RHYTHM ANALYSIS AND LINEAR MODELING OF METRICAL POETRY RESPIRATORY SIGNAL

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ABSTRACT

The paper studies the breathing patterns for four types of Chinese metrical poems, namely, five-character quatrain, five-character octave, seven-character quatrain and seven-character octave. A breathing belt was tied to the chest and the respiratory signal was acquired by EMG. Respiratory parameters were defined regarding the dynamical properties of the signal, and were automatically extracted by the respiratory signal analysis platform we developed. Results show that the rhythmic pattern for Chinese metrical poems is reflected by three breathing features: (1) Except for the five-character octave, the duration of inspiration phase of the first line in every couplet is longer with larger inspiratory peak and capacity. (2) The duration of inspiratory phase tends to be affected by the syllable number in a poem line. (3) The absolute slope values for breathing units and inspiration phase show a consistent pattern across four types. Finally, a linear analog model of breathing pattern is developed by using the relevant parameters.

Keywords: respiratory signal, model, rhythmic pattern, Chinese metrical poem

1. INTRODUCTION

Respiration is the driving force for speech sound. Quiet breathing and breathing over talking is not the same process. The expiratory phase and the inspiratory phase are similar during quiet breathing, while the expiratory phase during speaking is far greater than inspiratory phase during quiet breathing [2]. In [3] a first attempt was conducted to examine the distribution of magnitude and duration for breathing resetting in reading tasks of various literary forms, including modern-style poem, *Ci*, novel, prose and news.

The Chinese metrical poetry follows a set of strict rules in metrical organization regarding number of lines and syllables in each line, syllable components and tone, lexical antithesis and sentence arrangement. Compared with other literary forms, the rhythmic pattern for metrical poems is fixed when the above metrical rules are observed, and thus is relatively easy for modeling.

2. RESPIRATORY SIGNAL PROCESSING

2.1. Research material

Four representative metrical types were selected: five-character octave (FCO), five-character quatrain (FCQ), seven-character octave (SCO) and seven-character quatrain (SCQ). Five poems were selected for each type. All the poems are familiar with the speakers (one male and one female). The features of each type will be shown in Section 3.

2.2. Acquisition of respiratory signal

A breath bandage was tied to the subject's chest. The sensor in the bandage converted the length change of the bandage into electrical signal. The time-varying amplitude of the respiratory signal was acquired by an EMG produced by ADI.

2.3. Parameter definition

A full breathing process is defined as breath-unit, containing inspiration phase and expiration phase. The respiratory signal curve rise phase is the inspiration process, corresponding to the silent period in the domain of speech signal. The signal curve decrease phase is the expiration process, generally corresponding to the speech signal [1]. The main breath unit parameters are defined as follows:

1) Inspiration Phase (IP)

- duration: ID(unit:s)
- peak value: P
- slope: IK(n)= IQ(n)/ ID
- inspiratory capacity: IQ(n)= P(n)-V(n)

2) Expiration Phase (EP)

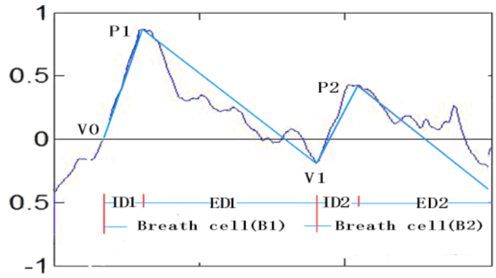
- duration: ED(unit:s)

- valley value: V
- slope: EK(n)= -EQ(n)/ED
- expiratory capacity: EQ(n)= P(n)-V(n)

3) Breath Unit (BU)

- duration: BD; BD(n)=ID(n)+ED(n)
- total amount of airflow: BQ(n)=IQ(n)+EQ(n)

Figure 1: Parameters for respiratory signal of Chinese metrical poem.

