid muscles activity in individuals with the horizontal growth pattern indicating that the pull in the anterior part of the lower border of mandible is less, which may be responsible for not having a steep mandibular plane in horizontal growers.

In the present study, the difference in the activities of suprahyoid muscles in different growth patterns was not statistically significant during protrusion. According to Vitti and Basmajian (1997)[40], only slight activity occurs in the suprahyoid muscle group during protrusion of the mandible in humans, with and without occlusal contact. This may explain the cause for not having the statistically significant difference in the activities of the suprahyoid muscle during protrusion.

At the end it can be said that the results of the present study rejects our null hypothesis and accepts the alternative hypothesis.

Summary and Conclusion

Electromyographic activities of suprahyoid muscles were evaluated in 30 adults between the age of 18 and 28 years (mean age 23.6 years). Cephalometric evaluation was used for the categorization of growth pattern. Electromyographic recording using submental surface electrodes was done in each individual to evaluate the activities of the Suprahyoid muscle group during opening and closing, swallowing, and protrusion. Mean amplitude and mean frequencies were used as parameters to evaluate muscle activities.

The results of the study show that the suprahyoid muscles group activities are highest in vertical growers and lowest in horizontal growers, the average growers lying somewhere between the two groups. The difference in the mean amplitude and the frequency among the three groups are statistically significant indicating that the suprahyoid muscles group activities may have role in modifying the mandibular growth pattern. As the present study was designed to study the correlation between the suprahyoid muscle activities and the mandibular pattern only, further study to explore the cause and effect relationship is suggested.

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