Australian Journal of Basic and Applied Sciences, 8(10) July 2014, Pages: 365-376

AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com

Testing the Existence of Cardiorespiratory Interference Sounds

[1]Nurida Finahari, [2]Setyawan P. Sakti, [3]Retty Ratnawaty, [3]M. Rasjad Indra

[1]Mech. Engineering of Engineering Faculty of Widyagama University of Malang. Jl. Borobudur 35 Malang East Java Indonesia 65128
[2]Physic Department of Natural Science Faculty of Brawijaya University of Malang. Jl. Veteran Malang East Java Indonesia 65145
[3]Post Graduate Program of Medical Faculty of Brawijaya University of Malang. Jl. Veteran Malang East Java Indonesia 65145

ARTICLE INFO

Article history:
Received 25 April 2014
Received in revised form
8 May 2014
Accepted 20 May 2014
Available online 17 July 2014

Keywords:
Heart sounds, lung sounds, auscultation, interference sounds, spectral analysis, cardiorespiratory

ABSTRACT

Background: Auscultation technique is the action of hearing body sounds as basic diagnostic. Heart sound auscultation is presumed easier to be done than the lung sound. This is due to the anatomical condition of the heart that produce sounds more certain with sound sources that easier to detected. In contrary, anatomical condition of the lungs show the complexity in sound production, identification and analysis. In the other side, heart and lung sound interferences very possible to be occur, besides the factor of their location in the chest cavity, it also because of the inter-influences action of that organs in sound production processes. This phenomenon will open the opportunity to use that phenomenon as diagnostic tool for cardio-respiratory diseases that promises the modestly and low costing**. Objective:** This research was conducted to prove that hypothesis even still be done in the state of heart performance analysis. In this condition, interference sound was extracted from the record of heart auscultation. **Results:** This effort was done by two research stages where the first was the process of getting data by standard technique of auscultation with the stethoscope that is connected to computer and then was analyzed by windows program. The second stage was the validation processes that involved synchronization test. In this stage, heart sounds was recorded simultaneously with respiratory cycles and ECG recording. The record was digitalized by ADC equipments that connected to computer and analyzed by Mathlab program. The research results show that interference sounds appear in the form of heart sound intensity difference, range of frequency, and graphical contour, between the data that have been recorded in the free and hold breathing condition. These parameter can be called as the color of sound (timbre). The color of sound can be observed and was analyzed easier if presented in the form of spectral graphic. The results of first and second research stages do not show significant differences. The results of spectral analysis show the existence of phase shifting and signal missing phenomena. The phase shifting phenomenon correlate with respiratory cycles, meanwhile the signal missing correlate with ECG record. **Conclusion:** The research results show that (1) cardio-respiratory interference sound does exists, and (2) the usage of interference sounds as heart physiological parameter does possible.

To Cite This Article: Nurida Finahari, Setyawan P. Sakti, 3Retty Ratnawaty, M. Rasjad Indra., Testing the Existence of Cardiorespiratory Interference Sounds. ***Aust. J. Basic & Appl. Sci.,*** *8(10): 365-376, 2014*

INTRODUCTION

Heart and lungs physioanatomical review show the existence of interdependent relationship between that two organs. Anatomically, heart and lungs share space in the chest cavity where their septum layers are connected each others (Tortora, 2005). The form of left lung differs from the right one. The left lung has notch that accomodate the heart tip (apex). Physiologically, the pressure changes in chest cavity that arise from inhalation-exhalation movement of the lungs, results pressure variation on outer heart wall. This wall pressure variation, in the end, will influence the contraction-relaxation of heart chambers. This conditions will affect on blood pump process. In turns, the blood flow produced by the heart, including the flow to the lungs, will also affected. From these relationship can be seen that the heart and lungs functions build the mutual system eventhough the individual mechanism is run and controlled separately. The failures of one of cardiorespiratory organs will affect on the function of the other organ.

Corresponding Author: Nurida Finahari, Mech. Engineering of Engineering Faculty of Widyagama University of Malang. Jl. Borobudur 35 Malang East Java Indonesia 65128.
E-mail: nfinahari@widyagama.ac.id

The interactions between heart and lungs activities are the manifestation of cardioresipratory synchronization. The harmonization between heart pulse and respiratory rate is a true synchronization phenomenon eventhough not the main variable of cardiorespiratory interaction (Toledo *et al*., 2002). Heart pulse is the common object of diagnostic technique named as auscultation. Auscultation define as hearing action of the internal body sound, mainly to determine the certain conditions of heart, lungs, pleura, abdomen, and other body organs (Dorland, 1981).

From the physical mechanic point of view, the neighboring position of heart and lungs, raising the possibility for the interference sound waves to be occure. This interference waves maybe occur in low frequency range (100-300 Hz) where were known that lungs sound frequencies overlap with heart sound frequencies (Charbonneau *et al*., 1982). If in these frequency ranges the interference sounds do occur, this things can be seen as one manifestation of cardiorespiratory synchronization. So, the cardiorespiratory interference sounds can be used as pathophysiological diagnostic variables. In this situation, the pattern of interference sounds can be utilized to backing up the existing auscultation analysis techniques, or can be developt as new diagnostic method.

It is important to know that this days, interference sounds of heart and lungs have just be understood as noise. So, the heart sounds are noise that interfere the process of lungs sounds evaluation (Ghaderi *et al*., 2011), or in the contrary, lungs sounds are being the noise for the evaluation of heart sounds. The noises are always being minimized or removed (Ghaderi *et al*., 2011; Jin *et al*., 2009; Falk & Chan, 2008; Cortes *et al*., 2006; Hossain & Moussavi, 2003; Yi & Zhang, 2001; Hadjileontiadis & Panas, 1997). Unfortunately, that processes are difficult to be done because of the naturality of heart and lungs sounds that overlap each others. The recording of the lungs sounds in the chest wall for normal condition shows the sound frequency ranges up to 500 Hz, meanwhile the abnormal sounds frequencies, like crackles, can be reach 2000 Hz (Sovijarvi *et al*., 2000). However, the mayority of lungs sounds energy focus on frequency of 200 Hz. On the other side, the normal heart sounds in the chest wall commonly catch in the frequency of 200 Hz. The overlapping frequencies between heart and lungs sounds also be aggravated by the environment noises, the complexity effects of thoracic tissues, and the noises from recording tools, during the recording time (Gnitecki and Moussavi, 2007). This research try to prove the existence of the interference sounds, explore the characteristics, and study the possibilities of the usages, to improve the method of auscultation analysis, especially to describe the heart performances.

