Synchronization between Respiration and Mastication Functional Coordination of Respiratory and Digestive Systems

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Abstract: The purpose of our study is to evaluate the relationship between respiratory period and chewing period. In 10 healthy peoples (6 males and 4 females, age 26 ± 7 years), EMG of masticatory muscles and respiratory curve during chewing of gum were measured and synchronicity between respiration and chewing were analyzed using the phase of chewing occurring within respiratory period. Results, the coherence between the two signals at the peak frequency of respiration was 0.06 ± 0.03 (mean ± SD). In all subjects, the relationship between respiration period and chewing period was random and was not correlated. In this experiment, chewing period wasn't controlled. Therefore, it is considered that respiration may have been synchronized if the period of chewing was controlled.

Key words: Chewing, respiration, EMG, synchronization.

1. Introduction

Cardio-respiratory coordination represented by respiratory sinus arrhythmia [1] is well known phenomenon and it suggests the presence of precise functional cooperation between respiratory and circulatory systems. On the other hand, little is known about coordination between respiratory and digestive systems. Therefore, in this study, we focused on mastication as the first step in digestive function and evaluated its possible coordination with respiration.

As the research of mastication, a lot of studies on chewing of gum have been reported for the effects on cerebral blood flow [2], driving performance [3], concentration of work [4], memory [5], cognitive function [6] etc. These studies are evaluated using electroencephalogram (EEG), heart rate variability, task score, and so on, but there are few reports on the relationship between chewing and respiration. In this paper, to evaluate the relationship between chewing and respiration, we proposed an algorithm to detect peak from electromyogram (EMG), and analyzed whether respiratory period is synchronized with chewing period of gum.

2. Method

2.1. Subjects

The subjects were 10 healthy people (6 males and 4 females, age 26 ± 7 years), the present study was performed according to the protocol that was approved by the Institutional Review Board of Nagoya City

University Graduate School of Medical Sciences and Nagoya City University Hospital (No. 60160174).

2.2. Experiment Protocol

Taste-free gum (*Kracie Holdings, Ltd., Japan*) was used for chewing. Subjects in the sitting position at rest chewed the gum at their own pace for 3min, during which electrocardiogram (ECG), EMG (masseter and temporalis muscles), and respiration curves were measured at a sampling frequency of 1kHz.

3. Analysis

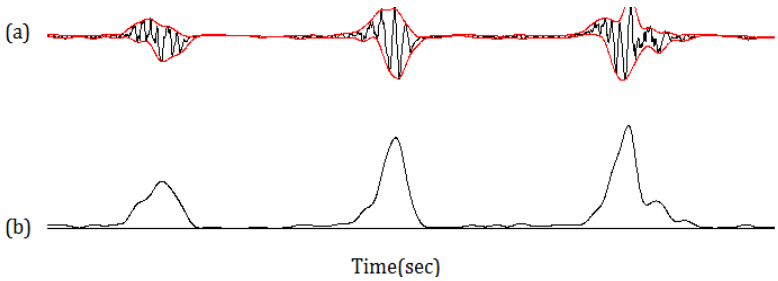
3.1. Phase Synchronization Analysis

For respiration and EMG signals, after removing 60-Hz AC noise using an 8⅓-point moving average filter, the upper and lower envelopes were calculated from EMG signals and the distance between them was computed as continuous functions of time (PEMG(t)). Then, peak points of chewing were detected using PEMG(t) (Fig. 1). EMG was recorded from the temporal muscle that the measurement accuracy was maintained.

To evaluate the respiration synchronicity with chewing, respiration intervals were standardized to a period of 2π and the distribution of chewing occurring within the period was analyzed. The phase of chewing (φ_n) occurring within respiratory period is defined by equation (1).

$$\varphi_n=2\pi T_n/RPI(k) \quad (1)$$

where *RPI* (*k*) is respiration *period* and T_n is the time of chewing *o*ccurring within respiratory *period* (Fig. 2).



(a) Upper and lower envelopes of the original EMG.
(b) The distance of upper and lower envelopes (PEMG(t)).
Fig. 1. Processed EMG signals.

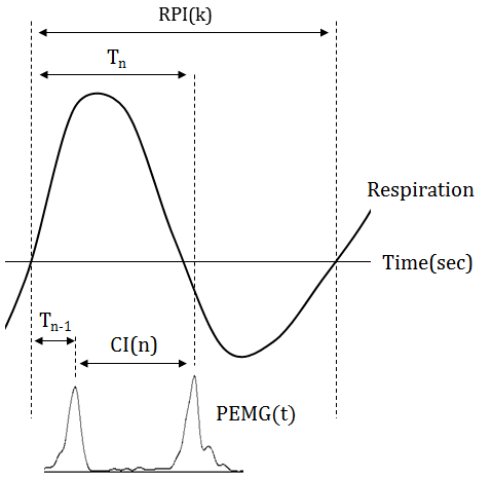


Fig. 2. Respiration synchronicity with chewing. CI(n): chewing interval

3.2. Coherence of Respiration and EMG

Coherence function of respiration curves and chewing interval time series (CI (t)) was calculated using cross-spectrum analysis. Also, correlation coefficient at the peak frequency of respiration was calculated using the coherence function for each subject.

