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ORIGINAL ARTICLE

NeXus-4 Physiological parameters in a choral singer – preliminary results

Ross G. Cooper[1], Usama ALAlami[2], Robert Ashford[3], Peter Johnson[4]

[1] *Department of Health Sciences, Faculty of Health, Birmingham City University, UK*
[2] *College of Arts & Sciences, Department of Natural Science & Public Health, UAE*
[3] *Faculty of Health, Graduate School, Birmingham City University, Birmingham, UK*
[4] *Birmingham Conservatoire, Birmingham City University, UK*

Abstract

The study determined the physiological changes of Heart Rate (HR) and Blood-Volume-Pressure (BVP) as bar note increase in male a singer vs. time (sec.) over a total recording time of a 6 min 28 sec pre-rehearsed piece: *Von den Striken meinen Sünden* ('From the Shackles of my Sins'), St. John's Passion No. 7 VS, p. 33j. The HR baseline recording of (105.94±14.27 bpm) and BVP (8.36 ± 2.42 mV) were higher than known basal readings in a 70-kg man. Possibly the expectation of the commencement of the singing episode predominated. Block changes II – bars 27, 28 & 37 (mostly sung well); II – bars 39, 47, 48 & 57 (some errors); III – bars 70 & 76 (shortness of breath); and IV – at 335 sec. from the start of the piano passage to the end and applause at 340 sec]. In block I, presumably the limbic and medullary pathways due to singing well, lowered HR to 68.98±14.93 bpm at bar 28. In block I, the BVP was significantly ($p<0.05$) raised, suggesting a physiologically-mediated muscle contraction of the diaphragm and intercostal muscles requiring a greater blood flow for the delivery of oxygen as a part of mitochondrial ATP generation. In block II, the errors in singing resulted in HR recordings that did not differ from each other. In block III, the singer was short of breath with a drop of HR to 98.20±26.42 bpm (bar 76), suggesting a time-point just prior to the commencement of inspiration (or the start of peak inspiratory capacity). In block IV, the HR dropped from the end of the piano passage (120.03±16.94 bpm vs. baseline of 105.94±14.27 bpm) until the applause (92.03±14.01 bpm). An expert singer may be trained to cope with stress from singing a difficult piece of music.

Keywords

Nexus, occupation, physiology, singing, stress

INTRODUCTION

Stress is a multi-faceted physiological phenomenon that influences one's performance and indeed functionality within a workplace environment. Music can strengthen relationships between family members by attenuating stress in dealing with children with difficulties [1]. Singing difficulties can sometimes be caused by emotional stress or from over-strain of vocal cords among choral singers [2]. Adrenaline release and enhanced skeletal muscle contractility and cardiac output increasing to supply the muscle cells with adequate oxygen, are important physiological responses to exercise, e.g. singing [3]. We wished to investigate the responses thereof using a novel physiological methodology of two selected physiological parameters: heart rate (HR) (bpm) and blood-volume-pressure (BVP) changes (mV). The current investigation formed an extension of previously published pre-liminary findings [4-6]. The aim of the current case study was to investigate the physiological changes in HR and BVP as bar note increase in male singer vs. time (sec.) over a total recording time of 6 min 28 sec (Bach: Von den Striken meinen Sünden ('From the Shackles of my Sins'), St. John's Passion No. 7 VS, p. 33). In cases where recording were taken over a timed range the physiological parameters were calculated at the completion of the time slot.

Corresponding author: Usama ALAlami, College of Arts & Sciences, Department of Natural Science & Public Health, UAE
E-mail: usama.alalami@zu.ac.ae

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MATERIALS AND METHODS

Choral singing and recording

A male semi-professional choral singer volunteered to perform a pre-rehearsed piece on Bach. Throughout the session, timings in minutes and seconds were obtained from video recordings. The precision of the timings was ideally within 1 msec. intervals, despite most events in the current investigation exceeding 2 sec. The piece was sung twice; and timings of the second performances beginning at stage entry were recorded in brackets and italicized. Following the performance the singer was given the opportunity to discuss his progress and the various points of interest in a semi-structured interview. The pianist gave a commentary of the performance. A score analysis and performance was undertaken and this was correlated with physiological data.