MATERIALS AND METHODS

The research was done in two stages. The first stage was examined the capability of standard auscultation technique to detect the interference sounds. In this stage, the standard stethoscope was modified so that could be connected to the computer and used as recording tools with windows sound recorder program. The modification was done by adding the usual mic condenser and audio jack to the ear tip of the stethoscope. The amplification and filtering process was done by Windows Sound Recorder (WSR) Program. This modification stethoscope was passed the accuracy test by signal to noise ratio (s/n) analysis.

The research second stage was verification processes. In this stage, heart sounds were recorded in the same time with respiratory cycles and ECG recording simultaneously. This could be done just by digital recording equipments. The verification data then be obtained from raw data of Amit *et al*. (2009), the researcher from School of Computer Science, Tel-Aviv University, Israel. The equipment schematic is shown in Fig. 1. Acquition data system of Amit *et al*. (2009) have five sensors that consisting of two piezoelectric contact transducers (PPG sensor model 3, OHK Medical Devices, Haifa, Israel) as heart sounds recorders, one respiratory pressure transducer made in Validyne Northridge California, and two contact points of single ECG lead made in Atlas Researcher Hod-Hasharon Israel. ADC unit consist of pre-amplifier made in Alfa-Omega Nazareth Israel that is connected to ADC made in National instruments Austin Texas with 11025 data/second capacity and 16 bit sample size. Digital data were recorded by Mathlab software (SigView.m).

Heart sounds were recorded from healthy male and female in sitting position. Recording was done in the condition of free (BB) and hold (TN) breathing. The results of first stage recording were analyzed with Wavepad Sound Editor (WSE) and Audacity Free Edition (AFE), meanwhile the second stage were analyzed with SigView.m ran in Mathlab R2009a.

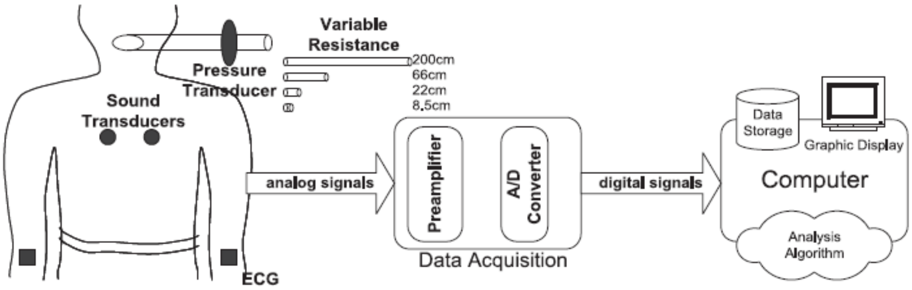


Fig. 1: Research equipments of Amit *et al*. (2009).

Results:

Stage I:

The example of recorded data in the form of WSE graphic visualization can be seen in Fig. 2. This graphical data then be quantified to obtain the numerical values. The statistical analysis conducted to that numerical values. Spectral analysis have been captured from the graphical data by AFE program.

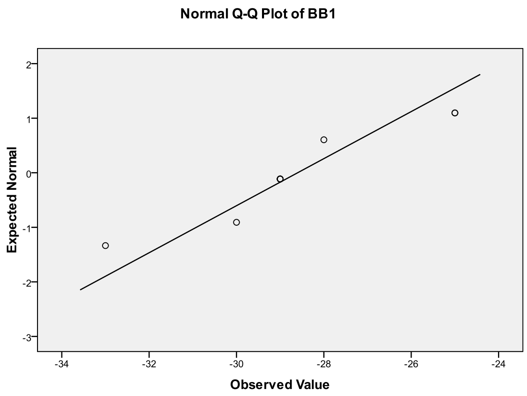
No.	Breathing condition	WSE visualization
A	Free breathing	
	Hold breathing	
B	Free breathing	
	Hold breathing	

Fig. 2: The example of recorded heart sounds graphical data. A. Original, B. 1000 x amplification.

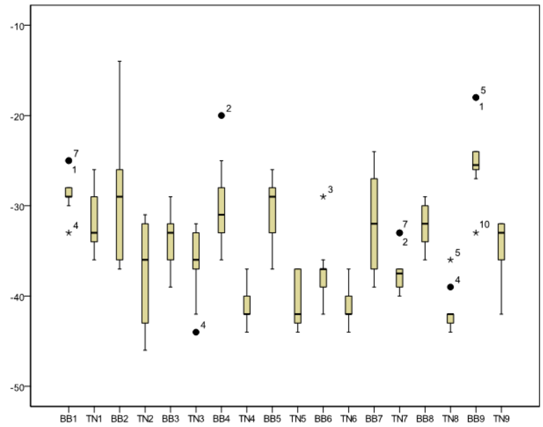
The results of normality test (by SPSS ver. 17.0) for the significant level of p = 0.05 show that there are some data groups that lies in lower border of normality significant level. This means that the values of that data groups, during the measurement process, maybe affected by other factors that have not been controlled, such as gender, body height and weight, and smoking habit. But generally all data passes the normality criteria.

To examine the data deviation from the normal line, homogeinity test was conducted by Kurtosis test (deviation from the central data) and Skewness test (data spreading and inclination of normal curve). The value of Kurtosis and Skewness lie in the range of -2 and 2 (Fig. 3a). The test results show that in the all of data groups, the individual values spread within the determined borders. From the Kurtosis test, it is found that there is only one data group that has values far from the central tendency. This data obtain from the object with highest values of body height and weight. So, the high deviation of the data maybe affected by its body condition.

Australian Journal of Basic and Applied Sciences, 8(10) July 2014, Pages: 365-376



a)



b).

Fig. 3: a). The normality plot of BB1 data. The expected normal values lie in the range of -2 dan 2, b) Ilustration of data spreading. The histogram for each data groups is completed by the sign of central tendency (mean), standard error mean, and the data that must be excluded.

