The Effects of Sex Steroid Hormones on Singer's Pitch Control

Filipa M. B. Lã[1], Johan Sundberg[2], David M. Howard[3], Pedro Sá-Couto[4], Adelaide Freitas[4]

1. Department of Communication and Arts, University of Aveiro, INET-MD, Portugal
2. Department of Speech, Music and Hearing, School of Computer Science and Communication, KTH, Stockholm, Sweden
3. Electronics Department, University of York, UK
4. Department of Mathematics and Center for Research and Development in Mathematics and Applications (CIDMA), University of Aveiro, Portugal
filipa.la@ua.pt

Abstract

Intonation accuracy is a prerequisite for quality in vocal performance. Difficulties with intonation have been reported to be associated with the menstrual cycle. A double blind randomized placebo controlled trial was carried out to assess the effects of the menstrual cycle and the use on an oral contraceptive pill (OCP) on singer's pitch control. An ascending octave starting on pitch F4 was recorded for three phases of the menstrual cycle, during both placebo and OCP conditions, to determine intonation accuracy in terms of octave size deviation from pure intonation. Results revealed significant differences in interval size during OCP use, suggesting complex interactions between hormonal milieu and pitch control.

Key-words: Menstrual cycle; oral contraceptive pill; intonation accuracy; singing performance.

Introduction

In the past, Eastern European Opera Houses were concerned with the consequences of the effects of the menstrual cycle on vocal health and performance quality of their female opera singers. Thus, singers' contracts used to include three "respect days", during which, if a singer was proven to be vocally affected by the menstrual cycle, vocal performance could be refrained (Brodnitz, 1971). Nowadays, "respect days" seem no longer to exist, and the extent to which sex steroid hormonal variations affect the singer's performance quality is still under investigation (Sataloff, Emerich & Hoover, 1997; Abitbol & Abitbol, 2000). On the one hand, there are studies which have found possible explanations for vocal symptoms associated with the menstrual cycle, such as hoarseness, vocal fatigue, and decreased vocal range (Frable, 1961; Perelló &

Comas, 1959; Isenberg, Brown & Rothman, 1983; Abramson *et al.,* 1984; Higgins & Saxman, 1989; Abitbol et al. 1999; Abitbol & Abitbol, 2000; Amir & Biron-Shental, 2004; Lã, Ledger, Davidson, Howard & Jones, 2007; Lã, Howard, Ledger, Davidson & Jones, 2009). On the other hand, however, there are other symptoms equally affecting the quality of the singer's performance which have not been yet understood. This is the case of reported difficulties in intonation accuracy during the menstrual cycle.

Results of previous studies have suggested that perceptual skills, neural functioning, fine motor movement and sensory thresholds might change in response to continuous hormonal variations (Hampson & Kimura, 1988; Sanders & Wenmoth, 1998; Saucier & Kimura, 1998; Al-Mana, Ceranic, Djahanbakhc & Luxon, 2010). Singing in tune involves particularly three of the above mechanisms, simultaneously coordinated: (1) fine motor control of different muscles for pre-phonatory tuning, such as laryngeal, oropharyngeal and respiratory muscles (Wyke, 1974); (2) perceptual skills, namely auditory feedback, to match the planned pitch and to make adjustments in pitch production (Burnet, Senner & Larson, 1997); and (3) kinaesthetic feedback, based on neuromuscular memory, to allow constant laryngeal adjustments in response to pre-planning and auditory feedback (Schultz-Coulon, 1978; Mürbe et al., 2002, 2004).

This study aims to test the hypothesis that difficulties in intonation accuracy can be observed during phases of the menstrual cycle. Because previous studies have found positive effects of OCP use on the periodicity of vocal fold vibration (Amir et al., 2004; Lã et al., 2009), an additional hypothesis to test is that these difficulties are improved when using an oral contraceptive pill (OCP).

Method

Study design

A double-blind randomised placebo controlled trial was carried out with 9 singers, over a period of 6 consecutive months. This specific study design was chosen so that both researchers and participants were unaware of the condition they were in (i.e. placebo or OCP), and thus their expectations could not affect

the outcomes (Jadad, 1998). Ethical approval was obtained from the South Sheffield Research Ethics Committee.

