NIH Public Access
Author Manuscript
J Prosthet Dent. Author manuscript; available in PMC 2008 August 27.

Published in final edited form as:
J Prosthet Dent. 2008 August ; 100(2): 93–98. doi:10.1016/S0022-3913(08)60155-9.

Estimating the color of maxillary central incisors based on age and gender

David Gozalo-Diaz, DDS, MS[a], **William M. Johnston, PhD**[b], and **Alvin G. Wee, BDS, MS, MPH**[c]

a*Assistant Professor, School of Dental Medicine, University of Colorado Health Science Center, Denver, Colo; Former Implant Fellow and Advanced Prosthodontic Resident, Craniofacial Color Research Laboratory, Section of Restorative and Prosthetic Dentistry, College of Dentistry, The Ohio State University, Columbus, Ohio*

b*Professor, Craniofacial Color Research Laboratory, Section of Restorative and Prosthetic Dentistry, College of Dentistry, The Ohio State University, Columbus, Ohio*

c*Associate Professor and Director, Division of Oral Facial Prosthetics/Dental Oncology, Department of Otolaryngology - Head and Neck Surgery, University of Nebraska Medical Center, Omaha, Neb*

Abstract

Statement of problem—There is no scientific information regarding the selection of the color of teeth for edentulous patients.

Purpose—The purpose of this study was to evaluate linear regression models that may be used to predict color parameters for central incisors of edentulous patients based on some characteristics of dentate subjects.

Material and methods—A spectroradiometer and an external light source were set in a noncontacting 45/0 degree (45-degree illumination and 0-degree observer) optical configuration to measure the color of subjects' vital craniofacial structures (maxillary central incisor, attached gingiva, and facial skin). The subjects (n=120) were stratified into 5 age groups with 4 racial groups and balanced for gender. Linear first-order regression was used to determine the significant factors (α=.05) in the prediction model for each color direction of the color of the maxillary central incisor. Age, gender, and color of the other craniofacial structures were studied as potential predictors. Final predictions in each color direction were based only on the statistically significant factors, and then the color differences between observed and predicted CIELAB values for the central incisors were calculated and summarized.

Results—The statistically significant predictors of age and gender accounted for 36% of the total variability in L*. The statistically significant predictor of age accounted for 16% of the total variability in a*. The statistically significant predictors of age and gender accounted for 21% of the variability in b*. The mean ΔE (SD) between predicted and observed CIELAB values for the central incisor was 5.8 (3.2).

Conclusions—Age and gender were found to be statistically significant determinants in predicting the natural color of central incisors. Although the precision of these predictions was less than the median color difference found for all pairs of teeth studied, and may be considered an acceptable precision, further study is needed to reduce this precision to the limit of detection.

Corresponding author: Dr David Gozalo, University of Colorado at Denver and Health Sciences Center, Department of Restorative Dentistry, PO Box 6508 Mail, Stop F845, Aurora, CO, 80045, Fax: 303-724-7079, E-mail: David.Gozalo@uchsc.edu.

Clinical Implications

Age is highly correlated with the natural color of the central incisors. When age increases, the central incisor becomes darker, more reddish, and more yellow. Also, the women subjects in this study had lighter and less yellow central incisors than the men.

Traditionally, dentists select shades for restorations by matching the natural teeth with shade tabs from a manufacturer's shade guide.[1] Unfortunately, for an edentulous patient with no preextraction records, shade selection for artificial teeth becomes a subjective process.[2] To fabricate the complete denture, the dentist must rely on clinical judgment, together with the esthetic preferences of the patient and the shade of the available artificial teeth. The process of fabricating the prosthesis with an esthetically pleasing color can be frustrating when the expectations of the patient do not match those of the dentist.[3,4]

The ultimate objective of esthetics in dentistry is to create a beautiful smile, with teeth having pleasing inherent proportions to one another, and a pleasing tooth arrangement in harmony with the gingiva and face of the patient.[5] Unfortunately, only limited scientific information exists concerning the relationship between tooth shade, skin, and gingival color.[6-8] Knowledge of this relationship can guide dentists in selecting artificial teeth for complete dentures that naturally complement the patient's face.

Dummett[8] reported that nonpigmented gingiva is found more often in fair-skinned individuals, while pigmented gingiva is usually seen in darkskinned persons. Although a correlation was observed, the amount of variance precludes the clinical use of facial skin complexion to predict gingival pigmentation or to determine the colors of the labial flange for removable prostheses.