The test results for the value differences show that the value of p for each pairs of BB-TN data are lies below the significant level, $p < 0.05$. It means that for each object, the heart sound recorded data in free breathing condition are different from the data in the hold breathing condition. The mean value of heart sound intensity for free breathing is -30.9 dB, meanwhile for the hold breathing is -38 dB (Fig. 4). The intensity value increase 7.1 dB that may be rise from respiratory effects. At least it can be said that the respiratory process does affect the generation of heart sounds. It can be seen from the Fig. 4 that eventhough there are the diffferences in values, the pattern of the data remain the same.

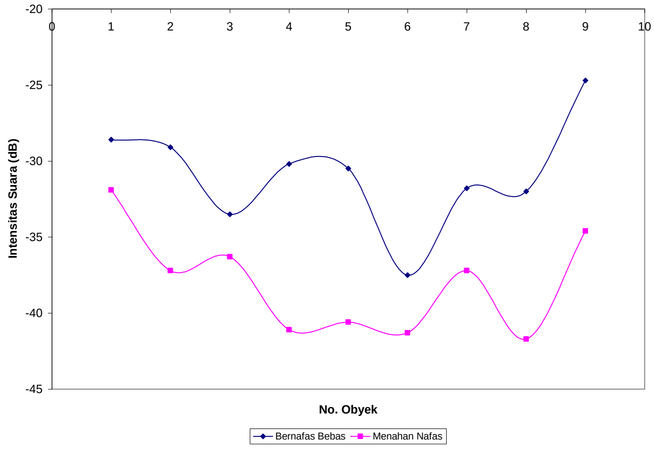


Fig. 4: The mean values of BB (blue) and TN (red) data.

Visually, the recorded heart sounds in free and hold breathing can be seen in the Fig. 5. The results of spectral analysis of heart sounds on the interval of 1 second are presented in Fig. 6. The differences characteristics of that two kinds of data are show as marked area. The amplitude differences in the sound graphic (Fig. 5) appear in the form of sound intensity differences in spectral graphic (Fig. 6). Meanwhile, the differences of nodes appear as frequency ranges and spectral contour differences. The frequency and spectral contour differences indicate the differences of sound colour (*timbre*).

Australian Journal of Basic and Applied Sciences, 8(10) July 2014, Pages: 365-376

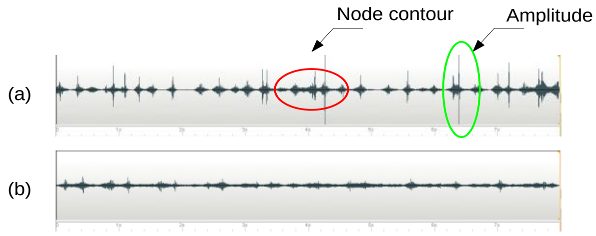


Fig. 5: The WSE Visualization of recorded heart sounds in the condition of a) free, and b) hold breathing. The characteristic differences appear as marked area.

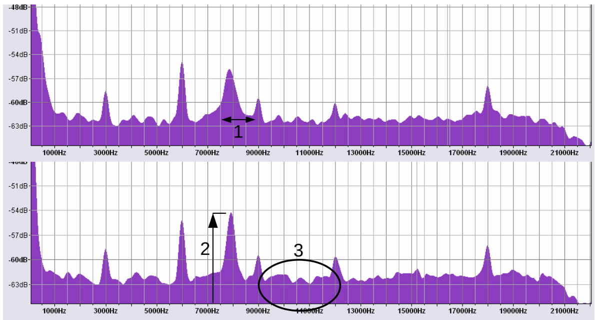


Fig. 6: The AFE spectral visualization of recorded heart sounds in the interval of 1 second. Upper graphic shows the free breathing condition, and the lower show the hold breathing condition. The characteristic differences of the two kind of sounds appear as 1) frequency ranges, 2) sound intensity, and 3) spectral contour.

Stage II:

The results of data presentation in the form of graphical heart sounds (HS-L), ECG, and respiratory cycles (PRS) can be seen in the Fig. 7. This graphical raw data from the acquition processes then be quantified randomly by image analysis program of ImageJ ver. 5.0. The quantification proces is done to obtain the values of R-wave voltage (mvolt), respiratory tidal pressure (mbar), and heart sound intensity (dB). The statistical analysis then conducted to this numerical data.

The results of statistical analysis show that the R-wave data follow the normality criteria eventhough there are several data that spread far from the mean value. Meanwhile, the differences value testing for the free and hold breathing condition shows the majority of the significant values above p = 0.05. It means that R-wave data of ECG do not affected by respiratory cycles. The mean values graphic support this test results (Fig. 8) where the overlapping graphical indicate the same values and pattern.

Statistically respiratory pressure data show the normality and homogeinity behaviour, eventhough some of the data deviate from the normal line. The data homogeinity is supported by Friedman test with significant value p = 1. The boxplot of respiratory tidal pressure show that the range of the values lie in the same level.

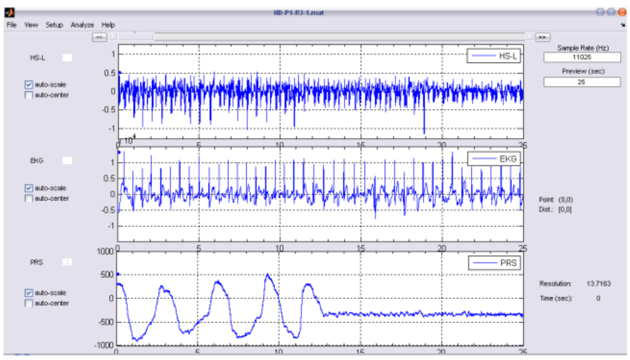


Fig. 7: The results of SigView acquisition in 25 seconds interval. It shows graphical data of heart sounds, ECG, and respiratory cycles respectively.

