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Effects of Different Resting Positions on the Heart and Respiratory Rate After Aerobic Exercise

Dae-Geun Kwak[1], Dong-Woo Yang[2], Jae-Hwan Song[3], Dong-Yeop Lee[4] , Ji-Heon Hong[5] Jae-Ho Yu[6] ,Jin-Seop Kim*[7]
[1]*BSc.student, Dept. of Physical therapy, SunMoon University, Korea*
[2]*BSc.student, Dept. of Physical therapy, SunMoon University, Korea*
[3]*BSc.student, Dept. of Physical therapy, SunMoon University, Korea*
[4]*Professor, Dept. of Physical therapy, SunMoon University, Korea*
[5]*Professor, Dept. of Physical therapy, SunMoon University, Korea*
[6]*professor, Dept. of Physical therapy, SunMoon University, Korea*
[*7]*Professor, Dept. of Physical therapy, SunMoon University, Korea*
hwantym@nate.com[1], ydw5112@naver.com [2], songjea74@gmail.com[3]
, kan717@hanmail.net[4], hgh1020@sunmoon.ac.kr[5], naresa@sunmoon.ac.kr[6], skylove3373@sunmoon.ac.kr[7]*
Corresponding author[*]: Jin-Seop Kim, E-mail : skylove3373@sunmoon.ac.kr

Abstract

Background/Objectives: The aims of this study is to compare the effects of five recovery postures (standing position, Upright sitting position, Forward sitting position on the table, Reclining position with the chair back, supine position) on heart rate and respiration rate during 5 minutes of rest after exercise to target heart rate (Maximum heart rate 70%) and find the best recovery posture.
Methods/Statistical analysis: A group of twenty-one healthy adult men from S University used treadmill for 5 to 10 minutes each at 70% of the maximum HR value. After exercise, each of the five recovery postures was measured for five minutes on different days.
Findings: As a result of the experiment, the heart rate showed the best recovery rate of the Supine position, followed by FSP(Forward sitting position) on the table, RPB(Reclining position with the chair back), USP(Upright sitting position), and Standing position. As the results of respiratory rate did not differ significantly between postures, statistics of each posture showed that the Supine postion showed the highest value among the recovery postures, and the FSP on the table showed the highest value among the three sitting postures.
Improvements/Applications: It is showed that the application of the heart rate and respiratory rate recovery rate is achieved by applying the Supine position and FSP on the table during the recovery posture.

***Keywords*:** Heart rate, Respiration rate, Recovery posture, Upright standing position, sitting position, Upright supine position

1. Introduction

Respiratory disease affects the respiratory environment and causes changes in the environment between different populations[1]. Alemaryeen et al. regarded respiration rate as one of the important vital signs because it provides important information about a person's health and physiological stability[2]. The respiratory muscle pumps are very important as they induce alveolar ventilation and the diaphragm, chest and abdominal wall muscles are considered the most important components of the respiratory muscle pump[3]. It considered that exhalation muscles include abdominal wall and rib muscles. Abdominal wall muscles exhibit a coelenteron action to offset the gravity acting on the abdominal contents to maintain the diaphragm at an optimal length for pressure generation in the upright position[4]. Aerobic exercise enables efficient lung oxygen absorption, activating large muscle groups and increasing heart rate to make the lungs work effectively[5]. According to previous study, different body postures on heart rate recovery after exercise, the indicators such as heart rate recovery and heart rate variability were used to quantify parasympathetic reactivation after exercise[6] shows an accelerated heart rate recovery in the lying position, compared to the partially sitting position, which is described by Takahashi et al[7]. Some study said the initial exponential decrease in heart rate(HR) is the result of a rapid recovery of vagus nerve tension after exercise stops[8]. Some study mentioned that the decrease in HR is influenced by the gradual weakening of sympathetic effects[8]. Migliore suggests that upright posture (as opposed to sitting or standing upright posture) can reduce dependence on secondary breathing muscles, and can also reduce shortness of breath by limiting assistive movements of the upper rib cage and scapula[9]. Four recovery conditions (Static sitting posture, dynamic sitting posture, right lying posture, leg up lying posture) were compared by fitting a heart rate attenuation curve that