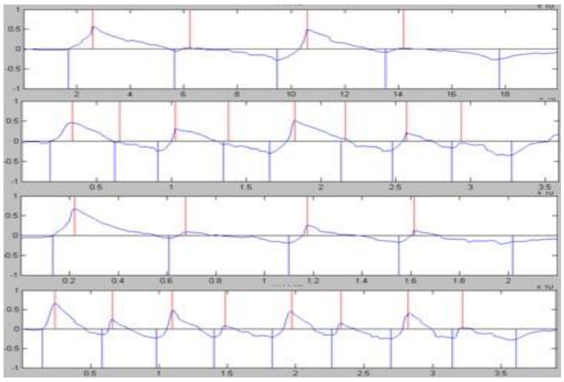


The peak point P(n) is a transition point of the inspiratory and expiratory phases during the respiration process. V0 is the starting point of inspiration when the value is zero; Valley point V (n) is a transition point of the inspiratory and expiratory phases, also a dividing point of breath-unit. Duration is the period for the inspiration phase and the expiration phase. Inspiratory capacity is the magnitude difference of inspiration phase from peak point to valley point, which means the volume of the airflow human inhale. Expiratory capacity is the magnitude difference of expiration phase from peak point to valley point, which means the volume of the airflow human exhale during reading. The total volume of airflow represents the airflow of breath unit. Slope means the changing speed of inspiratory capacity and expiratory capacity. The greater the absolute value of the slope, the faster speed of airflow.

2.4. Respiratory signal processing

The speech signal analysis platform was developed for the current study which is designed to achieve a variety of functions, such as automatically or manually tagging, parameter extraction, and systematic analysis of speech signal. Main functions are: 1)Using low-pass smoothing filter to clear away high-frequency noise and some slight interference signals; 2)Using local maximum method to automatically test locations of signal peaks supplemented with manual modification and adjustment;3)Extracting parameters of respiratory signals by tag information, and save it to the *xls file. FCQ (up), FCO (upper middle), SCQ (lower middle), and SCO (below), were shown in Figure2.

Figure 2: The sample map of poetry breathing makers.



With the speech signal platform, the processing steps for respiratory signal parameters are as followed: first, it collected voice, throat and breathing signals over poem reading, and made the breathing markers; then, the parameters of breath-units were automatically extracted and compared across four types of metrical poems; finally, the parameters were used to build a linear model to real the internal mechanism of breathing pattern in the process of reading metrical poems.

3. RESULTS

On the whole, poetry breathing signal is divided into two categories, *jue ju* (a poem of four lines, each containing five or seven characters, with strict tonal pattern and rhyme scheme), and *lü shi* (a classical poem of eight lines, each containing five or seven characters, with strict tonal pattern and rhyme scheme).FCQ and SCQ belong to the first category and the FCO and the SCO to the second.

FCQ, which is a type of poems of four lines, each containing five characters, a total of twenty characters appearing in each poem; SCQ of four lines, each containing seven characters, a total of twenty-eight characters in each poem; FCO, consists of eight lines; every two sentences conjoin into a couplet. Thus a poem has four couplets. Each sentence contains five characters, totally forty characters in each poem; and SCO of eight lines, each containing seven characters, and a total of fifty-six characters appearing in each poem.

3.1. FCQ

Five poems were selected as FCQ: *Jiang Xue*, *Deng Guanquelou*, *Min Nong*, *Chun Xiao* and *Jing Yesi*. Table 1 shows the average values of all parameters of breathing units from two subjects.

The breathing rhythm of FCQ is regular. Respiratory signal of whole poem is divided into four distinct ups and downs. The first and the third sentences regarded as the beginning of each couplet. In the inspiratory section, the P value, inspiratory capacity (IQ) and inspiratory duration (ID) are larger in the first and the third sentences than that in the second and the fourth ones, which servers as the final sentence for each couplet. Since the number of syllables in each sentence is identical, the duration is not different among inspiratory sections. However, the fourth sentence, as the end of a poem, has the phenomenon of drag sound and the longest exhalation duration, the minimum V and the largest negative pressure in thoracic cavity.

Table 1: Average values of breath-unit in FCQ.

