

WOMEN'S VOICE PITCH IS NEGATIVELY CORRELATED WITH HEALTH RISK FACTORS

JOVANA VUKOVIC¹, DAVID R. FEINBERG², LISA DEBRUINE¹, FINLAY G. SMITH¹,
BENEDICT C. JONES^{1,*}

¹School of Psychology, University of Aberdeen

²Department of Psychology, Neuroscience and Behaviour, McMaster University

Abstract. Previous studies have demonstrated that men prefer women's voices with relatively high pitch to those with low pitch, suggesting that men may use voice pitch as a cue of women's mate quality. However, evidence that voice pitch is a cue to women's long-term health is equivocal. Here we present evidence that women's average speaking voice pitch is negatively correlated with a health risk index derived from principle component analysis of various body measurements that are known to predict long-term health outcomes in women (weight, body mass index, percentage body fat, waist and hip circumference, and waist-hip ratio). Our results suggest that voice pitch is a cue to women's long-term health, supporting mate-choice accounts of men's preferences for raised pitch in women's voices.

Keywords: voice pitch, attractiveness, mate choice, fundamental frequency, femininity

INTRODUCTION

Many studies have demonstrated that vocal characteristics influence mate preferences and choices in a wide range of non-human mammals (for a recent review see TAYLOR and REBY 2009). Such findings have led researchers to investigate the effects of vocal characteristics on attractiveness judgments in humans (for reviews see FEINBERG 2008 and JONES et al. 2010). Source-filter models of vocal production (FANT 1960; see also TAYLOR and REBY 2009) propose that vocalizations are the product of an independent sound source (i.e., vocal-fold vibration) and filter (i.e., vocal-tract resonances). Vocal fundamental frequency, which is perceived as voice

* Corresponding author: BENEDICT C. JONES, University of Aberdeen, Scotland, UK; Phone: +44 (0)1224 273933, Fax: +44 (0)1224 273426, E-mail: Ben.jones@abdn.ac.uk

pitch, reflects the rate of vocal-fold vibration (TITZE 1994) and is negatively correlated with testosterone levels in men (TITZE 1994) and positively correlated with estrogen levels in women (ABITBOL et al. 1999; FEINBERG et al. 2006). Since cues of hormone levels are thought to be particularly important for attractiveness in humans (e.g., MILLER and TODD 1998), much of the research on human vocal attractiveness has investigated the relationship between voice pitch and attractiveness (APICELLA and FEINBERG 2009; COLLINS and MISSING 2003; FEINBERG et al. 2005, 2008; JONES et al. 2008).

Recent research has emphasized the importance of voice pitch for women's vocal attractiveness (e.g., APICELLA and FEINBERG 2009; COLLINS and MISSING 2003; FEINBERG et al. 2005, 2008; JONES et al. 2008). For example, COLLINS and MISSING (2003) and FEINBERG et al. (2008) reported positive correlations between voice pitch measurements taken from recordings of women's voices and attractiveness ratings of these voice recordings. Moreover, APICELLA and FEINBERG (2009), FEINBERG et al. (2008) and JONES et al. (2008) each found that men preferred versions of women's voices in which pitch had been raised to versions in which voice pitch had been lowered. These latter findings demonstrate that speaking voice pitch is an acoustic cue to women's attractiveness (APICELLA and FEINBERG 2009; FEINBERG et al. 2008; JONES et al. 2008; JONES et al. 2010). That men show stronger preferences for raised pitch in women's voices than women do (FEINBERG et al. 2008; JONES et al. 2008; JONES et al. 2010) raises the possibility that voice pitch may be a cue to women's mate quality (i.e., their long-term health). Indeed, indices of long-term health predict women's facial attractiveness (HENDERSON and ANGLIN 2003; HUME and MONTGOMERIE 2001; LAW SMITH et al. 2006), which is also correlated with women's voice pitch (FEINBERG et al. 2005). Moreover, estrogen levels are correlated with both women's voice pitch (ABITBOL et al. 1999; FEINBERG et al. 2006) and long-term health (see LAW SMITH et al. 2006).