NeXus-4

A Bluetooth (Linksys USB Adaptor Class 1) with a Toshiba laptop operating with a Window-XP environment was employed. Data recording from the NeXus-4 were limited to heart rate (HR) (bpm) and blood-volume-pressure (BVP) changes (mV). THE BVP finger sensor measured the relative blood flow via an infra-red light detection system. The NX1-EXGR-Snap cable enabled HR detection through ECG (electrocardiogram) signals. The ECG leads were positioned on the torso and wrists via disposable snap electrodes (Bio-logic Systems Corp., Crawley, UK), and earthed. Comparisons were made with a 5-min baseline trace. The following limitations were noted: some variation due to hand and trunk movement; and non-separation of pieces; a baseline recording immediately preceding the first performances, but not the others. The HR and BVP were plotted graphically and data exported into MS Excel 2003 for analysis. It was anticipated that the heights of the peaks from the plotted relative blood flow correlated with the level of vasodilatation/vasoconstriction; and the peak of blood flow was matched by a peak in the BVP sensor peak. Peak and trough corresponded to inspiration and expiration, respectively. All recordings were recorded every 1/100th sec.

Statistical analysis and ethics

Data was analysed using transposed data in MS Excel 2003 (Microsoft Office 2003) in a Students' t-test by comparison with baseline values and p<0.05 was taken as significant (Table 1). Where differences between adjacent bars were sought, the same test was performed. A single volunteer case study was performed by consent of the singer. Dr. U ALAlami gained consent thereof.

RESULTS AND DISCUSSION

Performance and commentary

During the initial performance, the singer was competent but not outstanding. He was musical rather dull. There was a slight feeling, perhaps, of boredom, or of duty done. Technical problems were mostly well-managed, although there were some criticisms concerning concept and interpretation. The pianist was sight-reading and made a number of serious mistakes at first play through; these are likely to have disturbed the singer's performance. The second piece was more musically interesting, despite the tempo being too fast. During the course of the performance the singer may have 'given up' (hence showing some signs of relaxation) or alternatively showed signs of frustration. During the interview, the singer indicated that he knew the piece but has never performed it in public. He said he has experience of other oratorio in public performance, however. There was no prior rehearsal and the pianist was sight-reading. The singer had a 10 min warm-up period in the absence of the pianist. The singer said he was mostly unaware of attached electrodes and leads, and they certainly did not interfere with his performance whatsoever. The singer said he felt an emotional rush at start of Bach, but only once the piano began playing. He felt personally that he had sung an average performance and, at the start, felt a little croaky and was trying to find a "place" for his voice. He said that he became more settled, "…halfway through the Bach". Overall he was comfortable and did not feel aggravated in any way. On reflection, he needed to think more about the music not his voice, and his tempo was rather slow. Some points to note were: the singer volunteered bars 25 and 87 (mental preparation for leap to E flat during rest, from c. 85) and 98 ditto; during bar 48 there was a D to A leap (prompted by the pianist); he preferred bar 90; and bar 70 was satisfactory.

NeXus-4 data analysis

All data analysed had low standard deviations suggesting that the quantity of data recorded (100 rec./sec.) and the transmission thereof via Bluetooth was devoid of real errors and/or interference.