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influences the heart rate recovery pattern in a previous study. The posture of leaning at 45 degrees is a position where the abdominal muscles are relaxed and can induce sufficient inspiration[10]. Buchheit et al examined for body position for reactivation of parasympathetic nerves after exercise. They showed low heart rate reserve(HRR) values in the standing position and did not find a difference between supine posture and lying down with legs up posture[6]. In addition to these correlations, this study looked up related data and articles to study how the heart rate and respiratory rate changes when the posture changes during the break, but found a lack of relevant basic data. Unlike previous papers, this study aims to include resting posture to help alleviate breathing difficulties in order to provide basic data for clinical application to patients with difficulty breathing by setting a resting posture and dividing it into various postures even after sitting. This study aims to measure the respiratory rate and heart rate in each recovery posture in 21 healthy adult males, when they were in a standing posture, RPB, USP, FSP, supine posture after 5 minutes of fast walking in a treadmill, and to determine whether there is a significant difference in respiration recovery rate by posture.

2. Materials and Methods

2.1. *Subject*

Adult male students with a healthy, sitting posture routine who were not currently suffering from respiratory disease participated in the experiment and the experiment purpose and method were explained without setting the blinds. Participants who have indicated intention to participate were selected and given written consent. The general characteristics of the subjects are shown in Table 1. Twenty-one people are in a group, all applying five different protocols. Heart rate peak was calculated using maximum heart rate formula and target heart was set through this.

Table 1. General characteristics (n=21)

Gender	Male(n=21)
Age (years)	21.38±1.93
Height (cm)	174.33±5.21
Weight (kg)	70±11.63

Values indicate mean ± standard deviation

Figure 1. CPX TEST

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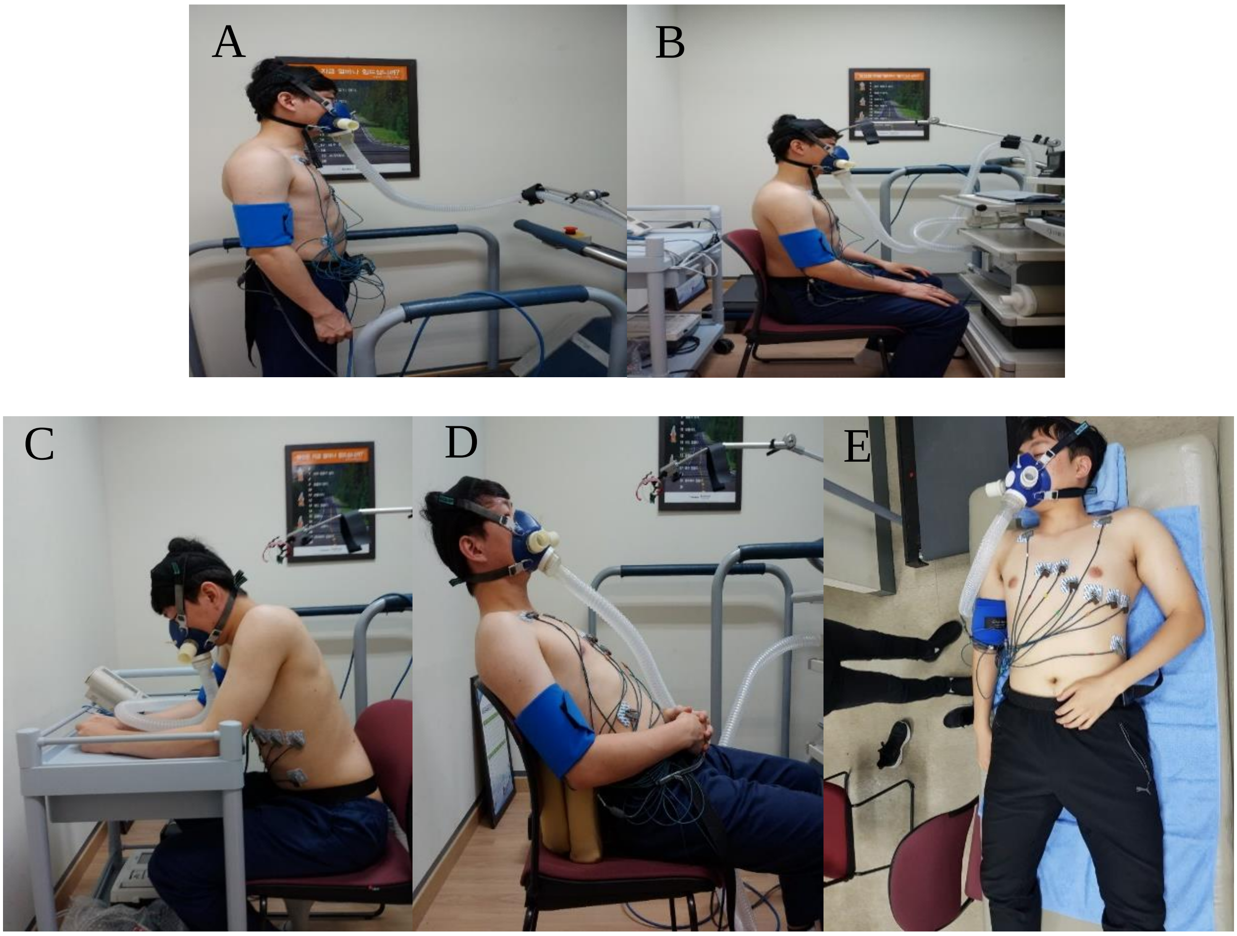