Jahangiri et al[6] studied the relationship between tooth shade and skin color in an observational study. Individuals (n=120) aged 18 to 80 years participated, and 2 calibrated investigators performed all examinations. A Vita Lumin shade guide (VITA Zahnfabrik, Bad Säckingen, Germany) was used to examine an unrestored central incisor, tooth shades were divided into 4 categories according to value, and the skin tones were divided into 4 categories with the use of compact makeup shades (True Illusion; L'Oréal USA, New York, NY) as a guide. No interaction among age, skin color, and tooth shade, or gender, skin color, and tooth shade was found; however, age was associated with tooth shade. People with darker and lighter skin tones were more likely to have teeth with darker and lighter shades, respectively, regardless of gender or age. The limitations of the previously mentioned studies and others that have investigated tooth color[9,10] include subjective placement of the structures being observed into categories of color[11,12] and subjective observation of the relationships between the structures.[13] These methods are less than accurate given the bias involved, thereby resulting in weaker evidence regarding the relationship between the colors of craniofacial structures.[14] None of the studies cited previously used objective color-measuring instrumentation.

It has been reported that color determination discrepancies among colorimetric devices with small window apertures[15] can be attributed to edge loss, which occurs with translucent materials, such as teeth[16] and maxil-lofacial materials.[17] Edge loss occurs when light that originally would be seen by the eye is scattered through the translucent material, and is then simply not measured by the instrument due to the configuration of the illuminant, sensor, and aperture. This occurs during conventional reflectance measurements of translucent materials, for instance, skin and teeth, when both the illumination and observation light paths travel through an aperture.

Only Hasegawa et al[18] have reported successfully performed color/translucency measurements of natural dentition using appropriate color-measuring instrumentation;

however, no studies have been published using objective and accurate color-measuring instrumentation to evaluate the color relationships of craniofacial structures.

The CIELAB-based color difference formula, introduced in 1976 and once recommended by the International Commission on Illumination,[19] defines a color space in which L* represents lightness, a* represents the chromaticity coordinate in a redgreen direction (+a* is the red-purple direction, and -a* is the blue-green direction), and b* represents the chromaticity coordinate in a yellow-blue direction (+b* is the yellow direction, and -b* is the purple-blue direction).[20] Color difference is defined by[21]

$$\Delta E_{L^*a^*b^*} = \sqrt{(L^*{}_1 - L^*{}_2)^2 + (a^*{}_1 - a^*{}_2)^2 + (b^*{}_1 - b^*{}_2)^2}$$

where the subscripts refer separately to each of the 2 different colors, the difference of which is being calculated.

Several studies have attempted to determine color-matching tolerances,[22-24] but only 2 studies, Johnston and Kao[25] and Douglas et al,[26] have attempted to determine perceptibility and acceptability tolerances under in vivo conditions. The first study rated a mean color difference of 6.8 ΔE units between compared teeth as a marginally acceptable mismatch. However, the second study considered a mean color difference of 5.5 ΔE to be clinically unacceptable color match.

The purpose of this study was to determine which factors, among age, gender, CIELAB values of gingiva, and facial skin, can predict the CIELAB values of an unrestored vital maxillary central incisor, and to quantify the CIELAB color difference between the measured and predicted colors for unrestored vital maxillary central incisors. The research hypothesis for this study was that the CIELAB values of a subject’s skin, lips, and gingiva, and the subject’s age and gender, can be used to estimate each of the CIELAB values of the subject’s maxillary central incisor.

MATERIAL AND METHODS

Human subject approval was obtained from The Ohio State University Institutional Review Board. A total of 120 human subjects over the age of 18 years were recruited for the study through notices posted around the University’s Health Science campus. Six subjects with equal gender balance (3 men and 3 women) from 4 racial/ethnic groups (White, Black, Asian or Pacific Islander, and Other) were recruited from each of the following age groups: 18-29 years, 30-39 years, 40-49 years, 50-59 years, and 60-85 years.

Potential subjects responded to the advertisements posted near the University’s Medical Center by calling the laboratory and were screened using a telephone screening form. This screening process increased the chance that a potential subject satisfied the inclusion and exclusion criteria for this study (Table I). Only subjects that were still needed for the study with reference to the stratified recruitment were requested to come in for a clinical examination.