Mate choice accounts of attractiveness judgments predict correlations between attractive cues and indices of long-term health, and many researchers have noted the importance of testing for such correlations (e.g., HENDERSON and ANGLIN 2003; KALICK et al. 1998; LAW SMITH et al. 2006; RHODES et al. 2001; THORNHILL and GANGESTAD 2006). While HUGHES et al. (2002, 2004, 2008) observed positive correlations between attractiveness ratings of women's voices and indices of women's long-term health (e.g., low waist-hip ratio and high body symmetry, LEIBEL et al. 1989; THORNHILL and GANGESTAD 2006), evidence that voice pitch *specifically* is correlated with indices of women's long-term health is equivocal. For example, HUGHES et al. (2008) observed no significant relationship between body symmetry and women's voice pitch. By contrast, COLLINS and MISSING (2003) reported a negative correlation between women's voice pitch and a body measurement factor that was derived from various body measurements, many of which are known to be good predictors of long-term health in women (e.g., body mass index, weight, hip and waist circumference, BIGAARD et al. 2004; FINE et al. 1999; MANSON et al.

1995; WILLET et al. 1995). This correlation was observed in a relatively small sample of women, however ($N = 30$).

In light of the above, we investigated the relationship between women's average voice pitch and a health risk index that was derived from a variety of different body measurements for which high values are known to predict poor long-term health outcomes in women; weight (FINE et al. 1999), body mass index (MANSON et al. 1995; WILLET et al. 1995), waist-hip ratio (LEIBEL et al. 1989), waist and hip circumference (BIGAARD et al. 2004), and percentage body fat estimated from bioelectrical impedance (ROUBENOFF et al. 1998). We predicted that women with relatively high speaking voice pitch would be more likely to possess physical traits associated with good long-term health than women with relatively low speaking voice pitch.

METHODS

Participants

Participants were 109 female undergraduate students at the University of Aberdeen. Participants took part in the study in return for course credit. The mean age for the sample was 19.89 years ($SD = 1.92$ years). All participants were between 17 and 26 years of age. Ninety percent of our participants were White.

Body measurements

Height ($M = 165\text{cm}$, $SD = 6.44\text{cm}$), weight ($M = 67.71\text{kg}$, $SD = 9.63\text{kg}$), waist circumference ($M = 73.52\text{cm}$, $SD = 7.07\text{cm}$), and hip circumference ($M = 98.53\text{cm}$, $SD = 6.67\text{cm}$) were measured from each participant. Following HUGHES et al. (2004), waist circumference was measured at the narrowest point between the rib cage and iliac crest and hip circumference was measured at the widest point between the waist and thigh. Percentage body fat, estimated from bioelectrical impedance, was also measured from each participant using an Omron Body Fat Monitor ($M = 32.22\%$, $SD = 5.40\%$). Body mass index and waist-hip ratio was calculated from each participant's height and weight (body mass index: $M = 22.91\text{kg/m}^2$, $SD = 3.11\text{kg/m}^2$). Waist-hip ratio was calculated from each participant's waist and hip circumferences (waist-hip ratio: $M = 0.75$, $SD = 0.05$).

Voice recordings and acoustic analyses

Voices were recorded in a quiet room using Praat recording software in mono at a sampling rate of 44.1 kHz at 16-bit amplitude quantization. In one of the voice recordings, women were instructed to say "Hi, I'm a student at the University of Ab-

erden” in their normal speaking voice. In the second voice recording, women were instructed to say the vowel sounds “eh” as in bet, “ee” as in see, “ah” as in father, “oh” as in note, and “oo” as in boot in their normal speaking voice. In the third voice recording, women were instructed to read the passage “When the sunlight strikes raindrops in the air, they act as a prism and form a rainbow” in their normal speaking voice. These three types of voice recording have been used to assess voice pitch in previous studies (BRYANT and HASELTON 2009; COLLINS and MISSING 2003; FEINBERG et al. 2008; PUTS et al. 2006). Following Feinberg et al. (2005a, 2008a), fundamental frequency was measured using Praat’s (BOERSMA and WEENINK 2007) autocorrelation function with input parameters set at 100Hz to 600Hz. Acoustic measurements were conducted at 11.025 kHz sampling rate to increase frequency resolution. Mean voice pitch for the ‘Hi’ statement was 209.68Hz ($SD = 19.03\text{Hz}$), for recordings of vowel sounds was 207.61Hz ($SD = 23.56\text{Hz}$), and for the rainbow passage was 209.47Hz ($SD = 17.31\text{Hz}$).