Figure 2. Recovery position

A: Upright standing position; B: Upright sitting position; C: Forward sitting ;

D: Reclining position with the chair back ; E: supine position

2.2. *Measurement*

CPX test was used as the experimental machine. Moreover, these machines were used to measure HR and RR during exercise and recovery after exercise in figure 1. CPX test is a comprehensive assessment of cardiac, lung, and muscle movements using an electrocardiogram and aerobic gas analysis during exercise load using a treadmill or ergometer. Subjects were instructed not to exercise vigorously but to rest the night before the experiment. The maximum power and the highest HR made an HRR measurement on the first day, followed by an HRR measurement for four visits. Participants measured all different recovery protocols five times in figure 2. Participants placed their feet on the footrests with their legs bent at about 90 degrees in a straight position. This keeps most of their weight on their seat. Their arms were on thighs. Participants face up flat on the bed next to the treadmill in a supine position. Stable heart rate was obtained in the same posture, similar to the recovery protocol. Participants each treadmill for 5 to 10 minutes with 70% strength of the maximum HR value. Although the HR response varies significantly between individuals, the 80% levels of maximum HR load is below the lactate threshold and mainly avoids anaerobic behavior but causes significant cardiac autonomic responses. Participants follow the recovery period for 5 minutes after exercise, depending on recovery conditions. Participants can change body posture within 5 seconds. (However, they do not deviate significantly from the specified posture.)

2.3. *Assessment of post-exercise*

2.3.1. Heart rate recovery

ECG and respiratory rate were measured by Exercise stress test and Gas analyzer. HRR was assessed for 5 minutes after submaximal treadmill exercise in the following manner: (1) Difference between peak HR at the end of the workout and HR recorded after 60 seconds of recovery (HR60), (2) the time value of the decay constant was obtained by HRR for 5 minutes after the exercise, fitted to the first-order exponential curve.

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2.4. *Statistical analysis*

It was investigated via Two-way repeated ANOVA. All statistical analyzes were performed using SPSS 22. Version. Once significant interactions have been identified, posttest of Bonferroni is used to further explain the recovery location and main effects of activity level.

3. Results & Discussion

The difference in HRR and RR values according to the recovery posture in 21 male students from S university in Chungnam city with a normal sitting posture was compared.