4. Results

Fig. 3 shows phase of *chewing* occurring within respiratory *period for all subjects*. The vertical axis of Fig. 3 represents the difference between the average value of CI(t) and CI corresponding to T_n. In addition, the correlation coefficient at the peak frequency of respiration calculated using the coherence function is 0.06 ± 0.03 (mean ± s.d.). Fig. 4 shows power spectrum calculated using CI(t) *of all subjects.* Many peaks appeared in all subjects.

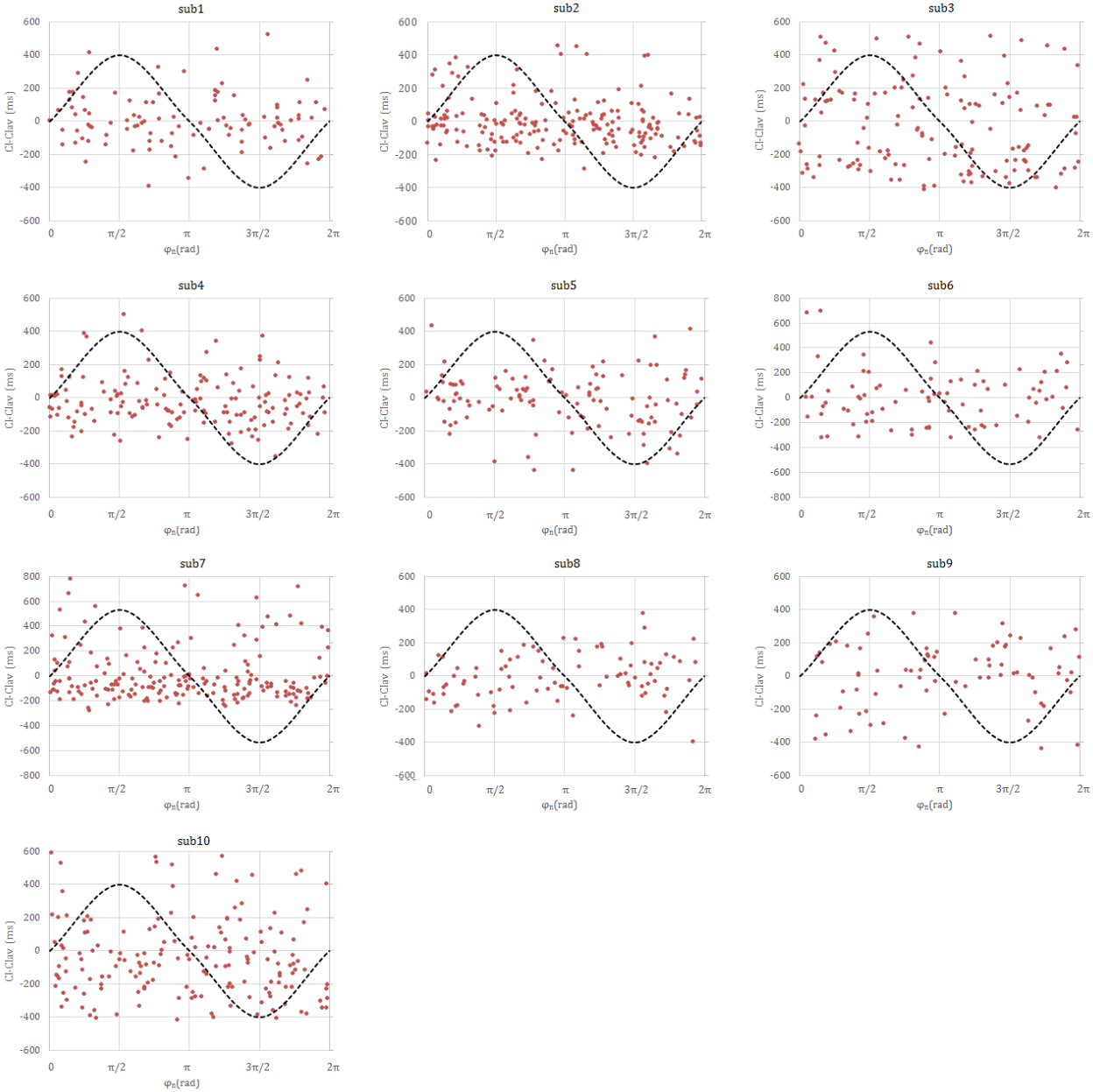


Fig. 3. Respiration synchronicity with chewing of all subjects.