Each potential subject was thoroughly informed about the purpose of this study, the study design, potential harm and benefit, the measures to protect their privacy, and the right to withdraw participation at any point during the project. Any study-related questions were answered, and if the subject expressed interest in participating, then informed consent and HIPAA forms were signed. Each potential subject was clinically screened to determine if the maxillary central incisor chosen was nonrestored and free from external staining or bleaching.

Subjects that qualified for the study were provided with a toothbrush (Butler GUM, 411 Soft; Sunstar Americas, Inc, Chicago, Ill) and toothpaste (Crest; Proctor and Gamble, Cincinnati, Ohio) and were requested to brush their teeth for 3 minutes. Subjects were also asked to remove any facial makeup. The subjects were seated with their lower jaw and forehead resting lightly on a head-frame (similar to that used in an optometry examination) that was attached to an optical table (Mecom, Inc, Risingsun, Ohio). A spectroradiometer (PR-705; Photo Research, Inc, Chatsworth, Calif) and fiber optic light cable were fixed on an optical table (Mecom, Inc). The fiber optic light cable was connected to a Xenon arc lamp (300W; Oriel Instruments Newport Stratford Inc, Stratford, Conn). The spectroradiometer and the optic light cable, positioned at a 45-degree angle inferior to the horizontal plane, provided an optical configuration of 0-degree observation and 45-degree illumination to the object. For all color measurements in this study, spectral reflectance was obtained from 380 nm to 780 nm with a 2-nm interval (SpectraWin 2; Photo Research, Inc) and subsequently converted to CIE L*, a*, and b* (CIELAB) values for D65 illumination and CIE Standard Human (2-degree) Observer. The spectroradiometer was standardized to a distance of 8 cm from the measured object with a measurement aperture size of 1 mm in diameter.

The spectral reflectance of the maxillary central incisor, attached gingiva, lips, and facial skin were measured for each subject, as sequenced and described in Table II. After facial skin and lips were measured, cheek retractors (PhotoMed Intl, Van Nuys, Calif) were used to allow measurements of the attached gingiva and teeth.

Subjects were financially compensated and a parking coupon was provided, if necessary, for each color measurement session. The validity and reliability of the instrumental configuration for color measurements of craniofacial structures on human subjects were evaluated in a previous study.[27]

Since only the age group was recorded for each subject, the age used in the following regressions was the mean of the group limits. Standard linear (first order) multiple regression was used to determine the statistically significant (α=.05) factors of each of the color directions (L*, a*, and b*) of the maxillary central incisors, using the following variables: each direction (L*, a*, and b*) of each of gingival color, lip color, and facial skin color, age (average age of the age group limits), and gender (Female was used as an indicator variable with Female=1 for women and Female=0 for men). The factors that were found to be statistically significant in each of CIE L*, a*, and b* color directions of the maxillary central incisor were then used to calculate a predicted value of L*, a*, and b*, respectively. The color difference (ΔE) between the observed CIELAB values and the predicted CIELAB values for the maxillary central incisor were calculated and summarized. All statistical analyses and calculations were completed with statistical program (SAS 8.0; SAS Institute, Inc, Cary, NC).

RESULTS

Summaries of the color parameters for the subjects' central incisors are given in Table III. For these 120 teeth, the 2 teeth farthest apart were separated by a color difference of 39.7 CIELAB units, and the mean color difference for all 7140 subject pairs was 9.7, with a lower quartile of 5.4, a median of 8.6, and an upper quartile of 12.9 CIELAB units.

The factors of the full regression models for L*, a*, and b* which were statistically significant are listed as variables in Tables IV and V.

The analysis of variance tables the complete linear multiple regressions and parameter estimates using only the statistically significant factors in the final prediction models for L*, a*, and b* for central incisors are shown in Tables IV and V. The prediction model for L* is:

$$\widehat{L}^{*}_{\text{central}} = 86.5 - 0.22 \times \text{Age (yrs)} + 2.0 \quad \text{if Female}$$

Age and gender account for 36% of the total variability in the L* values of central incisors. L* changed as age increased at a rate of -0.2 CIELAB units/year and was 2 CIELAB units higher for women.

The final prediction model for a* is:

$$\widehat{a}^{*}_{\text{central}} = 1.9 + 0.05 \quad \times \quad \text{Age (yrs)}$$

Age accounts for 16% of the total variability in the a* values of central incisors. The CIELAB parameter a* changed as age increased at a rate of +0.05 CIE units/year. The final prediction model for b* is:

Age and gender accounts for 21%

$$\widehat{b}^{*}_{\text{central}} = 15.4 + 0.10 \times \quad \text{Age (yrs)} - 1.6 \quad \text{if Female}$$

of the total variability in the b* values of central incisors. The CIELAB parameter b* changed as age increased at a rate of 0.10 CIE units/year. The mean $\Delta E_{L^*a^*b^*}$ between predicted and observed CIELAB values for the central incisor was 5.8, with a standard deviation of 3.2.