Participants

Participants were all healthy volunteers, non-smokers, had regular menstrual cycles (raging from 28 to 30 days), and never had been or wished to be pregnant at the time of the study. They were semi-professional western classically trained singers (mean age = 23.10 years, SD = 2.183; range = 21 to 27 years old), studying at several music colleges in the U.K. Previous to the study, participants had an individual medical examination with a Professor in Gynaecology and Obstetrics, to assess the participant's suitability for the experiment. All were suitable to use a combined monophasic OCP which contained 30μg of ethinylestradiol and 3 mg of drospirenone. This particular OCP was chosen as it contains low-dosages of hormones, and is thus expected to cause fewer side effects and good cycle control (Huber et al. 2000; Foidart, 2000). Identical packs of OCP and matched placebo were given in a randomised order to each participant, so that both pills were taken during 6 consecutive months, 3 for each condition (i.e. placebo or OCP).

Data collection

Electrolaryngograph and audio signals were recorded for each participant, at three phases of the cycle (i.e. the menstrual phase, and follicular and luteal phases), for the third month of placebo and the third month of OCP use. Singers were asked to perform a vocal exercise that consisted of an ascending octave, followed by a descending major triad using the vowel [a]. This particular exercise was chosen because: (i) it is commonly used as a warming-up exercise, thus unfamiliarity with the vocal task was minimised; (ii) it contains an ascending octave interval aiming at a sustained note at the top, allowing reliable fundamental frequency (F0) extraction and facilitating accurate measurement of interval size; and (iii) because it is reasonable to assume that a large interval (i.e. an octave), would more clearly expose potential intonation difficulties than a narrower interval. Although this exercise was performed starting at several pitches (A3 to C4), the pitch F4 was the one chosen for analysis, as the

sustained note F5 falls within a register transition, requiring exceptional vocal control (Titze, 2000).

Data analysis

The selected recorded files for each participant were analysed using the Soundswell signal workstation. The pitch tracking was carried out by means of autocorrelation (the *Corr* tool of the Soundswell software) applied to the audio or the electrolaryngograph signal (ELG), depending on what signal gave the most reliable output. Both F4 and F5 were selected for analysis, as they were long tones and reasonably stable, thus clearly represented in the F0 curves. The *Histogram* tool of the Soundswell signal workstation was used to determine the mean F0 values of these two tones. The values obtained were then transferred to an excel file where the interval between them was calculated in semitones. As some participants tended to consistently produce wide or narrow octaves, the signed deviation from pure octave (SgD), was calculated in semitones. It represents how sharp or flat the octave was as compared to the frequency ratio of 2:1.

Due to the small sample size and since each participant was evaluated under all conditions (repeated-measures design), both median and interquartile range were considered, and non-parametric k-related samples hypothesis test based on rank comparisons (Friedman and Wilcoxon's Signed Rank tests) were calculated. The level of significance used was $\alpha = 0.05$. A Friedman test was used to examine whether there was a significant difference between the three phases of the cycle within each condition (i.e. placebo or OCP). Wilcoxon's Signed Rank test was applied to test whether there were significant differences between placebo and OCP use, for each of the three phases of the cycle. Since this test involves three simultaneous comparisons, a Bonferroni correction was considered and so, these results were identified as significant when $p<0.05/3 = 0.017$. All statistical analyses were conducted using the SPSS 17.0 for Windows (SPSS Inc, Chicago, IL, USA).

RESULTS

Table 1 represents the medians and interquartile ranges for the sign deviation from pure octave (SgD). For the placebo condition, the shortest octave was sung at the luteal phase of the cycle, whereas for OCP use, the shortest octave was sung at the follicular phase. Comparing OCP and placebo conditions, OCP use showed stretched octaves for all phases in comparison with placebo use, except for the follicular phase.

F5 SgD (n=9)	Menstrual phase				Follicular phase				Luteal phase			
	Placebo		OCP		Placebo		OCP		Placebo		OCP	
	Med	IQR	Med	IQR	Med	IQR	Med	IQR	Med	IQR	Med	IQR
	0.12	0.68	0.14^{+}	0.48	0.18	0.74	-0.15^{+}	0.79	-0.09	0.48	0.03^{+}	0.96

Table 1: Summary results of the descriptive statistics (median and interquartile range) carried out for SgD during the three phases of the menstrual cycle and for the two conditions (n=9).