Australian Journal of Basic and Applied Sciences, 8(10) July 2014, Pages: 365-376

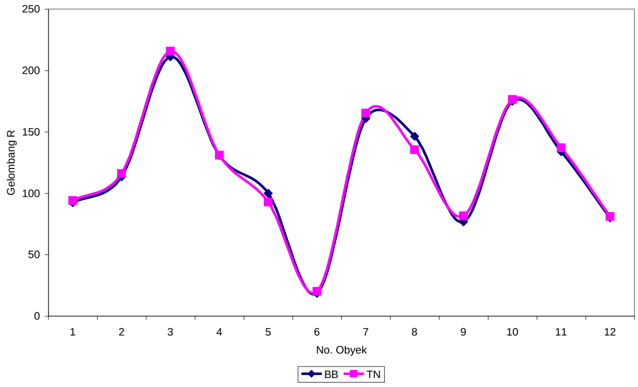


Fig. 8: The data characteristics of R-wave in free (blue) and hold (red) breathing.

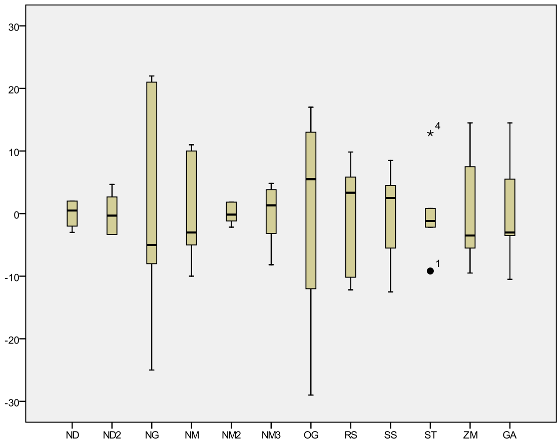


Fig. 9: The boxplot of respiratory tidal pressure.

The descriptive analysis shows that electricity cycles of the heart that is represented by R-wave does not affected by respiratory cycles. Respiratory tidal pressure data are also proven follow the criteria of normality and homogeinity. So, these two kind of data can be treated the synchronization analysis, and be used as standard reference to evaluate the heart and lungs interference sounds characteristics.

For the heart pulse that consist less than 20 R-waves, Cysarz *et al*. (2004) said that there were two methods based on bivariance analysis that offer simplicity and accuracy in the detection of cardiorespiratory synchronization. The methods are Synchronization λ and Phase recurrences. This analysis choose the phase recurrences for the easiest to be understood. The mathematical equations that be used in the process analysis of this method (variables identification references presented in Fig. 10) are:

a. the relative distance between the inspiration point and the following R-wave

$$\varphi_i = \left(\frac{R_i - I_j}{I_{j+1} - I_j} + j \right) \bmod n$$

b. phase synchronization term of condition

$$\exists k > 1 \; \left| \varphi_{i+m} - \varphi_i \right| < \varepsilon, \;\; i \in \left\{ l, \ldots, l+k-1 \mid 0 \le l < N_r - k + 1 \right\}.$$

Phase synchronization term of condition need k value at least in the number of 2m. Its condition only can be fulfilled if the recorded number of respiratory cycles are k. In this analysis, the synchronization then refers to the ideal definition that is ***the φ value for each respiratory cycle are considered the same***. The shifting of φ values indicate synchronization level. The shifting values of φ are determined in the ranges of statistical confidence interval as mean value ± 2 deviation standard (ε = $\bar{x} \pm 2\sigma$). This 95% confidence interval allows the error values as 5%.

Australian Journal of Basic and Applied Sciences, 8(10) July 2014, Pages: 365-376

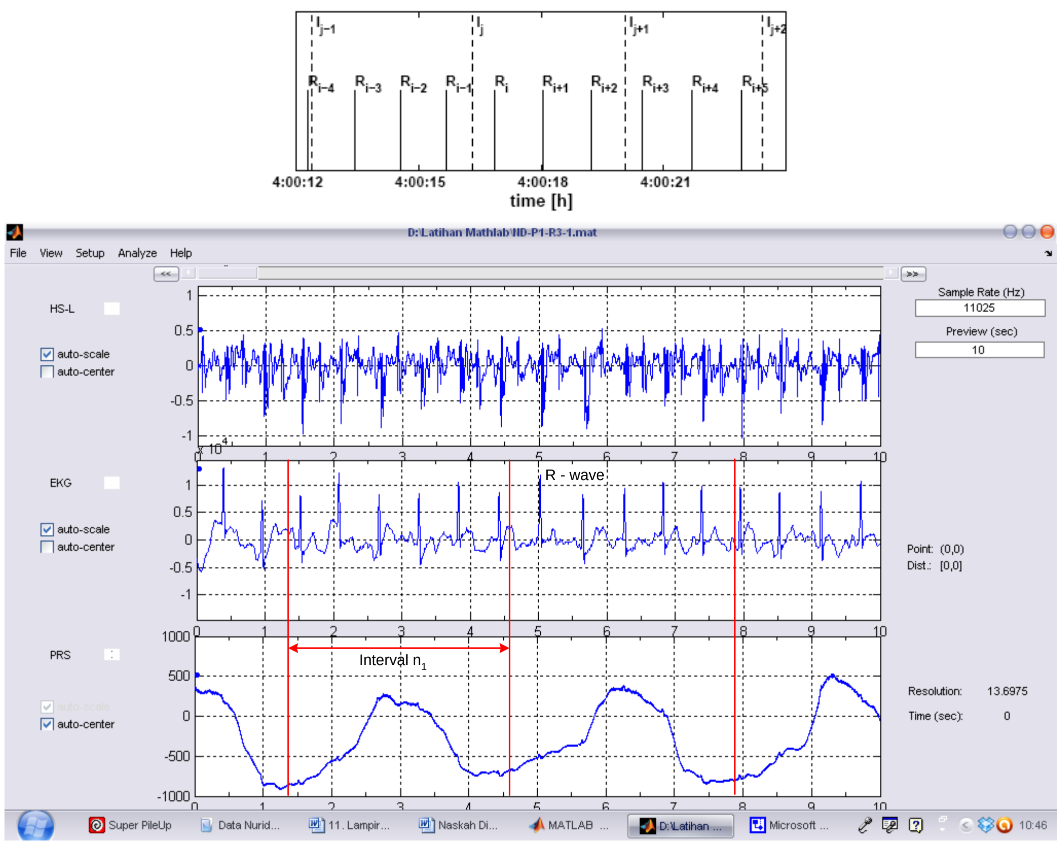


Fig. 10: The variables identificationof *Phase Recurrences* synchronization analysis due to Cysarz *et al*. method [18]. The vertical red line marked 1 respiratory cycle as measurement references for R-wave. Phase φ_i is the time point when the i-th R-wave occurs.