Since some of these variables were not normally distributed, pitch measurements were analyzed using nonparametric tests. Inter-correlations among the three different measures of women’s voice pitch were high (all $r_s > .67$, all $p < .001$) and there were no significant differences among these measures ($Chi\text{-square} = .22$, $df = 2$, $p = .90$). Consequently, we calculated the mean voice pitch for each woman by averaging values across her three voice recordings ($M = 208.92\text{Hz}$, $SD = 17.96\text{Hz}$). These mean pitch values were used in subsequent analyses.

RESULTS

The body measurement data (weight, height, waist circumference, hip circumference, body mass index, percentage body fat, and waist-hip ratio) were first analyzed using principal component analysis. This analysis produced a first factor that explained 61.5% of the variance in body measurements and had an eigenvalue of 4.30. High scores on this factor indicated high body weight, high percentage body fat, high body mass index, high waist circumference, high hip circumference, and high waist-hip ratio. We labelled this factor the *health risk index*. Table 1 shows the component matrix for this analysis.

Table 1. Component matrix for principle component analysis of body measurements. The *health risk index* explained 61.5% of the variance in scores and had an eigenvalue of 4.30

Body measurement	Health risk index
Weight	.93
Percentage body fat	.79
Body mass index	.95
Waist circumference	.94
Hip circumference	.86
Waist-hip ratio	.49
Height	.21

Since average voice pitch was not normally distributed, nonparametric tests are reported for all correlations. As we had predicted, there was a significant negative correlation between women's average voice pitch (i.e., the mean voice pitch across all three types of voice recording) and the *health risk index* ($r_s = -.19$, $N = 109$, $p = .045$). This correlation is shown in *Figure 1*. There were no significant correlations between participant age and scores on the health risk index ($r_s = .11$, $N = 109$, $p = .25$) or between participant age and average voice pitch ($r_s = -.17$, $N = 109$, $p = .08$).