Table 1. HR and BVP changes by bar during performance of Bach

Recording	Time (sec) HR (bpm)	Physiological recording BVP (mV)	Physiological recording
Baseline	30	105.94±14.27	8.36 ± 2.42
Bar 1-piano starts	38	127.03±24.05*	7.48±1.52
Bar 9- singer starts	58	129.19±23.24*	6.24± 1.16
Bar 17-piano interlude	78	124.79±22.90*	7.31±1.85
Bar 21-singer resumes	87	118.06±26.44*	9.47±2.07
Bars 23-piano brief interlude	93	133.21±5.24*	9.62±2.38
Bar 25- minor error in voice	97	103.26±26.95	13.16±1.50*
Bars 27-sung very confidently	100	80.84±33.42 *	9.87±1.54*
Bar 28-minor error in voice	105	68.98±14.93 *	9.76±1.13*
Bar 37-potentially tricky, sung well	129	85.28±25.30*	9.46±1.22
Bar 39-piano interlude	134	118.55±13.96*	8.97±1.54
Bar 47-singer resumes	154	115.62±21.58*	9.98±1.54*
Bar 48-semiquavers laboured	158	116.29±3.43 *	10.47±1.00*
Bar 57-error first C nat.	180	113.63±20.92	10.40±1.98*
Bars 58- sense of 'expressive' compensation very secure and musical	182	126.53±4.21*	11.38±1.12*
Bar 63-error F# – G nat.	196	118.31±19.88*	10.73±1.58*
Bar 66-piano interlude	204	129.46±4.23*	10.63±1.75*
Bar 70-singer resumes	215	130.22±21.78*	11.31±1.53*
Bar 76-singer short of breath	232	98.20±26.42	10.23±1.36*
Bar 81-piano interlude	244	104.62±26.48	10.61±1.19*
Bar 85-singer resumes	254	129.46±7.78*	11.18±1.81*
Bar 88-singer exposed to high note	264	101.41±22.54	10.63±1.66*
Bar 98-technically difficult passage, effectively managed	291	123.60±21.68*	10.85±1.47*
Bars 106-very confident, 'in the groove'	311	129.48±19.57*	10.96±1.26*
Piano passage to end of piece	335	120.03±16.94*	11.27±1.18*
Applause	340	92.03±14.01	10.89±1.29*
Putting down music, 'out of role'.	346	102.55±6.65	10.75±1.16*

* p<0.05 vs. baseline, Students't-test, Excel 2003, Microsoft Office 2003

The HR baseline recording of (105.94 ± 14.27 bpm) and associated BVP (8.36 ± 2.42 mV) were raised above known basal readings in a 70-kg man due to, we suggest, the expectation of the commencement of the singing episode. This we proposed was a linked error as the expectation of start would have changed physiological, medulla-mediated changes in HR and blood flow. The HR during the piano interludes (bars 17, 39, 66 & 81) were significantly (p<0.05) elevated except at bar 81 when the HR did not differ significantly from baseline. In the absence of respiratory data, we were unable to make associations with these changes. We therefore evaluated blocks of changes [I – bars 27, 28 & 37 (mostly sung well); II – bars 39, 47, 48 & 57 (some errors); III – bars 70 & 76 (shortness of breath); and IV – at 335 sec. from the start at the piano passage to the end and applause at 340 sec. During block I presumably the limbic and medullary pathways as a consequence of singing well lowered HR to 68.98 ± 14.93 bpm at bar 28. In block I the BVP was significantly (p<0.05) raised suggesting a physiologically- mediated muscle contraction of the diaphragm and intercostal muscles requiring a greater blood flow for the delivery of oxygen as a part of mitochondrial ATP generation. In block II the errors in singing resulted in HR recordings that did not differ from each other with a range from 113.63 ± 20.92 (bar 57) to 118.55 ± 13.96 (bar 39). A similar mechanism of extra blood flow requirements to the muscles in block II was deduced as similar in block I. Block III saw the singer short of breath with a drop of HR to 98.20±26.42 bpm (bar 76) suggesting a time- point just prior to the commencement of inspiration (or the start of peak inspiratory capacity). The BVP at bar 70 and 76 were significantly ($p<0.05$) elevated by comparison with the baseline value. In block IV we expected the HR to drop from the end of the piano passage (120.03±16.94 bpm vs. baseline of 105.94±14.27 bpm) until the applause (92.03±14.01 bpm) which was not significantly different from the baseline. In block IV BVP still remained significantly ($p<0.05$) elevated by comparison with baseline and both values at piano end and applause did not differ significantly from each other. We suggest that the dynamics encompassed in muscle contraction require a period of settling and normalising in terms of oxygen delivery and glycogen storage such that a state of rest would be achieved.

CONCLUSION

From an occupational perspective, the performance of a difficult piece by a choral singer may require much motivation with associated training of inspiratory/expiratory capacities and trunk muscular-aided contractility and articulation. Lifestyle changes attenuating stress may be required. An expert singer may be trained to cope with stress whilst singing a difficult piece of music. To improve the interpretation of the results, we suggested that respiration data and blood analyses could possibly be used in future investigations to back up the current findings.

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