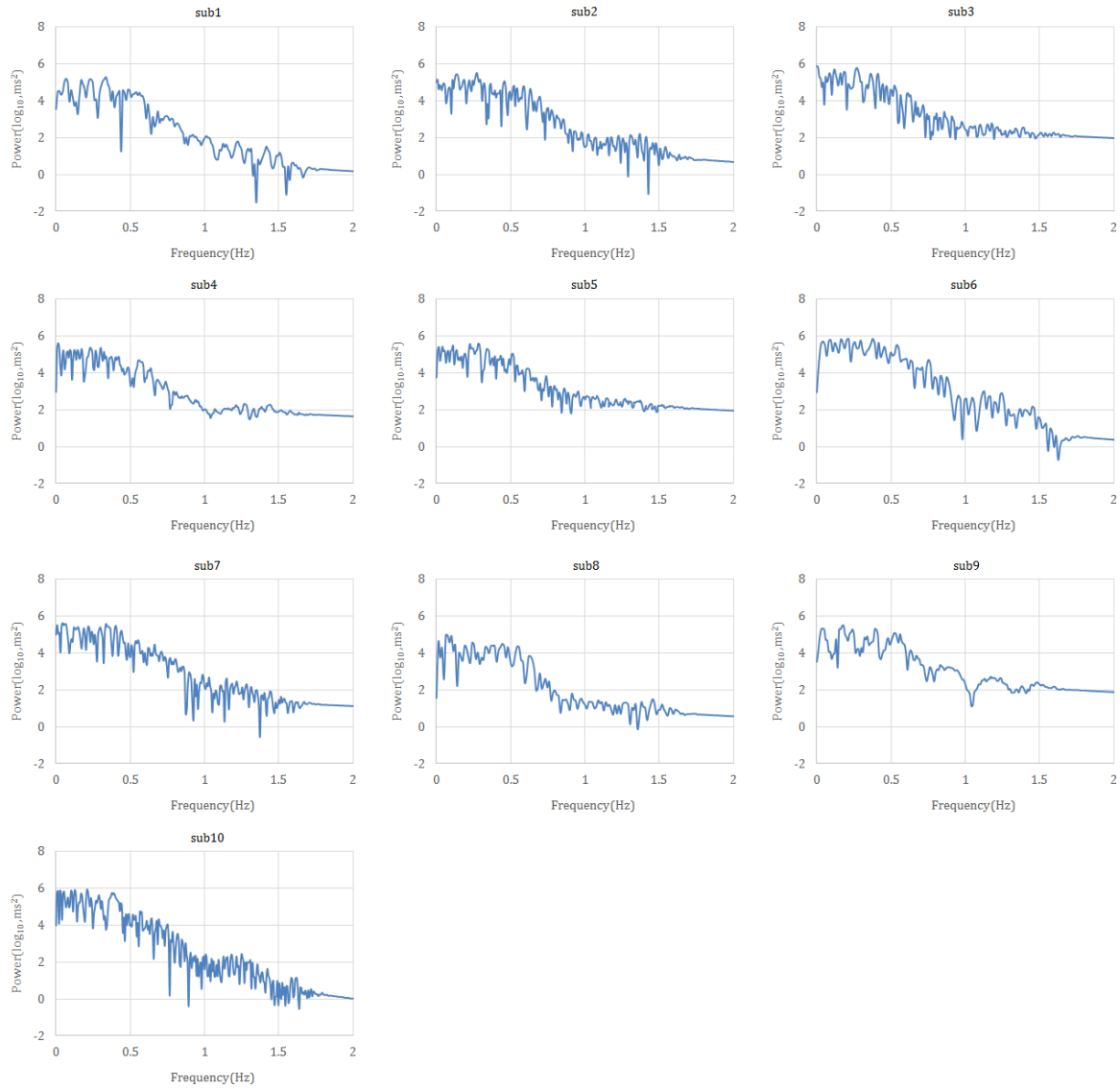


Fig. 4. Power spectrum calculated from CI(t) of all subjects.

5. Discussion

In this study, to evaluate the relation between respiratory period and chewing period, we detected chewing peak and its time from EMG envelope, analyzed the respiration synchronicity with chewing.

In all subjects, the relationship between respiration period and chewing period was random and was not correlated. In the previous paper, studied the ECG synchronicity with chewing but they also did not synchronize [7]. These observations appear not to support for the presence of coordination between respiratory and digestive systems.

On the other hand, there are reports demonstrating that heart rete are synchronized with respiratory period [8]-[10]. In this experiment and previous experiment, chewing period wasn't controlled. For this reason, many peaks appeared in the power spectrum calculated using CI(t), and respiration and heart rate did not synchronize with chewing. Therefore, it is considered that respiration may have been synchronized if the period of chewing was controlled.

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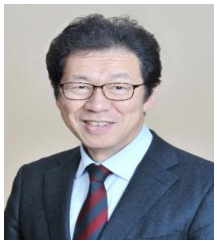

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