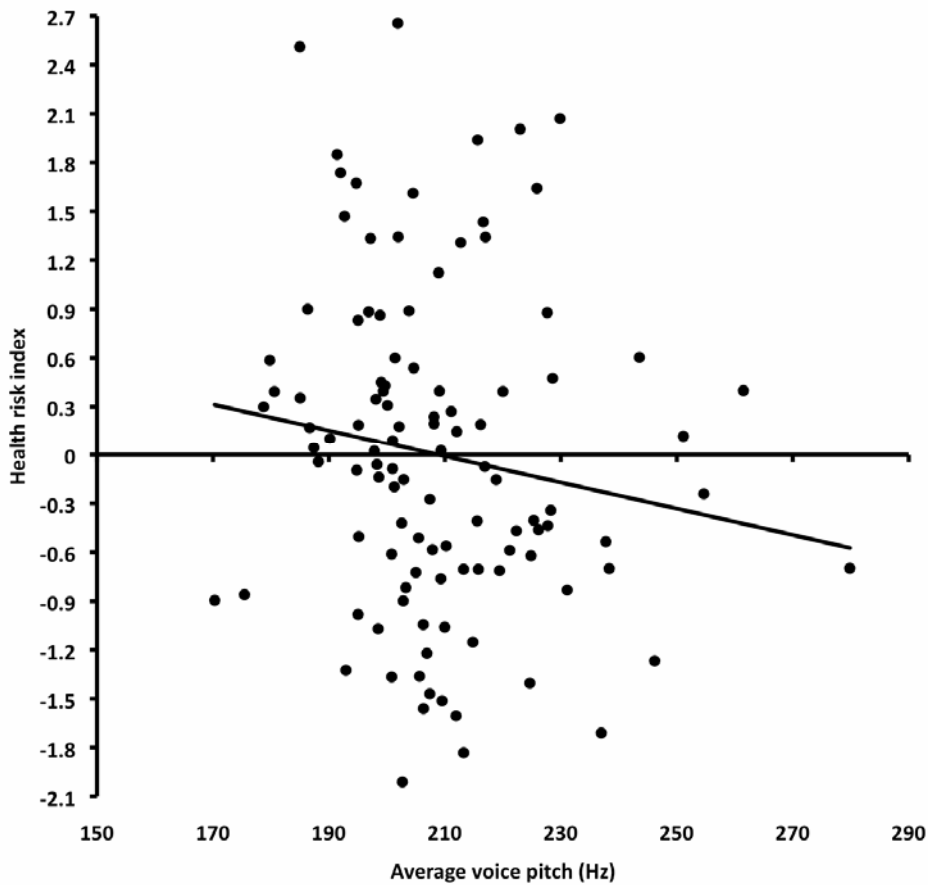


Figure 1. The significant correlation between average voice pitch and the health risk index ($r_s = -.19$, $N = 109$, $p = .045$)

Analyses considering each body measurement individually indicated that average voice pitch was negatively correlated with women's weight ($r_s = -.25$, $N = 109$, $p = .008$), body mass index ($r_s = -.19$, $N = 109$, $p = .043$) and hip circumference ($r_s = -.21$, $N = 109$, $p = .028$). By contrast, the relationships between average voice pitch

and women's waist circumference ($r_s = -.13, N = 109, p = .17$), percentage body fat ($r_s = -.14, N = 109, p = .15$), waist-hip ratio ($r_s = .03, N = 109, p = .75$), and height ($r_s = -.14, N = 109, p = .14$) were not significant.

DISCUSSION

We observed a negative correlation between women's voice pitch and a *health risk index* that was derived from various body measures that are known to predict long-term health outcomes in women (weight, body mass index, waist-hip ratio, waist and hip circumference, and percentage body fat estimated from bioelectrical impedance). This correlation suggests that women with high voice pitch are less likely to possess physical characteristics associated with poor long-term health outcomes than are women with relatively low voice pitch. Weight, body mass index and hip circumference were each significantly and negatively correlated with women's average voice pitch. These findings suggest that voice pitch is positively associated with indices of women's long-term health.

Previous findings for the relationship between women's average voice pitch and indices of long-term health have been mixed (COLLINS and MISSING 2003; HUGHES et al. 2008). In our study, we observed a negative correlation between health risk factors and women's average voice pitch that is consistent with the relationship between a similar factor derived from weight, body mass index, waist circumference and hip circumference in COLLINS and MISSING (2003). FEINBERG et al. (2005) have previously found that women's voice pitch and facial attractiveness are positively correlated and proposed that average voice pitch and facial attractiveness may signal a common underlying quality in women. Our findings then suggest that this common underlying quality may be long-term health. Consistent with this proposal, HUME and MONTGOMERIE (2001) have previously reported negative correlations between women's facial attractiveness and both body mass index and frequency of past health problems, while other studies have reported similar correlations between facial attractiveness and other indices of women's long-term health (HENDERSON and ANGLIN 2003; LAW SMITH et al. 2006).

The mechanisms through which the negative correlation between average speaking voice pitch and health risk factors emerges among women are unclear. One possibility is that the vocal apparatus of women with large bodies produces lower pitched vocalizations (COLLINS and MISSING 2003). Thus, the significant relationships observed in the current study may reflect a correlation between body size and voice pitch. However, this explanation is unlikely since several studies have found that height, a direct measure of body size, is not correlated with voice pitch in humans (see, e.g., APICELLA and FEINBERG 2009; EVANS et al. 2006; GONZALEZ 2007; GRADDOL and SWANN 1983; KUNZEL 1993). Similarly, height was not related to voice pitch in our sample and body size is not associated with pitch in other primate species, such as rhesus macaques (e.g., FITCH 1997), or other non-

human mammals, such as red deer (e.g., REBY and MCCOMB 2003). A more plausible mechanism is that between-subjects variation in hormone levels affects both vocal characteristics and other physical characteristics that are related to health risk factors in similar ways (see, e.g., FEINBERG et al. 2005). Indeed, previous studies have found that both voice pitch and long-term health are correlated with women's estrogen levels (ABITBOL et al. 1999; FEINBERG et al. 2006; LAW SMITH et al. 2006). These, and other possibilities, are important topics for future research. It is important to note here, however, that, regardless of the mechanisms through which the relationship emerges, our findings suggest that voice pitch in women is associated with physical characteristics that are health risk factors and that voice pitch may, therefore, provide useful information about women's long-term health. An additional issue for future research is whether the association between indices of long-term health and voice pitch apparent in our sample of young adult women (see also COLLINS and MISSING 2003) also occurs in samples of older women or samples with a wider age range.