Table 2 shows the summary results of the statistical tests carried out. The comparison between phases of the cycle for each condition (i.e. placebo and OCP use) shows significant differences in the sign deviation from pure octave (SgD) between phases only during OCP use (Placebo: $\chi2(2) = 2.000$, $p = 0.398$; OCP: $\chi2(2) = 8.00$, $p = 0.019$). The follicular phase presented the shortest octave size when compared to the other phases (see Figure 1). Phases showed no significant differences in SgD during placebo use.

Hypothesis		Test	
H0: M=F=L	Placebo	0.398	Friedman $p<0.05^{+}$
H0: M=F=L	OCP	0.019^{+}	
H0:Placebo=OCP	M	0.426	Wilcoxon's Sign Rank $p<0.017^{\ddagger}$
	F	0.027	
	L	0.910	

Table 2: Summary results of the statistical tests carried out. A Friedman test was carried out to evaluate if there are significant statistically differences ($p<0.05$) between the three phases of the menstrual cycle within each condition (i.e. placebo or OCP), while a Wilcoxon's Sign Rank test was conducted to assess whether there are significant statistically differences ($p<0.017$) between conditions (i.e. placebo and OCP) for each phase of the menstrual cycle. SgD: Signed deviation from pure octave (in semitones); M: menstrual; F: follicular; L:Luteal.

Comparing conditions (i.e. placebo versus OCP use), no significant differences were found for any of the phases (menstrual phase: $z = -0.889$, $p = 0.426$;

follicular phase: z = -2.192, p = 0.027; luteal phase: z = -0.178, p = 0.910) (see Figure 1), thus suggesting no effects of OCP use in comparison to placebo use.

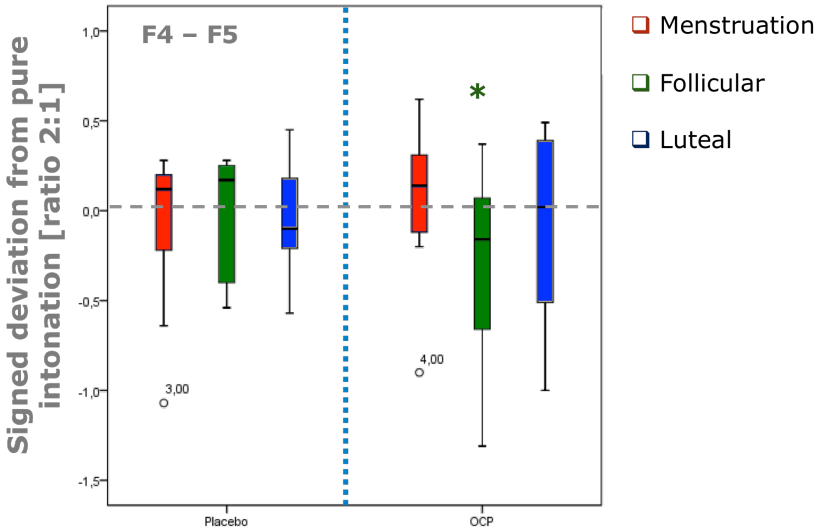

Figure 1: Signed departure from pure octave (representing how sharp or flat the octave was sung) averaged across subjects, for the three phases of the cycle during the placebo and OCP conditions. Moderate (○) outlier was found for participants 3 and 4 in the data. The dashed line represents no deviations from pure intonation.

Discussion

Taking into account singer's reports of difficulties with intonation associated with the menstrual cycle, and results of previous studies suggesting a relation between sex steroid hormonal variations and motor and perceptual skills, one would expect that significant changes in pitch control across the three phases of the cycle would occur. Variations on sex steroid hormones are larger in a natural menstrual cycle (i.e. placebo use) and these are dampened during OCP use. However, this was not found as no significant differences were observed concerning variations in intonation across the cycle during placebo use. Thus, the hypothesis that singer's intonation accuracy varies during a natural menstrual cycle should be rejected. The second hypothesis to be tested was that the dampening of the hormonal variations during OCP use would provide a better control of intonation accuracy. Once again, this was not confirmed by the results, as data showed differences in intonation between phases of the menstrual cycle only during OCP use. Singers sung a shorter octave during the follicular phase of OCP use.