3.1. *HR-Result*

It was found that there was a difference in HRR according to posture as a result of experiments on tvalues in all recovery postures(p<.05). As a result of two-way repeated ANOVA, unit matrix test of Mauchly showed a multivariate test as there was a difference in significance level. In multivariate tests with time dependent effects, Wilks's lambda values showed significant differences(p<.05). In postural results, standing posture was not significantly different from USP and RPB(p>.05), but was significantly different from FSP and supine posture(p<.05). USP was not significantly different from standing posture, FSP and RPB(p>.05), but was significantly different from supine posture(p<.05). FSP was not significantly different from USP, RPB and supine posture(p>.05), was significantly different from standing posture(p<.05). RPB was not significantly different from standing posture, USP, FSP(p>.05) and was significantly different from supine posture(p<.05). supine posture was not significantly different from FSP(p>.05) and was significantly different from standing posture and USP, RPB(p<.05). There was a significant difference in the results with time(p<.05) and there was no significant difference only between 90 seconds later(V3), 180 seconds later (V4) (p>.05) in Table 2.

Table 2. The change value of heart rate in each posture over time.

Time(s) / Posture	0s	30s	90s	180s	300s		Time X Posture	Time	Posture
Stand	139.19±1.40	124.42±9.23	104.19±7.37	97.47±6.59	95.38±8.63	F	5.130*	973.791 *	62.350*
Upright. Sit	139.19±1.40	119.85±13.34	94.28±11.75	94.28±11.48	92.38±10.58				
`Ant. Sit	139.19±1.40	119.23±10.37	88.81±9.54	85.90±8.85	85.52±8.34				
Post. Sit	139.19±1.40	123.81±10.08	92.61±9.47	92.33±9.06	90.85±8.65				
Supine	139.19±1.40	113.71±14.80	82.19±8.66	82.14±8.87	78.76±6.37				

* p <.05

3.2. *RR-Result*

RR measurements showed significant differences at all times. (p<.05) However, all the postures were not statistically significant according to the posture comparison(p>.05). The comparison of posture versus time shows that there is no correlation between all recovery postures(p>.05) in table 3

Table 3. The change value of respiration rate in each posture over time.

Time(s) / Posture	0s	60s	120s	180s	300s		Time X Posture	Time	Posture
Stand	26.84±5.67	22.25±4.62	21.36±4.88	20.36±4.85	19.33±4.06	F	1.442	105.807^{b*}	3660
Upright. Sit	26.92±4.81	21.67±4.94	20.33±5.33	19.11±5.14	17.83±4.93				
`Ant. Sit	29.28±6.89	23.26±4.33	20.82±3.38	19.50±4.34	18.84±3.68				
Post. Sit	28.42±5.53	23.70±4.46	22.45±3.63	20.53±2.55	19.86±3.72				
Supine	30.25±6.28	24.34±4.62	20.73±4.90	20.26±4.8	18.75±5.18				