Previous studies have shown that men demonstrate strong preferences for both women's voices with experimentally raised pitch (FEINBERG et al. 2008; JONES et al. 2008; JONES et al. 2010) and women's voices with naturally high pitch (COLLINS and MISSING 2003; FEINBERG et al. 2005, 2008). Our findings suggest that such preferences may occur, at least partly, because voice pitch is positively correlated with indices of good long-term health in women. Although the relationship between health risk factors and average voice pitch among women appears to be relatively weak, many researchers have emphasized that even weak associations between attractive cues and long-term health may be important for reproductive success when the benefits are considered across multiple generations (see, e.g., GEARY 2005). Thus, our findings add to growing evidence that attractive characteristics in women are associated with indices of their long-term health (see also, e.g., GANGESTAD and THORNHILL 2006; HENDERSON and ANGLIN 2003; HUME and MONTGOMERIE 2001; LAW SMITH et al. 2006).

REFERENCES

- ABITBOL, J., ABITBOL, P. & ABITBOL, B. (1999): Sex hormones and the female voice. *Journal of Voice*, 13, 424–446.
- APICELLA, C. L. & FEINBERG, D. R. (2009): Voice pitch alters mate-choice relevant perception in hunter-gatherers. *Proceedings of the Royal Society of London B*, 276, 1077–1082.
- BIGAARD, J., FREDERIKSEN, K., TJØNNELAND, A., THOMSEN, B. L., OVERVAD, K., HEITMANN, B. L. & SØRENSEN, T. I. A. (2004): Waist and hip circumferences and all-cause mortality: Usefulness of the waist-to-hip ratio? *International Journal of Obesity*, 28, 741–747.
- BOERSMA, P. & WEENINK, D. (2007): *Praat*. Summer Institute of Linguistics. <http://www.praat.org>.
- COLLINS, S. & MISSING, C. (2003): Vocal and visual attractiveness are related in women. *Animal Behaviour*, 6, 997–1004.