DISCUSSION

The hypothesis that the subject's age and gender can be used to estimate each of the CIELAB values of the subject's maxillary central incisor is supported by the data. Age and gender were found to be statistically significant factors in predicting the color of the central incisors. When age increases, the central incisor color becomes darker, more reddish, and more yellow, if all the rest of the factors in the predicting model are held constant. Predictions of L* and b* indicate that the women in this study have lighter and less yellow central incisors than the men in this study. Hasegawa et al[19] described no difference between men and women's teeth in the central area of the central incisors. However, Goodkind[10] and Odioso[11] reported that the teeth of women were lighter than men.

In terms of color difference between observed and predicted data, the results were not highly accurate with a low $\Delta E_{L^*a^*b^*}$, but may still be clinically useful. The precision of the 3 prediction models obtained for the central incisor was a mean $\Delta E_{L^*a^*b^*}$ of 5.8. The results of this study may be applied to subjects without teeth, when it is not possible to match the patient's preexisting teeth. A $\Delta E_{L^*a^*b^*}$ of 5.8 may be sufficient for this particular clinical use, although further study is needed to fully support or refute this conclusion. Nevertheless, in relation to the color range of the teeth as found in this study, as reported in Table III, this precision is less than the median color difference found for all pairs of teeth studied (8.6), less than the range of each L* (34.6), a* (11.1), and b* (25.7) color parameter found for these teeth, and approximates the lower quartile found for the color differences of all pairs of teeth studied (5.4).

According to Douglas et al,[26] a ΔE of 5.5 CIELAB units is considered a clinically unacceptable color difference. However, Johnston et al[27] performed an in vivo evaluation of color acceptability in a clinical scenario and reported that an average color difference of 6.8 CIELAB units between adjacent teeth and teeth veneered with composite was rated as an "acceptable mismatch," which was within the normal range of tooth color. If a clinically acceptable color mismatch is 6.8 $\Delta E_{L^*a^*b^*}$, a prediction obtained in the 3 models of 5.8 $\Delta E_{L^*a^*b^*}$ would most likely fall within an acceptable range.

Aside from the limitations on instrumentation and measurements described in the present study, a larger sample size is likely necessary to reduce the error in the prediction models. Future studies should include measuring different areas of the skin, for example, the palm, sole, or armpit, where there is less variation due to pigmentation from the sun. Future investigations should focus specifically on predicting the color using the models and then testing patient acceptability tolerances.

The final multiple regression models for this study could only predict 36% of the total variability found for L*, 16% for a*, and 21% for b*, of the central incisors. Thus, the other 64% of variability in L*, 84% in a*, and 79% in b* for these models results from unexplored factors or from error. Further studies are needed to determine the other possible contributing factors to the color of teeth, such as genetics and influence of nutrition during the development of the tooth bud. In this study, factors which would have been significant at α=.10 and worthy of further study were: (1) L* of the gingiva (P=.07) as a predictor for L* of MCI; (2) gender (P=.06) and b* of the gingiva (P=.10) as predictors for a* of the MCI; and (3) b* of the gingiva (P=.07) as a predictor for a* of the MCI.

CONCLUSIONS

Within the limitations of this study, age and gender were found to be statistically significant determinants in predicting the 3 color parameters of central incisors. The multiple regression models explained 36% of the variability of L*, 16% of the variability of a*, and 21% of the variability of b* among maxillary central incisors. The regression models collectively were able to predict the color of central incisors to an average $\Delta E_{L^*a^*b^*}$ of 5.8. Age is correlated with each CIELAB color parameter of central incisors, and gender influenced the 2 more highly variable of these parameters. When age increases, the central incisors become darker, more red, and more yellow. The women subjects in this study were found to have lighter and less yellow central incisors than the men.

Acknowledgements

The authors thank Mrs April Logue, former research assistant, for help with subject recruitment, Mr Carl Kipp, restorative laboratory manager, for technical assistance, and Ms Jaclyn Laylle for help in manuscript submission. The authors also thank former undergraduate students involved in this study, including Mr Corey Valentine, Ms Tiffany Kocol, and Ms Pamela Kamolpechara.