The results of synchronization analysis (Table 1) show that the average of respiratory cycles occur three times per 10 seconds, and there are four R-waves on averages in each cycles. This findings coincide with the reference [19]. The meauring phase values of φ indicate that all of the data fulfilled synchronization criteria that means that all research objects, physiologically, in the normal state or show the good condition of health level.

The normality test of heart sounds show that all data pass the examination and supported by the plot of normal curve (Fig. 11a). The graphic of data spreading in Fig. 11b. does not supported the normal indication eventhough all individual normal curves exhibit the normality. The homogeinity test has the identical results. The test values exhibit the homogeinity eventhough the data spread far from the mean values. The mean values graphic of BB and TN heart sounds show identical pattern, almost overlapping (Fig. 12), eventhough in the some points occur the differences.

The limit differences in the graphical presentation do not supported by statistical analysis that shows significant differences. Seven of the twelve data show difference values significantly, meanwhile two of the five data that support the equality have significant values near the lower border. It means that the data tends to prove the hypothesis that is the respiratory process affected the heart sounds intensity values significantly.

With the point of view that heart sound data tend to be affected by respiratory cycles, visual analysis for the sounds spectral can be done. Visually, the example of sound data in the free and hold breathing are shown in Fig. 13. The results of spectral analysis in the one second interval and the differences of BB – TN conditions are shown in Fig. 14. It is found that besides the variable values differences, the TN graphical spectral exhibit the phenomena of signal missing and phase shifting.

The signal missing and phase shifting phenomena only can be analyzed in the form of numerical data. The phase shifting phenomenon show the differences of the sound generation time, so then can be represented by the value of time interval of sound generation. The signal missing phenomenon is the extreme value of the sound intensity differences, so then can be represented by the subtraction of the sound intensity data of the BB – TN condition. The differences of sound intensity of BB – TN condition actually represent the manifestation of interference sound wave.

Australian Journal of Basic and Applied Sciences, 8(10) July 2014, Pages: 365-376

The results of correlation test for the quantification data of spectral phenomena with ECG signal and respiratory cycles show that the phase shifting correlate with respiratory cycles (in the variable of tidal pressure), meanwhile the signal missing correlate with ECG signal (in the variable of mean differences of BB – TN R-wave values).

Table 1: Resume of the results of synchronization analysis.

Object	∑ respiratory cycles (n)	∑ R wave/respiratory cycle (m)	Mean φ_i	Synchronization criteria	Conclusion
GA	2	5,5	0,067	The data declare synchronous if the φ values lie in the range of $-\varepsilon \leq \varphi_i \leq \varepsilon$	Synchronous
ND	3	5,0	0,094		
ND2	4	3,0	0,190		
NG	3	3,3	0,159		
NM	3	3,3	0,043		
NM2	4	3,5	0,076		
NM3	3	4,7	0,140		
OG	4	3,3	0,054		
RS	3	3,0	0,142		
SS	2	3,0	0,182		
ZM	3	3,3	0,094		
Average	3	4	N_{ref} = 1,6 – 3 cycles / 10 seconds M_{ref} = 12 cycles / 10 seconds (Klabunde, 2004)		

Source: The results of data processing

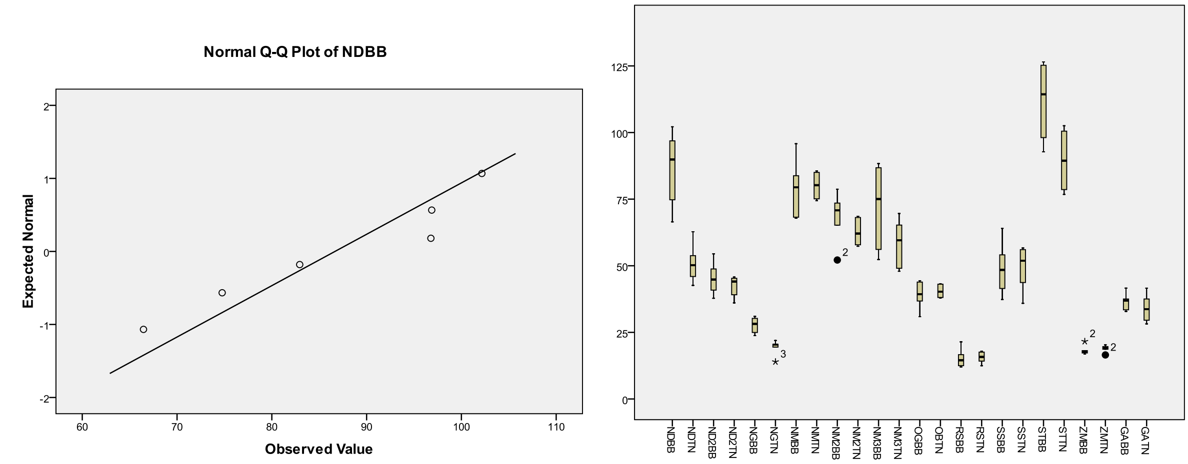


Fig. 11: (a) Normality plot of ND data. The expected normal values lie in the range of -2 dan 2, b) illustration of data spreading.

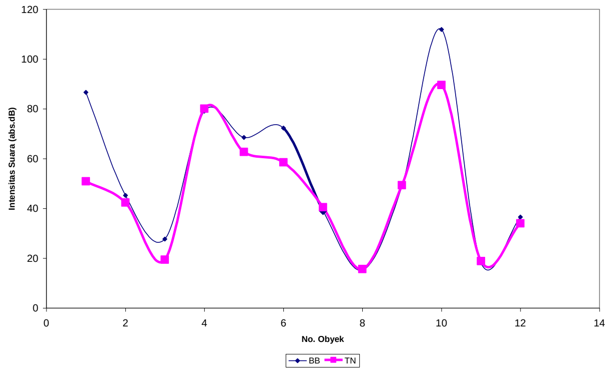


Fig. 12: Characteristic of absolut mean values of BB – TN heart sounds.