Number	IP				EP				BU	
	ID	P	IQ	IK	ED	V	EQ	EK	BD	BQ
1	1.19	0.61	0.61	0.51	3.06	-0.03	0.64	0.21	4.26	1.24
2	0.59	0.04	0.07	0.12	3.04	-0.23	0.27	0.09	3.63	0.34
3	1.10	0.47	0.71	0.64	2.87	-0.12	0.59	0.21	3.97	1.29
4	0.63	-0.06	0.05	0.08	3.74	-0.27	0.20	0.05	4.38	0.26

3.2. SCQ

Five poems such as Du Fu's *Jue Ju*, were selected, and the breath-unit parameters of each poem were extracted and average values of parameters are shown in Table 2.

Table 2: Average values of breath-unit in SCQ.

Number	IP				EP				BU	
	ID	P	IQ	IK	ED	V	EQ	EK	BD	BQ
1	0.95	0.59	0.59	0.62	3.83	-0.08	0.68	0.18	4.78	1.27
2	0.60	0.10	0.18	0.31	3.88	-0.18	0.28	0.07	4.48	0.47
3	0.95	0.34	0.52	0.54	3.56	-0.16	0.50	0.14	4.51	1.01
4	0.54	0.05	0.21	0.38	4.09	-0.24	0.28	0.07	4.63	0.49

Although the number of syllables in each sentence of SCQ is slightly more than that in the FCQ, the breathing pattern of these two kinds of poetry is similar. In the second and fourth sentences, the inspiratory capacity of the inspiration phase in SCQ is greater than that in FCQ, and its breathing pattern seems more independent, being obviously different with the respiratory pattern discussed.

3.3. FCO

FCO, modern style poetry, which has very strict rules and forms, especially stringent regulations in poem lines, word numbers/syllables, tone, and lexical antithesis and sentence arrangements, with regular fixed numbers in each aspect. Five poems were selected *Wang Yue*, *lü Ye Shu huan*, *Chun Wang*, *Tian Mo Huai Libai*. The parameters are shown in Table 3.

Table 3: Average values of breath-unit in FCO.

Number	IP				EP				BU	
	ID	P	IQ	IK	ED	V	EQ	EK	BD	BQ
1	1.11	0.50	0.50	0.45	5.86	-0.20	0.70	0.12	6.98	1.19
2	1.09	0.26	0.46	0.42	5.75	-0.28	0.74	0.13	6.83	1.19
3	1.36	0.49	0.76	0.56	5.84	-0.16	0.93	0.16	7.20	1.69
4	0.96	0.22	0.39	0.40	6.35	-0.26	0.48	0.08	7.31	0.87

Because the FCO contains more sentences with each line including fewer characters, the breathing pattern is relatively complex. In order to facilitate analyzing the breath signals, the breath-unit was processed for each couplet. Except that the last unit is not very stable, the first three couplets only have one breath unit for each. And the breathing pattern intervenes between FCQ and SCO.

3.4. SCO

Table 4 shows the parameter for the five poems of SCO type: *Ke Zhi*, *Deng Gao*, *Deng Lou*, *Shu Xiang* and *Wen Guan Jun Shou Henan Hebei*.

Table 4: Average values of breath-unit in SCO.

Number	IP				EP				BU	
	ID	P	IQ	IK	ED	V	EQ	EK	BD	BQ
1	1.03	0.59	0.59	0.57	3.37	-0.19	0.77	0.23	4.40	1.36
2	1.18	0.14	0.33	0.28	3.52	-0.22	0.55	0.15	4.70	0.87
3	1.81	0.39	0.61	0.33	3.71	-0.19	0.80	0.21	5.52	1.40
4	1.75	0.09	0.28	0.16	4.23	-0.22	0.50	0.12	5.98	0.78
1	2.58	0.46	0.67	0.26	4.43	-0.18	0.86	0.19	7.01	1.53
2	2.38	0.13	0.31	0.13	4.95	-0.24	0.55	0.11	7.33	0.86
3	3.13	0.53	0.76	0.24	5.02	-0.17	0.93	0.19	8.15	1.70
4	3.09	0.12	0.29	0.09	6.03	-0.24	0.53	0.09	9.12	0.82

The difference between SCO and FCO is that the former has one full breath-unit for each sentence. In each couplet, the inspiration unit of the first sentence is much larger than the second one. The durations of the inspiration and expiration were shown as linear growth mode with the increasing of sentence numbers.