This research was supported in part by: (1) National Eye Institute, National Institute of Health Grant (R15 EY013527), (2) Awards and Grants Program of the Editorial Council for *The Journal of Prosthetic Dentistry*, 2003, and (3) and Greater New York Academy of Prosthodontics Student Research Grant.

REFERENCES

1. Curd FM, Jasinevicius TR, Graves A, Cox V, Sadan A. Comparison of the shade matching ability of dental students using two light sources. J Prosthet Dent 2006;96:391–6. [PubMed: 17174655]
2. Sellen PN, Jagger DC, Harrison A. The selection of anterior teeth appropriate for the age and sex of the individual. How variable are dental staff in their choice? J Oral Rehabil 2002;29:853–7. [PubMed: 12366540]
3. Carlsson GE, Wagner IV, Odman P, Ekstrand K, MacEntee M, Marinello C, et al. An international comparative multicenter study of assessment of dental appearance using computer-aided image manipulation. Int J Prosthodont 1998;11:246–54. [PubMed: 9728119]
4. Marunick MT, Chamberlain BB, Robinson CA. Denture aesthetics: an evaluation of laymen's preferences. J Oral Rehabil 1983;10:399–406. [PubMed: 6355414]
5. Mayekar SM. Shades of a color. Illusion or reality? Dent Clin North Am 2001;45:155–72. [PubMed: 11210693]
6. Jahangiri L, Reinhardt SB, Mehra RV, Matheson PB. Relationship between tooth shade value and skin color: an observational study. J Prosthet Dent 2002;2:87-149–52.
7. Dummett CO, Barens G. Pigmentation of the oral tissues: a review of the literature. J Periodontol 1967;38:369–74. [PubMed: 5341949]

8. Dummett CO. Oral pigmentation - physiologic and pathologic. NY State Dent J 1959;25:407–12.

9. Goodkind RJ, Schwabacher WB. Use of a fiber-optic colorimeter for in vivo color measurements of 2830 anterior teeth. J Prosthet Dent 1987;58:535–42. [PubMed: 3479551]

10. Odioso LL, Gibb RD, Gerlach RW. Impact of demographic, behavioral, and dental care utilization parameters on tooth color and personal satisfaction. Compend Contin Educ Dent Suppl 2000:S35–41. [PubMed: 11908408]

11. Sproull RC. Color matching in dentistry. II. Practical applications of the organization of color. J Prosthet Dent 1973;29:556–66. [PubMed: 4513307]

12. Schwabacher WB, Goodkind RJ. Three-dimensional color coordinates of natural teeth compared with three shade guides. J Prosthet Dent 1990;64:425–31. [PubMed: 2231451]

13. Ferreira D, Monard LA. Measurement of spectral reflectance and colorimetric properties of Vita shade guides. J Dent Assoc S Afr 1991;46:63–5. [PubMed: 1962307]

14. Judd, DB.; Wyszecki, G. Color in business, science and industry. 3rd ed.. John Wiley & Sons; New York: 1975. p. 26-40.

15. Seghi RR, Johnston WM, O'Brien WJ. Performance assessment of colorimetric devices on dental porcelains. J Dent Res 1989;68:1755–9. [PubMed: 2600256]

16. Bolt RA, Bosch JJ, Coops JC. Influence of window size in small-window colour measurement, particularly of teeth. Phys Med Biol 1994;39:1133–42. [PubMed: 15552102]

17. Johnston WM, Ma T, Kienle BH. Translucency parameter of colorants for maxillofacial prostheses. Int J Prosthodont 1995;8:79–86. [PubMed: 7710631]

18. Hasegawa A, Motonomi A, Ikeda I, Kawaguchi S. Color of natural tooth crown in Japanese people. Color Res Appl 2000;25:43–8.

19. Recommendations on uniform color spaces, color difference equations, psychometric color terms. Bureau Central de la CIE; Paris: 1978. Supplement No 2. CIE Publication No. 15, Colorimetry 1971

20. Rosentiel SF, Johnston WM. The effects of manipulative variables on the color of ceramic metal restorations. J Prosthet Dent 1988;60:297–303. [PubMed: 3050048]

21. Berns, RS. Billmever and Saltzman's principles of color technology. 3rd ed.. John Wiley & Sons; New York: 2000. p. 68-9.

22. Ragain JC, Johnston WM. Color acceptance of direct dental restorative materials by human observers. Color Res Appl 2000;25:278–85.