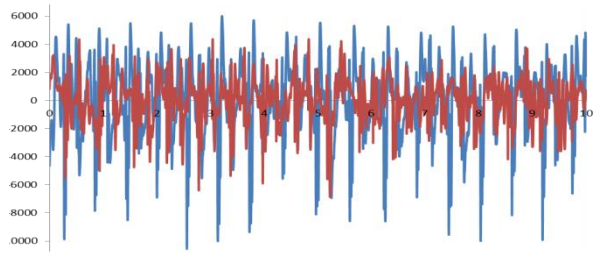


Fig. 13: The time vs amplitude graphical representation of ND object (100x amplification) for free (blue) and hold (red) breathing condition.

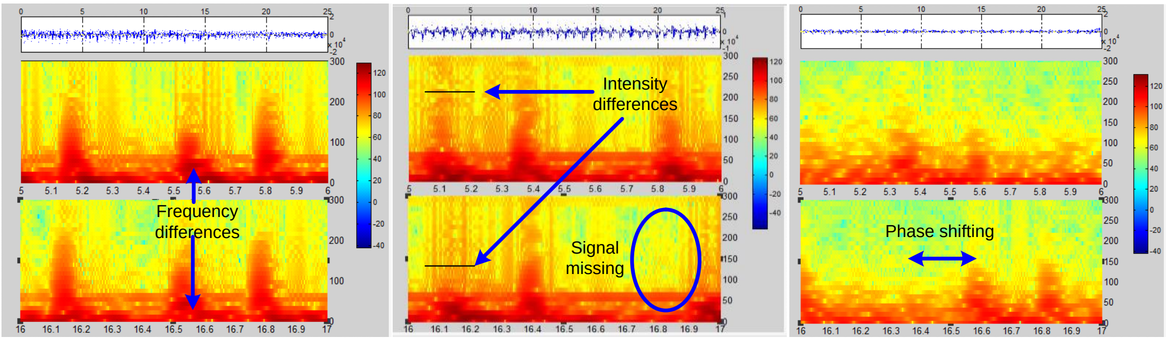


Fig. 14: The results of spectral analysis for free (upper) and hold (lower) breathing condition. The colour represent the magnitude of frequency, the horizontal axis represent time (phase), and the vertical axis represent the sound intensity.

Discussion:

Stage I:

According to the number of the normal heart pulse in the range of 60-80 bpm (Despopoulos and Sibernagl, 2002) with the average of 72 bpm (Klabunde, 2002), from the 8 second data recording will be obtained 8-10 pulses. The usual heart sounds that be heard in every pulse are S1 and S2, so there will be total of 16-20 sound nodes or in average of 18 nodes. The average respiratory cycles are about 18 times per minute. According to that number, in the 8 seconds will be occur 2-3 cycles. Because of the respiratory cycles consist two airflow events that have possibility to produce sounds (inhalation and exhalation), it is assumed that there will be 4-6 nodes of heart sounds affected by respiratory cycles.

Generally there are present the significant differences between the heart sound data obtained in free (BB) and hold (TN) breathing. It means that respiratory processes do affected the heart sounds heard in the body surfaces. The differences appear in the form of node and amplitude. The node indicate the differences on sound color, meanwhile the amplitude indicate the differences on sound intensity (Fig. 5). The findings of spectral characteristic differences between BB-TN heart sounds, strengthen that facts (Fig. 6). Later, these characteristics can be used as interference sound spesific parameters. For comparison, the time of sound generation (phase), the hardness of the sound (intensity), duration, and pitch, are natural characteristics of the heart sound waves that be used as identification processes and analysis of murmur (Jabbari and Ghassemian, 2011).

From the visual analysis can be seen also that the differences number of recording data reach the number of respiratory cycles, so there is possibility that the differences does affected by respiratory processes. This findings coincide with the research results of Amit *et al.* (2009) that declaire that heart sounds modulated by respiratory activities. In the normal respiratory condition, heart sounds exhibit high morphological variability but occur periodically due to respiratory cycles.

The differences occur both in the male and female object even though the characteristic variations do exist. This variations may occur due to the differences of physical conditions of each object. This fact is supported by the statistical calculation finding that shows that the only object that does not meet the normality and homogeinity criteria have the highest level of body height and weight. The ratio of body height and weight exceed the ideal criteria too. This is indicate that BB and TN data maybe correlate with physical condition. So, it can be concluded temporary that respiratory processes do affect the heart sound characteristics. It means that the interference sounds between heart and lungs do exist and correlate with the physical conditions.

Stage II:

Statistical analysis result the findings that ECG signal that represented by the voltage of R-wave does not affected by respiratory cycles. The recorded R-wave value in the free breathing condition not differs from the hold breathing condition. Even though the variation does occur among the objects, normality and homogenity test show the positive behavior. The same results found in the respiratory tidal pressures that represented the respiratory cycles. These conditions results in the possibility of conducting the synchronization analysis to examine the physiological condition of the objects.

Synchronization analysis based on phase recurrences show the synchronous behavior of the data. It means that heart and lungs activities state in harmony. Cardio-respiratory synchronization indicate the physiological normality of the objects (health condition). It means also that the characteristic of heart sounds recorded in the same time with ECG and respiratory cycles, will follow the synchronous pattern. So, physiologically, all of the data source from the healthy objects. The average data result from the analysis exhibit the same number with the reference, that is three cycles and twelve heart pulses per 10 seconds (Klabunde, 2002). All of those cycles within the ideal range of phase values.

From the analysis of heart sounds, the difference values of sound intensity in the BB and TN condition indicate the values of heart and lungs interference sounds. Even though the statistical analysis exhibit the normality and homogeinity of the heart sound data, the spreading values seems wide. There are no absolut differences between BB and TN because of the existence of the same manner of the data, but the existence of the interference can be denied and supported by spectral analysis.