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* p <.05

3.3. *Discussion*

The aims of this study is to find the appropriate recovery posture by comparing the effects on HR and RR through rest after 5 recovery postures (standing posture, sitting back straight at 90 degrees posture, lying down on trunk and placing arms on the table posture, sitting back at 120 degrees posture, supine posture) for 5 minutes after the exercise up to the target heat rate (Maximum heart rate 70%). Supine posture and FSP have been shown to promote more HRR than other postures among them. Explaining the mechanism of HRR regulation, post exercise HR reduction is due to a sudden increase in parasympathetic activity due to interruption of exercise due to loss of central nervous command (The brain commands to stop exercising)[11]. Complex control mechanisms that regulate the cardiovascular system of rest and recovery include central nervous system, pressure reflex and muscle metabolic reflex control[12]. Arterial pressure is said to decrease dramatically when dynamic movement stops and static recovery occurs in a sitting position with the back straight[13]. Restorative posture after aerobic exercise can affect the interaction between these control mechanisms and lead to HRR regulation. In addition to endurance training, intense exercise training has proven to increase HRR[14]. Darr et al found that post workout HRR largely depends on the level of cardiopulmonary fitness of the individual and the intensity of the work out[15]. In the heart rate statistic, HR decreased in order of standing posture, sitting at 90 degrees posture, sitting backwards posture, leaning forward posture and lying down posture, therefore, supine posture showed the highest level of decline. Kubota et al said that lean position of the upper body in the Flowler position(sitting position leaning back 30 ° between upper and lower body) activates respiratory function and increased vagus nerve activity[16]. In maximal exercise in the standing posture, arterial systolic blood pressure and HR were higher than in the supine position. This result is consistent with many previous reports of higher blood pressure and heart rate in the standing posture compared to the supine posture. Takahashi reported that higher plasma noradrenalin and angiotensin II were observed in the standing posture[7]. And neurological and hormonal effects have been shown to increase blood pressure and HR. In general, the cardiac output in the standing posture is lower than the cardiac output in the supine posture. The effect of posture on cardiac output during exercise has been reported in some studies. The cardiac output in the supine position was significantly higher than in the sitting back straight position in the study by Mizumi et al. This is due to an increase in venous return in the supine position[17]. In the respiratory rate statistics, the order of heart rate was slightly different in the order of standing posture, leaning backward posture, sitting at 90 degrees posture, leaning forward posture and supine posture. All subjects showed slow recovery compared to lying down posture with their back straight posture, regardless of their level of physical activity. Similar results were shown by Takahashi et al. and Buchheit et al[6,7] When the three recovery postures of standing posture, sitting posture group and lying posture were classified into three categories, HRV and RRVs showed significant differences over time. In healthy adults, the lung capacity is reduced by 7.5±5.7% in the supine posture rather than in the standing posture[18] and in the case of measuring breathing according to abdominal muscle activity, the lung capacity was significantly increased in the sitting position rather than the supine position[19]. When comparing the sitting posture groups, FSP of both HR and RR showed a high decrease level. Before starting the experiment, the study anticipated that siting backward posture, similar to supine posture, would give the best results among the sitting posture groups, but actual experimental results showed that the forward leaning position showed the best HRR impact in the sitting position group comparison. Kisner and Collby said that the posture of leaning at 45 degrees is a position where the abdominal muscles are relaxed to induce sufficient inspiration[10]. Based on these findings, Matinmaki et al reported that changing from supine posture to sitting posture and standing posture decreased vagus nerve activity and increased sympathetic nervous system activity[20]. Previous study said that if similar changes occur in the two components of the autonomic nervous system after exercise, it can be seen that vagus nerve activity exhibits a faster decrease in HR at higher lying postures, compared with USP[6]. There are several other work related to this study was also explored during the execution [21-31]. Prior papers warned of orthostatic hypotension, but three subjects in the athlete group developed orthostatic hypotension. In this experiment, as the experiment was conducted only for general students who had a generalized sedentary as in the previous paper and as preventive education was conducted before the start of the experiment to prevent orthostatic hypotension, no orthostatic hypotension patients occurred in this study. The main limitation of this study is that chair and table may be practically inconvenient to the subject because the same chair and table height are used without considering the chair height setting used for the recovery posture. And it is difficult to generalize the results of the experiment for all ages since ages are limited to

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the mid-20s. The lack of consideration of individual exercise level and cardiopulmonary ability is also included in the limitations of this study and further studies need to be supplemented with these limitations.

4. Conclusion

This study was conducted to compare the effects on HRR through HRR300 of 5 recovery postures (standing posture, sitting back straight at 90 degrees posture, lying down on trunk and placing arms on the table posture, sitting backwards posture, supine posture). All subjects were tested five times for a total of four weeks with changing resting postures and the following conclusions were obtained by comparing the difference in heart rate and respiratory rate of resting posture taken for minutes. After comparing the HRV in the sitting posture, the resting posture, after exercise, there was no significant difference in standing posture, leaning forward posture and leaning backward posture, but there was a significant difference in supine posture ($p<0.05$). Comparing the 0s, 30s, 90s, 180s and 300s values of each resting postures, there was no significant difference between the 90s and 180s results, but there was a significant difference in the HRV differences with each other time ($p<0.05$). There was no significant difference between postures in respiratory rate statistics, but there was a significant difference between times. In the order of standing posture, RPB, USP, FSP, supine posture, supine posture showed the highest respiratory rate reduction rate among the five postures. The leaning forward posture showed the highest rate of respiration in the three sitting posture groups. This led to the conclusion that supine posture and leaning forward posture had the most positive effect on HRR. As a result of this study, the posture and time correlate with each other in HR as the difference of HRR values appeared over time. In the case of RR, there was no correlation because there was no difference in posture. Clinically, resting posture may suggest that the recovered heart rate and respiratory rate are different. The results of this study are expected to be used as basic data for further studies considering rest posture, duration of intervention and age.