One may say that the results of this study were unexpected, so that this study raised more questions and brought further discussion to the field of the endocrinology of the voice. For example, what could explain the significant differences in octave size between the three phases during OCP use but not during placebo use? And why no differences were found in SgD between placebo and OCP use for each phase of the menstrual cycle, considering that hormonal levels are significantly different (Lã et al., 2009)?

No definite answers can be provided yet. Further research is needed to understand the complex interactions underlying pitch production and control. However, based on previous evidence, one may speculate about possible explanations: results may be justified based on the fact that both F0 production and auditory feedback control are modified in response to hormonal variations. The mechanical properties of the vocal folds may change accordingly to concentrations of sex steroid hormones (Abitbol, Abitbol & Abitbol, 1999) and during the use of an OCP (Amir & Biron-Shental, 2004; Lã et al., 2007). As intonation accuracy depends on the adjustments of laryngeal muscles to correspond to the pre-planned pitch, if the mechanical properties of the vocal folds are different, the kinaesthetic neuromuscular memory will be affected and previously learnt laryngeal adjustments would no longer be efficient. Additionally, mild effects of sex steroid hormones on the function of neural/auditory control have been found during the ovarian cycle (Al-Mana et al., 2010), so that the lowered concentrations of E2/P ratio and testosterone associated with OCP use could have a negative impact on the auditory feedback mechanism necessary to allow constant laryngeal adjustments in response to pre-planning and auditory feedback.

Conclusion

Intonation accuracy is essential for an excellent vocal performance. This investigation suggests that singer's intonation accuracy during OCP use may be modified, as a result of complex interactions between sex steroid hormones and mechanisms responsible for singing in tune. The multitude of bodily responses to variations in sex steroid hormones, and the singer's trained ability to perform under non-optimal physiological conditions, may well create masking effects

which jeopardise the understanding of these complex responses. It would be thus worthwhile in the future to analyse the impacts of hormones on singers' intonation accuracy applying multiple analysis of various mechanisms that account for the underlying complexity of the endocrinology of the voice.

References

Abitbol, J. & Abitbol, P. (2000) "Endocrine disorders of the larynx". *In* A. Ferlito (Ed.) *Diseases of the Larynx*. London: ARNOLD. (pp. 311-333)

Abitbol, J. Abitbol, P. & Abitbol, B. (1999) "Sex hormones and the female voice". *Journal of Voice*, 13: 424-446.

Abitbol J, Brux J, Millot G, Masson MF, Mimoun OL, Pau H & Abitbol B (1989) "'Does a hormonal vocal cord cycle exist in women?' Study of vocal premenstrual syndrome in voice performers by videoscopy-glottography and citology on 38 women". *Journal of Voice* 3: 157-162.

Abramson, A. L., Steinberg, B. M., Gould, W. J., Bianco, E., Kennedy, R. & Stock, R. (1984). "Estrogen receptors in the human larynx: clinical study of the singing voice" *In* V. Laurence (Ed.) *Transcripts of the Thirteenth Symposium: Care of the Professional Voice*. Part II. New York: The Voice Foundation. (pp. 409-413)

Al-Mana D., Ceranic, B., Djahanbakhc, O. & Luxon, L. M. (2010) "Alteration in auditory function during the ovarian cycle". *Hearing Research*, 268: 114-122.

Amir, O. & Biron-Shental, R. (2004) "The impact of hormonal fluctuations on female vocal folds". *Current Opinion in Otolaryngology and Head and Neck Surgery*, 3: 180-184.

Brodnitz, F. S. (1971) "Hormones and the human voice". *Bulletin of the New York Academy of Medicine,* 47: 183-191.

Burnett, T. A., Senner, J. E. & Larson, C. R. (1997) "Voice F0 Responses to Pitch-Shifted Auditory Feedback: A Preliminary Study". *Journal of Voice*, 11(2): 202-211.

Frable, M. A. N. (1961) "Hoarseness, a symptom of premenstrual tension". *Archives of Otolaryngology,* 75: 66-68.