- EVANS, S., NEAVE, N. & WAKELIN, D. (2006): Relationships between vocal characteristics and body size and shape in human males: An evolutionary explanation for a deep male voice. *Biological Psychology*, 72, 160–163.
- FANT, G. (1960): *Acoustic Theory of Speech Production*. The Hague: Mouton & Co.
- FEINBERG, D. R., DEBRUINE, L. M., JONES, B. C. & PERRETT, D. I. (2008): The role of femininity and averageness of voice pitch in aesthetic judgments of women's voices. *Perception*, 37, 615–623.
- FEINBERG, D. R., JONES, B. C., DEBRUINE, L. M., LAW SMITH, M. J., CORNWELL, R. E., HILLIER, S. G. & PERRETT, D. I. (2006): Maintenance of vocal sexual dimorphism: Adaptive selection against androgyny. *Human Behavior and Evolution Society* in Philadelphia, PA USA. June 2006.
- FEINBERG, D. R., JONES, B. C., DEBRUINE, L. M., MOORE, F. R., LAW SMITH, M. J., CORNWELL, R. E., TIDDEMAN, B. P., BOOTHROYD, L. G. & PERRETT, D. I. (2005): The voice and face of woman: One ornament that signals quality? *Evolution and Human Behavior*, 26, 398–408.
- FINE, J. T., COLDITZ, G. A., COAKLEY, E. H. et al. (1999): A prospective study of weight change and health-related quality of life in women. *Journal of American Medical Association*, 282, 2136–2142.
- FITCH, W. T. (1997): Vocal tract length and formant frequency dispersion correlate with body size in rhesus macaques. *Journal of the Acoustic Society of America*, 102, 1213–1222.
- GEARY, D. C. (2005): Evolution of life-history trade-offs in mate attractiveness and health: Comment on Weeden and Sabini (2005). *Psychological Bulletin*, 131, 654–657.
- GONZALEZ, J. (2007): Correlations between speakers' body size and acoustic parameters of voice. *Perceptual and Motor Skills*, 105, 215–220.
- GRADDOL, D. & SWANN, J. (1983): Speaking fundamental-frequency – some physical and social correlates. *Language and Speech*, 26, 351–366.
- HENDERSON, J. J. A. & ANGLIN, J. M. (2003): Facial attractiveness predicts longevity. *Evolution and Human Behavior*, 24, 351–356.
- HUGHES, S. M., PASTIZZO, M. J. & GALLUP, G. G. (2008): The sound of symmetry revisited: Subjective and objective analyses of voice. *Journal of Nonverbal Behavior*, 32, 93–108.
- HUGHES, S. M., DISPENZA, F., GALLUP, G. G. (2004): Ratings of voice attractiveness predict sexual behavior and body configuration. *Evolution and Human Behavior*, 25, 295–304.
- HUGHES, S. M., HARRISON, M. A. & GALLUP, G. G. (2002): The sound of symmetry - Voice as a marker of developmental instability. *Evolution and Human Behavior*, 23, 173–180.
- HUME, D. K. & MONTGOMERIE, R. (2001): Facial attractiveness signals different aspects of quality in men and women. *Evolution and Human Behavior*, 22, 93–112.
- JONES, B. C., FEINBERG, D. R., DEBRUINE, L. M., LITTLE, A. C. & VUKOVIC, J. (2010): A domain-specific opposite-sex bias in human preferences for manipulated voice pitch. *Animal Behaviour*, 79, 57–62.
- JONES, B. C., FEINBERG, D. R., DEBRUINE, L. M., LITTLE, A. C. & VUKOVIC, J. (2008): Integrating cues of social interest and voice pitch in men's preferences for women's voices. *Biology Letters*, 4, 192–194.
- KALICK, S. M., ZEBROWITZ, L. A., LANGLOIS, J. H., JOHNSON, R. M. (1998): Does human facial attractiveness honestly advertise health? Longitudinal data on an evolutionary question. *Psychological Science*, 9, 8–13.
- KUNZEL, H. J. (1989): How well does average fundamental-frequency correlate with speaker height and weight. *Phonetica*, 46, 117–125.
- LEIBEL, R. L., EDENS, N. K. & FRIED, S. K. (1989): Physiologic basis for the control of body fat distribution in humans. *Annual Review of Nutrition*, 9, 417–443.

- MANSON, J. E., WILLET, W. C., STAMPFER, M. J., COLDITZ, G. A., HUNTER, D. J., HANKINSON, S. E., HENNEKENS, C. H. & SPEIZER, F. E. (1995): Body weight and mortality among women. *New England Journal of Medicine*, 333, 677–685.
- REBY, D. & MCCOMB, K. (2003): Anatomical constraints generate honesty: Acoustic cues to age and weight in the roars of red deer stags. *Animal Behaviour*, 65, 519–530.
- RHODES, G., ZEBROWITZ, L., CLARK, A., KALICK, S. M., HIGHTOWER, A. & MCKAY, R. (2001): Do facial averageness and symmetry signal health? *Evolution and Human Behavior*, 22, 31–46.
- ROUBENOFF, R., DALAT, G. E. & WILSON, P. W. F. (1998): Predicting body fatness: The body mass index vs estimation by bioelectrical impedance. *American Journal of Public Health*, 85, 726–728.
- TAYLOR, A. M. & REBY, D. (2009): The contribution of source-filter theory to mammal vocal communication research. *Journal of Zoology*, 280, 221–236.
- THORNHILL, R. & GANGESTAD, S. W. (2006): Facial sexual dimorphism, developmental stability, and susceptibility to disease in men and women. *Evolution and Human Behavior*, 27, 131–144.
- TITZE, I. R. (1994): *Principles of Voice Production*. Englewood Cliffs, New Jersey: Prentice Hall.
- WILLET, W. C., MANSON, J. E., STAMPFER, M. J., COLDITZ, G. A., ROSNER, B., SPEIZER, F. E. & HENNEKENS, C. H. (1995): Weight, weight change and coronary heart disease in women: Risk within the 'normal' weight range. *Journal of the American Medical Association*, 273, 461–465.