3.5. Summary

The inner constraints of rhythm form a unique breathing pattern for poetry. The main features of breath signal are as follows:

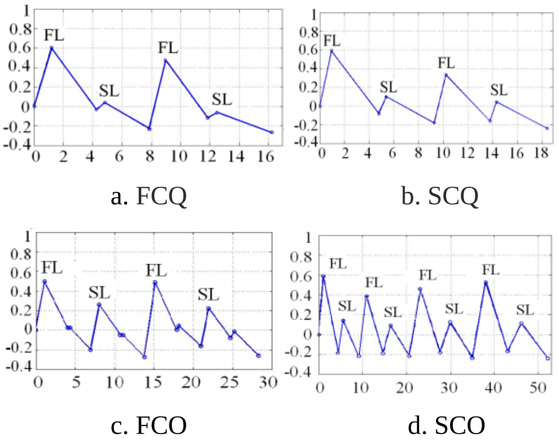
- Except for the FCO, all the other poems have large values among the duration of inspiration phase, peak values and inspiratory capacity, which is called the first level of breath-units. The second sentence of each couplet is called the second level of breath-units in Figure 3.

- The duration of inspiration phase are related with the number of syllables contained in a poem line. Generally, the last sentence as ending also has drag sound and the longest duration of expiration.
- The absolute slope values of breathing units have obvious consistency with the inspiration phase in different poems. It means in the same breath-unit, if the inspiration rate is high, so does the expiration rate.
- Inspiration rate is obviously higher than expiration rate in general: IK (n)> | EK (n) |.

4. THE MEAN LINEAR MODEL OF RESPIRATORY SIGNAL

Based on the results in the previous section, a linear model is developed by using the mean values of breathing unit's duration and amplitude for each kind of Chinese metrical poems discussed.

Figure 3: Respiratory signal linear-models.



In Figure 3, respiratory signal models as several couplets, all inspiration units' durations (ID) of first sentences in couplets are much larger than the second ones, and the absolute value of slope in first sentence is much bigger than the second one. In addition, the three former couplets all have one whole breath unit except the last couplet in FCO, but breathing pattern is similar to the FCQ. The inspiration units and expiration units of SCO are basically symmetric. Eight breath-units all present as 'an isosceles triangle mode'. Therefore, poetry breathing pattern can be linearly simulated as two-level breath-unit.

(1) $Y=kx+b$

K means the slope of inspiration and expiration phases in breach-units (IK, EK); b means intercept between inspiration and expiration phases (IB, EB). Two-level breath-unit total has 8 parameters (IK1/2, IB1/2, EK1/2 and EB1/2), in Table5.

FCQ, SCQ and SCO have one whole breath unit for each sentence, and each couplet forms one basic breathing model. FCO has one breath-unit for each couplet and each two couplets form one basic breathing model. Table 5 shows the coefficients of respiratory basic model for four types of poetries.

Table 5: Coefficient table of poetry breathing model.

Coefficient	FCQ	SCQ	FCO	SCO
IK1	0.51	0.62	0.45	0.57
IB1	0	0	0	0
EK1	-0.21	-0.18	-0.04	-0.23
EB1	0.86	0.76	0.54	0.82
IK2	0.12	0.31	0.21	0.28
IB2	-0.53	-1.55	-1.19	-1.40
EK2	-0.09	-0.07	-0.05	-0.10
EB2	0.47	0.49	0.85	0.71

5. CONCLUSION

The paper discusses the respiratory rhythmic patterns of twenty poems and develops a linear model of respiratory signal. If non-linear models of breathing signal are simulated, it is also difficult to achieve representing reality about the internal features of respiratory signal, because it is not only related to articles or poetries themselves, but is influenced by personal habits. Thus it is difficult to establish a physiological model of respiration just based on statistical algorithms. In addition, chest breathing signal representing the respiratory mechanism during reading process is not sufficient to unfolding the physiological process in reading metrical poems. Further work has to include the movement of abdominal muscles for better modeling and stimulating the dynamic mechanism that controls the rhythmic pattern in poetry reading.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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