23. Douglas RD, Brewer JD. Acceptability of shade differences in metal ceramic crowns. J Prosthet Dent 1998;79:254–60. [PubMed: 9553875]

24. Ruyter IE, Nilner K, Moller B. Color stability of dental composite resin materials for crown and bridge veneers. Dent Mater 1987;3:246–51. [PubMed: 3479360]

25. Johnston WM, Kao EC. Assessment of appearance match by visual observation and clinical colorimetry. J Dent Res 1989;68:819–22. [PubMed: 2715476]

26. Douglas RD, Steinhauer TJ, Wee AG. Intraoral determination of the tolerance of dentists for perceptibility and acceptability of shade mismatch. J Prosthet Dent 2007;97:200–8. [PubMed: 17499089]

27. Gozalo-Diaz DJ, Lindsey DT, Johnston WM, Wee AG. Measurement of color for craniofacial structures using a 45/0-degree optical configuration. J Prosthet Dent 2007;97:45–53. [PubMed: 17280891]

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table I

Inclusion and exclusion criteria for MOCOCS study

Inclusion Criteria	
1.	Generally healthy, between 18 and 85 years of age
2.	Presence of at least 1 maxillary central incisor, 1 lateral incisor, and 1 canine
3.	Willingness to brush teeth for 3 minutes prior to color measurement
4.	Willingness to spend approximately 1 hour participating in study
5.	Willingness to sign informed consent and HIPAA forms

Exclusion Criteria	
1.	Subjects with any direct or complete coverage restorations on both similar maxillary anterior teeth
2.	Subjects with any external surface staining on both similar maxillary anterior teeth
3.	Subjects with any intrinsic staining on both similar maxillary anterior teeth, for example, tetracycline stains, or fluorosis
4.	Subjects with severe attrition resulting in incisal enamel wear
5.	Subjects with spontaneous gingival bleeding due to periodontal disease
6.	Pregnant subjects, eliminating possibility of any misunderstanding that color measurement instrument may cause any harm to unborn child
7.	Psychiatric, cognitive, or social (for example, alcoholism or drug abuse) conditions that would interfere with giving consent and cooperation
8.	Prisoners

Table II

Sequence and description of color measurements of subjects' craniofacial structures

Order	Maxillofacial Structure	Location
1	Skin color	Tip of nose
2	Lip color	Color of middle of lower lip at vermillion border
3	Attached gingiva color	3.5 mm apical to free gingival margin of central incisor
4	Maxillary central incisor	Center of labial surface

Table III

Summaries of color parameters of central incisors of 120 teeth (CIELAB units)

	L*	a*	b*
Mean	77.3	4.2	19.5
Standard deviation	6.5	2.1	4.2
Lower 95% confidence limit	76.1	3.8	18.7
Upper 95% confidence limit	78.5	4.5	20.2
Minimum	54.9	0.9	10.0
Maximum	89.5	12.0	35.7
Range	34.6	11.1	25.7

Table IV

ANOVA summary for multiple linear regression of L*a*b* for central incisor

Source of Variation	***df***	**Mean Square**	**F**	***P***
Full model L*	8	261.76	10.06	<.001
Error L*	111	26.03		
Full model a*	8	14.26	3.98	<.001
Error a*	111	3.58		
Full model b*	8	65.47	4.47	<.001
Error b*	111	14.63		

Table V

Associated parameter estimates for central incisor of L*a*b*

		Parameter Estimates**					
Variable	***df***	**Estimate**	**Standard Error**	**Student's *t******	***P***	**Lower 95% C.I.**	**Upper 95% C.I.**
Intercept L*	1	86.5	1.46	59.7	<.001	67.0	92.6
Age (in years) L*	1	-0.22	0.03	-7.8	<.001	-0.28	-0.17
Female L*	1	1.95	0.95	2.05	.043	0.06	3.84
Intercept a*	1	1.89	0.51	3.74	<.001	0.89	2.89
Age (in years) a*	1	0.05	0.01	4.79	<.001	0.03	0.07
Intercept b*	1	15.49	1.07	14.49	<.001	13.38	17.61
Age (in years) b*	1	0.10	0.02	5.04	<.001	0.06	0.15
Female b*	1	-1.62	0.70	-2.33	.022	-3.0	-0.24

** Parameter estimates were developed using only statistically significant factors found in full model, as noted in text.

*** For null hypothesis, population value = 0.