Foidart, J. M. (2000) "The contraceptive profile of a new oral contraceptive with antimineralocorticoid and antiandrogenic effects". *The European Journal of Contraception and Reproductive Health Care*, 5: 25-33.

Hampson, E. & Kimura, D. (1988) "Reciprocal effects of hormonal fluctuations on human motor and perceptual-spatial skills". *Behavioral Neuroscience* 102: 456–459.

Higgins, M. B. & Saxman, J. H. (1989) "Variations in vocal frequency perturbation across the menstrual cycle". *Journal of Voice*, 3: 233-243.

Huber, J., Foidart, J. M., Wuttke, W., Merki-Feld, G. S., The, H. S., Gerlinger, C., Schellschmidt, I. & Heithecker, R. (2000) "Efficacy and tolerability of a monophasic oral contraceptive containing ethinylestradiol and drospirenone". *The European Journal of Contraception and Reproductive Health Care,* 5: 25-34.

Isenberg, H., Brown, W. S. & Rothman, H. B. (1983) "Effects of menstruation on the singing voice; Part II: Further developments in research". In V. Laurence (Ed.) *Transcriptions of the twelfth symposium for the care of the professional voice*. Part I. New York: The Voice Foundation. (pp. 117-123)

Jadad, A. (1998). *Randomised Controlled Trials: a user's guide*. London: BMJ Publishing Group.

Lã, F., Davidson, J. W., Ledger, W., Howard, D. M. & Jones, G. (2007) "A case-study on the effects of the menstrual cycle and the use of a combined oral contraceptive pill on the performance of a western classical singer: an objective and subjective overview". *Musicae Sciencea. Special Issue: Performance Matters*, 85-107.

Lã, F. M. B., Howard, D.M., Ledger, W., Davidson, J.W. & Jones, G. (2009) "Oral contraceptive pill containing drospirenone and the professional voice: an electrolaryngographic analysis". *Logopaedics Phoniatrics Vocology*. 34 (1): 11-19.

Mürbe, D., Pabst, F., Hofmann, G. & Sundberg, S. (2002) "Effects of a professional solo singer education on auditory and kinesthetic feedback – a longitudinal study of singers' pitch control". *Speech, Music and Hearing, Quarterly Progress and Status Report,* 43: 81-87.

Mürbe, D., Pabst, F., Hofmann, G. & Sundberg, S. (2004). Effects of a professional solo singer education on auditory and kinesthetic feedback – a longitudinal study of singers' pitch control. *Journal of Voice*, 43: 81-87.

Perelló, J & Comas, J. (1959). Etude de la cytology exfoliative du larynx. *Acta-Rhino-Laryngologica Belgica*, 13: 194-198.

Sanders, G., & Wenmoth, D. (1998). Verbal and music dichotic listening tasks reveal variations in function cerebral asymmetry across the menstrual cycle that are phase and task dependent, *Neuropsychologia* ,36: 869–874.

Sataloff, R. T., Emerich, K. A. & Hoover, C. A. (1997). Endocrine Dysfunction. In R. T. Sataloff (Ed.). *Professional Voice: The Science and Art of Clinical Care*.

Saucier, D.M. & Kimura, D. (1998). Intrapersonal motor but not extrapersonal targeting skill is enhanced during the midluteal phase of the menstrual cycle, *Developmental Neuropsychology*, 14: 385–398.

Schultz-Coulon, H. J. (1978). The neuromuscular phonatory control system and vocal function. Acta Otolaryngol 86: 142-153.

Titze, I. R. (2000). *Principles of Voice Production*. 2nd Edition. Iowa: National Center for Voice and Speech.

Wyke, B. D. (1974). Laryngeal neuromuscular control systems in singing, *Folia Phoniatrica, 26:* 295-30.

Author´s biography
Filipa Lã (BSci, MMus, PhD) is responsible for Singing Pedagogy, Music Psychology and Musician's Medicine courses at the Department of Communication and Arts at the University of Aveiro. She is a researcher at the National Institute of Ethnomusicology, Music and Dance. Her work is published on *Journal of Voice*, *LPV*, *Research studies in Music Education* and *Musicae Scientiae.*