The visual analysis of the spectral graphics of BB and TN heart sounds show that the BB sounds have higher and wider frequency range values. At the some objects, BB sounds have lower values than TN. It is hypothesize due to the respiratory cycles. This phenomenon do not the deviation pattern and can be explained as the result of inhalation – exhalation contrary effects. Inhalation phase strengthen the heart sounds, meanwhile the exhalation phase obtain the contrary effect. It is according to the relationship scheme shows in Fig.1.

The results of visual analysis on spectral graphic also obtain the findings of signal missing and phase shifting. These phenomena correlate with physiological condition of the objects, represented by ECG and respiratory cycles. The signal missing correlate with ECG, and the phase shifting correlate with respiratory cycles.

The interference sounds that are indicated by the intensity differences between BB and TN sounds exhibit normality and homogeinity among twelve objects. Its indicate that the pattern of interference sounds do not affected by the object characteristic differences such as age, body height and weight, and gender. But the verification processes that involved more massive variability and number of the objects are still needed. It is also found that the interference sound pattern tends to be identical with the graphical pattern of R-wave. This findings support the fact that spectral signal missing of the heart sound correlate with the ECG data.

General Discussion:

Naturally, the heart and lungs sounds have the overlapping frequency range. The recording of lungs sound on the body surfaces, for the normal condition (vesicular sound), show the frequency range up to 500 Hz, meanwhile in the abnormal condition like crackles, the frequency can be measures up to 2000 Hz (Sovijarvi *et al*., 2000). Even so, the majority of lungs sound energy focus on frequency of 200 Hz. In the other side, the normal heart sound on the body surfaces can be measure in the range up to 200 Hz. The main frequency components of the heart sounds are found in the range of 20 – 150 Hz (Arnott *et al*., 1984).

The frequency overlapping between heart and lungs sounds cause the separation of these two kind of sounds hard to be done, especially if it is considered also the existence of environmental noises, the effects of thoracic tissues complexity, and the noise from the measurement tools (Gnitecki and Moussavi, 2007). It is worsten by the fact that heart and lungs sounds have the unstable pattern. The characteristics of lungs sound are affected by the respiratory airflow pattern due to the gas fluctuation and the oscillation of hard tissues (Charbonneau *et al*., 1983), meanwhile the heart sound characteristics are affected by the contants movement of the valves and dynamic movement of heart muscles (Xu *et al*., 2001). The dynamic of that cardiorespiratory sounds may be occuring the variability of recording results eventhough the recording position is fixed. These conditions show that the recording processes of the cardiorespiratory sounds on the chest surfaces need the position acquisition to ensure the presicion of the results (Wood and Barry, 1994). According to that conditions, it can be understood that separation processes of the heart sounds from the lungs sounds are the time and fund consumpt efforts, especially for the acquisition of computational algorithm processes (Ghaderi *et al*., 2011).

It have been known that heart sound characteristics are affected also by the performance of respiratory system. In the inspiration time, the pleural pressure decrease so that the pressure differences in thoracic area increase. It is cause the increment of the filling volume of right ventricle that in turn will increase the filling stroke, according to Frank-Starling mechanism (Bromberger-Barnea, 1981). The increasing of the filling stroke and volume of right ventricle will be decrease the stretching power of left ventricle following the interventricular interdependent relationship. So that the filling volume of the left ventricle decreases. In the same time, the decreasing of pleural pressure will be decrease the pressure differences and the blood flow from pulmonar vena to the left ventricle, meanwhile the aortic pressure of the transmural diastolic just rises. These combination effects will also be decrease the filling stroke of left ventricle (Scharf *et al.*, 1979). The expiratory processes reverse the effects when the final volume of the left ventricle just rises. At the end, the final total volume of the left ventricle that are provided in the beginning of the systolic stroke will affect the S1 intensity sound.

All of that facts above show that if the cardiorespiratory interference sounds can be proved physiologically function significant, the analysis of heart and lungs sounds can be done in the integrated manners. That will easier the diagnostic processes without decreasing the precision aspect of the results. In this point of view, the research series that have been done, have been proven that the interference sounds, in the mean of the sound waves superposition, do exist. The analysis results of recorded heart sound from the first stage show that interference sounds variate in parameter of amplitude and node. These two parameters can be resume as sound colour parameter (timbre). In the spectral analysis, the sound colour characteristic can be represented by the spectral envelope, that is the contour of the frequency magnitude in the range of references time. The first stage research results show that in interference condition heart sounds recorded in the range intensity of about -38 dB, rising 7.9 dB higher than the non-interference condition. The results of the second stage research support the first stage results. Eventhough the sound intensity mean value of the second stage higher 2 dB, statistically that two mean values do not have significant differences. So, it can be state that the interference sound intensity can be found in the range of -45.2 ± 7.8 dB. The BB heart sound frequencies can be obtain up to 120 Hz meanwhile the TN heart sounds will be range up to 100 Hz.

The intensity and frequency differences that manifest the differences of spectral contour show that the analysis of interference sounds can be done easier if using the sound colour parameter (timbre). The timbre differences of the BB and TN heart sounds according to the research results of Amit *et al*. (2009) about the morphological variation of the heart sound due to the respiratory cycles. The characteristic identification of spectral intersection of the BB and TN heart timbre indicate the spectral form of the interference sounds. Unfortunately that intersection processes can not be done to the first and second stage research data, due to the limitation of the provided image analyser program capabilities. Even so the similarities between the first and second stage research results show that interference sounds can be detected easily, just by the modification of standard stethoscope connected to the computer with the windows program.

The heart sound spectral pattern analyzing also possible to detect the phenomena of signal missing and phase shifting. These phenomena can not be detected by the 2D axis based on time and amplitude only. The findings that the TN spectral signal missing correlate with ECG seem to be relate with the hold breathing condition. In the first stage, the object hold the breathing after inhale the air maximally. This condition similar with the permanent inspiration. Means that the filling volume of the left ventricle remain constant so that the changes of the heart sound on that left area only affected by the variation of the constraction-relaxation power generated by the heart electricity.

On the other hand, the phase shifting that correlate with respiratory cycles also can be understood in the same manner. The hold breathing condition is identical with the permanent inspiration that make the decrement of the left ventricle filling volume also permanent. It will occuring the delay time to reach the minimum blood volume that trigger the valve opening. It means the heart sound generation will be late. However, the signal missing and phase shifting phenomena just support the facts that heart and lungs interference sounds do have physiological meaning and can be used as measurment parameter of heart performance.