5. References

1. Schraufnagel DE, Blasi F, Kraft M, Gaga M, Finn P, Rabe KF. An official American Thoracic Society and European Respiratory Society policy statement: disparities in respiratory health. Eur Respir J. 2013 Oct;42(4):906-15. doi: 10.1183/09031936.00062113.
2. Alemaryeen A, Noghanian S, Fazel-Rezai R. Respiratory rate measurements via Doppler radar for health monitoring applications. Conf Proc IEEE Eng Med Biol Soc. 2017 Jul;2017:829-832. doi: 10.1109/EMBC.2017.8036952.
3. De Troyer A, Boriek AM Mechanics of the respiratory muscles. 2011 Compr Physiol 1:1273–1300
4. Shi ZH, Jonkman A, de Vries H, Jansen D, Ottenheijm C, Girbes A, Spoelstra-de Man A, Zhou JX, Brochard L, Heunks L. Expiratory muscle dysfunction in critically ill patients: towards improved understanding. Intensive Care Med. 2019 Aug;45(8):1061-1071. doi: 10.1007/s00134-019-05664-4. Epub 2019 Jun 24.
5. Lazovic-Popovic B, Zlatkovic-Svenda M, Durmic T, Djelic M, Djordjevic Saranovic S, Zugic V. Superior lung capacity in swimmers: Some questions, more answers Rev Port Pneumol (2006). 2016 May-Jun;22(3):151-6. doi: 10.1016/j.rppnen.2015.11.003. Epub 2016 Feb 22.
6. Buchheit M, Al Haddad H, Laursen PB, Ahmaidi S Effect of body posture on postexercise parasympathetic reactivation in men. Exp Physiol. 2009 Jul;94(7):795-804. doi: 10.1113/expphysiol.2009.048041. Epub 2009 Apr 24.
7. Takahashi T, Okada A, Saitoh T, Hayano J, Miyamoto Y. Difference in human cardiovascular response between upright and supine recovery from upright cycle exercise. Eur J Appl Physiol. 2000 Feb;81(3):233-9.
8. Perini R, Orizio C, Gamba A, Veicsteinas A. Kinetics of heart rate and catecholamines during exercise in humans. The effect of heart denervation. Eur J Appl Physiol Occup Physiol. 1993;66(6):500-6.
9. Migliore A. Improving dyspnea management in three adults with chronic obstructive pulmonary disease. Am J Occup Ther. 2004 Nov-Dec;58(6):639-46.
10. Kisner C, Collby LA. Therapeutic exercise: foundations and techniques(5th ed.). Philadelphia. 2002, 852-3
11. O'Leary DS. Autonomic mechanisms of muscle metaboreflex control of heart rate. J Appl Physiol (1985). 1993 Apr;74(4):1748-54.
12. Carter JB, Banister EW, Blaber AP. Effect of endurance exercise on autonomic control of heart rate. Sports Med. 2003;33(1):33-46
13. Carter R 3rd, Watenpaugh DE, Wasmund WL, Wasmund SL, Smith ML. Muscle pump and central command during recovery from exercise in humans. J Appl Physiol (1985). 1999 Oct;87(4):1463-9.
14. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF, Oja P. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003 Aug;35(8):1381-95.
15. Darr KC, Bassett DR, Morgan BJ, Thomas DP. Effects of age and training status on heart rate recovery after peak exercise. Am J Physiol. 1988 Feb;254(2 Pt 2):H340-3.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 1, 2021, Pages. 937 - 943
Received 15 December 2020; Accepted 05 January 2021.

16. Kubota S1, Endo Y, Kubota M. Effect of upper torso inclination in Fowler's position on autonomic cardiovascular re gulation. J Physiol Sci. 2013 Sep;63(5):369-76. doi: 10.1007/s12576-013-0273-8. Epub 2013 Jul 2.
17. Mizumi S, Goda A, Takeuchi K, Kikuchi H, Inami T, Soejima K, Satoh T. Effects of body position during cardiopul monary exercise testing with right heart catheterization. Physiol Rep. 2018 Dec;6(23):e13945. doi: 10.14814/phy2.1 3945..
18. Allen SM, Hunt B, Green M. Fall in vital capacity with posture. Br J Dis Chest. 1985 Jul;79(3):267-71
19. Kera T, Maruyama H. The effect of posture on respiratory activity of the abdominal muscles. J Physiol Anthropol A ppl Human Sci. 2005 Jul;24(4):259-65.
20. Martinmäki K, Rusko H, Kooistra L, Kettunen J, Saalasti S. Intraindividual validation of heart rate variability indexe s to measure vagal effects on hearts. Am J Physiol Heart Circ Physiol. 2006 Feb;290(2):H640-7. Epub 2005 Sep 19.
21. Bhoi, A. K., Sherpa, K. S., & Khandelwal, B. (2018). Arrhythmia and ischemia classification and clustering using Q RS-ST-T (QT) analysis of electrocardiogram. Cluster Computing, 21(1), 1033-1044.
22. Reddy, A. V., Krishna, C. P., & Mallick, P. K. (2019). An image classification framework exploring the capabilities of extreme learning machines and artificial bee colony. Neural Computing and Applications, 1-21.
23. Mallick, P. K., Mishra, D., Patnaik, S., & Shaw, K. (2016). A semi-supervised rough set and random forest approach for pattern classification of gene expression data. International Journal of Reasoning-based Intelligent Systems, 8(3-4), 155-167.
24. Mallick, P. K., Mohanty, B. P., & Jha, S. A novel approach using. Supervised and Unsupervised Learning" to preve nt the adequacy of Intrusion Detection Systems", International Journal of Engineering & Technology, 7(3.34), 474-4 79.
25. Satapathy, S. K., Mishra, S., Sundeep, R. S., Teja, U. S. R., Mallick, P. K., Shruti, M., & Shravya, K. (2019). Deep l earning based image recognition for vehicle number information. International Journal of Innovative Technology an d Exploring Engineering, 8, 52-55.
26. Mallick, P. K., Kar, S. K., Mohanty, M. N., & Kumar, S. S. (2015). Use of histogram approach in color band detecti on for electrical passive component. International Journal of Applied Engineering Research, 10(44), 31446-31450.
27. Mishra, S., Mallick, P. K., Tripathy, H. K., Bhoi, A. K., & González-Briones, A. (2020). Performance Evaluation of a Proposed Machine Learning Model for Chronic Disease Datasets Using an Integrated Attribute Evaluator and an I mproved Decision Tree Classifier. Applied Sciences, 10(22), 8137.
28. Bhoi, A. K., Sherpa, K. S., & Mallick, P. K. (2014, April). A comparative analysis of neuropathic and healthy EMG signal using PSD. In 2014 International Conference on Communication and Signal Processing (pp. 1375-1379). IEE E.
29. Bhoi, A. K., Sherpa, K. S., & Khandelwal, B. (2015). Multidimensional analytical study of heart sounds: A review. I nternational Journal Bioautomation, 19(3), 351-376.
30. Bhoi, A. K., & Sherpa, K. S. (2014). QRS Complex Detection and Analysis of Cardiovascular Abnormalities: A Rev iew. International Journal Bioautomation, 18(3), 181-194.
31. Bhoi, A. K., Sherpa, K. S., & Khandelwal, B. (2018). Ischemia and Arrhythmia Classification Using Time-Frequenc y Domain Features of QRS Complex. Procedia computer science, 132, 606-613.