Conclusion:

From the results and discussion can be drawn the conclusion that the heart and lungs interference sounds appear in the form of sound frequency and intensity differences. The interference sound intensity range in the value of $45{,}2 \pm 7{,}8$ dB, can be detected in the frequency range of 100 – 120 Hz. This interference is obtaining the phenomena of spectral signal missing and phase shifting that correlate with ECG and respiratory cycles, so that can be used as physiological parameter of heart performances. To ensure that interference sounds do proper as physiological parameter of heart performance, it is needed the mapping processes of the timbre spectral pattern that involve wider variability of the objects. The variability suggested to be consist of the ras, gender, age, and the common physiological states such as body height and weight. The physiological and pathophysiological state mapping are needed too. The mapping processes need the image analyser program that can be drawn the uniqe pattern of the spectral intersection of BB and TN data.

AKNOWLEDGEMENT

This research was funded by The Ministry of Education and Culture of Indonesia, cq. The Directorate General of Higher Education by BPPS Scholarship and Doctoral Grant.

REFERENCES

Amit, G., K. Shukha, N. Gavriely, N. Intrator, 2009. Respiratory modulation of heart sound morphology, *Am J Physiol Heart Circ Physiol.*, 296: H796-H805.

Arnott, P.J., G.W. Pfeiffer and M.E. Tavel, 1984. Spectral analysis of heart sounds: relationships between some physical characteristics and frequency spectra of first and second heart sounds in normals and hypertensives, *J. Biomed.Eng.*, 6(2): 121-128.

Bromberger-Barnea, B., 1981. Mechanical effects of inspiration on heart functions: a review, *Fed. Proc.*, 40: 2172-77.

Charbonneau, G., J.L. Racineux, M. Sudraud, E. Tuchais, 1982. An accurate recording system and its use in breath sounds spectral analysis, *J. Appl. Physiol.*, 55: 1120-1127.

Charbonneau, G., J.L. Racineux, M. Sudraud, E. Tuchais, 1983. An accurate recording system and its use in breath sounds spectral analysis, *J. Appl. Physiol.*, 55 (4): 1120-1127.

Cortes, S., R. Jane, A. Torres, J.A. Fiz, J. Morera, 2006. Detection and adaptive cancellation of heart sound interference in tracheal sounds, *Proc. Of the 28th IEEE EMBS Ann. Int. Conf. 2006,* pp: 2860-2863.

Cysarz, D., H. Bettermann, S. Lange, D. Geue, P. van Leeuwen, 2004. A quantitative comparison of different methods to detect cardiorespiratory coordination during night-time sleep, *BioMedical Engineering OnLine*, 3: 44.

Despopoulos, A., S. Silbernagl, 2003. Color Atlas of Physiology, Fifth Edition, Thieme Stutgart Germany *Dorland's Illustrated Medical Dictionary.* 26th ed, 1981, Philadelphia, Pa: WB Saunders Co

Falk, T.H., W.Y. Chan, 2008. Modulation filtering for heart and lung sound separation from breath sound recordings, *Conf Proc IEEE Eng Med Biol Soc*., pp: 1859-62.

Ghaderi, F., H.R. Mohseni, S. Sanei, 2011. Localizing heart sounds in respiratory signals using singular spectrum analysis, *IEEE Transactions On Biomedical Engineering*, 58(12): 3360-67.

Gnitecki, J. and Z. Moussavi, 2007. Separating heart sounds from lung sounds-Accurate diagnosis of respiratory disease depends on understanding noises, *IEEE Eng. Med. Biol. Mag.*, 26(1): 20-29.

Hadjileontiadis, L., S.M. Panas, 1997. Adaptive reduction of heart sounds from lung sounds using fourth-order statistics, *IEEE Trans. on Biomed. Eng.*, 44(7).

Hossain, I., Z.M.K. Moussavi, 2003. An overview of heart-noise reduction of lung sound using wavelet transform based filter, *Proc. of the 25th Ann. Int. Conf.of The Eng. in Med. and Biol. Society*, pp: 458-461.

Jabbari, S., H. Ghassemian, 2011. Modelling of heart systolic murmurs based on multivariate matching pursuit for diagnosis of valvular disorders, *Computers in Biology and Medicine*, 41: 802-811.

Jin, F., F. Sattar, D.Y. Goh, 2009. A filter bank-based source extraction algorith for heart sound removal in respiratory sounds, *Comput Biol Med.*, 39(9): 768-77.

Klabunde, R.E., 2004. Cardiovascular Physiology Concepts; published by Lippincott Williams & Wilkins

Scharf, S.M., R. Brown, N. Saunders, L.H. Green, 1979. Effects of normal and loaded spontaneous inspiration on cardiovascular function, *J. Appl. Physiol.*, 47: 582-590.

Sovijärvi, A.R., L.P. Malmberg, G. Charbonneau, J. Vanderschoot, F. Dalmaso, C. Sacco, M. Rossi, J.E. Earis, 2000. Characteristics of breath sounds and adventicious respiratory sounds, *European Resp. Rev*., 10: 591-596.

Toledo, E., S. Akselrod, I. Pinhas, D. Aravot, 2002. Does synchronization refect a true interaction in the cardiorespiratory system? (abstract), *Med Eng Phys.*, 24: 45-52.

Tortora, G.F., 2005. Principles of human anatomy, tenth edition, John Wiley & Sons, Inc, Hoboken NJ 07030, USA.

Wood, J.C. and D.T. Barry, 1994. Quantification of first heart sound frequency dynamics across the human chest wall, *Med. Biol. Eng. Comput.*, 32: S71-S78.

Xu, J., L.G. Durand, P. Pibarot, 2001. Extraction of the aortic and pulmonary component of the second heart sound using nonlinear transient chirp signal model, *IEEE T. Biomed. Eng*., 48: 277-283.

Yi, L., Y.T. Zhang, 2001. Reduction of heart sounds from lung sound recording by automated gain control and adaptive filtering techniques, *Proc. of the 25th Ann. Int. Conf.of The Eng. in Med. and Biol. Society*, pp: 2154-2156.