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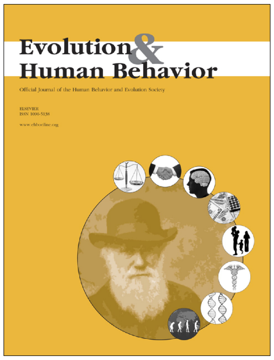

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Skin texture and colour predict perceived health in Asian faces

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Abstract

Facial skin texture and colour play an important role in observers' judgments of apparent health and have been linked to aspects of physiological health, including fitness, immunity and fertility. However, most studies have focused on Caucasian populations. Here, we report two studies that investigate the contribution of skin texture and colour to the apparent health of Malaysian Chinese faces. In Study 1, homogenous skin texture, as measured by wavelet analysis, was found to positively predict ratings of apparent health of Asian faces. In study 2, homogenous skin texture and increased skin yellowness positively predicted rated health of Malaysian Chinese faces. This finding suggests that skin condition serves as an important cue for subjective judgements of health in Malaysian Chinese faces.

Keywords: face perception, skin texture, skin colour, perceived health, Asian

1. Introduction

Physical appearance is one of the most important criteria used for mate selection, for both sexes (Rhodes, 2006; Stirrat, Gumert, & Perrett, 2011). Individuals who are physically attractive tend to have more options when choosing a mate, and have more opportunity to pursue a good quality mate. Researchers have identified a number of cues to facial health and attractiveness, including averageness (Langlois & Roggman, 1990; Rhodes et al., 2001), symmetry (Hume & Montgomerie, 2001; Perrett et al., 1999; Rhodes, Zebrowitz, et al., 2001a; Thornhill & Gangestad, 1993), sexual dimorphism (Jones et al., 2005; Penton-Voak et al., 2001) and skin condition (Matts, Fink, Grammer, & Burquest, 2007; Scott, Pound, Stephen, Clark, & Penton-Voak, 2010; Stephen, Coetzee, & Perrett, 2011; Stephen, Law Smith, Stirrat, & Perrett, 2009).

1.1 Skin condition and face perception

Previous studies on facial correlates of attractiveness and healthy appearance have tended to focus on facial shape (Said & Todorov, 2011; Carre & McCormick, 2008; Rhodes et al., 2001; Fink et al., 2006). More recently, however, studies have begun to highlight the importance of skin texture and colour (Fink, Bunse, Matts, &, D'Emiliano, 2012; Fink, Matts, D'Emiliano, Bunse, Weege, & Röder, 2012; Stephen, Coetzee, & Perrett, 2011).

Facial skin condition, as a rapidly changing health signal, provides useful information about an individual's current health and physiological status (Stephen et al., 2012, 2011). Both the texture and colouration of human skin change with the influence of various internal and external factors. Skin colour is related to skin blood perfusion and oxygenation, which are associated with physical fitness and pulmonary and cardiac health, and with concentration of melanin, which is associated with photoprotection and production of vitamin D, and carotenoids, which are thought to be associated with healthy immune and reproductive systems (Alaluf, Heinrich, Stahl, Tronnier, & Wiseman, 2002; Charkoudian, 2001 & 2003; Edwards & Duntley, 1939; González-Alonso, Crandall, & Johnson, 2008; Jablonski, 2004; Stephen et al., 2011).

The colour distribution of facial skin has also been found to influence the perception of age and attractiveness in female faces, independent of facial shape and skin surface topography (Fink et al., 2006). Faces with homogenous skin colour distribution were perceived as younger, healthier and more attractive as compared to faces with relatively inhomogeneous skin colour distribution. The same pattern was found for male faces, whereby ratings of cheek skin can be used to predict the age, health status and attractiveness of men's faces (Fink, Bunse, Matts, & D'Emiliano, 2012). Further, Fink and colleagues (2001) found that skin texture affected male judgments of attractiveness in female faces, while Jones and colleagues (2004) found an association between male facial attractiveness and the health rating of their skin patches, after controlling for structural cues.

The texture of facial skin is influenced by both internal biological factors (such as aging and hormonal balance) and external environmental factors (for example diet and humidity), which have been suggested to be more important (Kammeyer and Luiten, 2015). As we age, our skin loses its elasticity, becoming fragile and frail (Al-Nuaimi, Sherratt, & Griffiths, 2014; Naylor, Watson, & Sherratt, 2011), mainly due to the progressive loss of skin tissue (Robert, Labat-Robert, & Robert, 2009). Elevated levels of sex hormones has also been highlighted as a factor that contributes to the physiological changes in skin. Specifically, women with increased levels of androgens were found to have more severe dermatosis problems (Essah, Wickham, Nunley, & Nestler, 2006; Karrer-Voegeli, Rey, & Reymond, 2009). Environmental dryness and individual differences in diet have also been found to be related with the prevalence of acne (Danby, 2005; Davidovici & Wolf, 2010; Egawa, Oguri, Kuwahara, & Takahashi, 2002; Spencer, Ferdowsian, & Barnard, 2009). Research conducted by Nkengne and colleagues (2008) showed that skin condition was one of the most important criteria used when judging the perceived age of individuals. It is apparent, therefore, that the physical appearance of human skin, both its texture and colour, play an important role in determining its attractiveness and perceived health.

Historically, studies have tended to focus on a single cue in isolation. More recently, however, studies have begun to examine multiple cues in a single study, though there is mixed evidence about which cues are most important in determining perceptions of attractiveness and health. It has been suggested that skin condition may play a more important role in defining perceived facial health and attractiveness than structural cues (Scott et al., 2010; Stephen et al., 2012). Using geometric morphometric methods (GMM), researchers (Scott et al., 2010; Stephen et al., 2012) found no contribution of morphological masculinity in predicting attractiveness. Increment in skin yellowness and decrement in skin luminance, however, predicted rated attractiveness when judged by own ethnicity raters. A recent study by Mogilski and Welling (2016), though, found that individuals prioritised sexual dimorphism over averageness and skin colour.

The relationship between facial cues, perceived health and actual health is complex and inconclusive. Foo et al (2017) found a week association between attractive facial cues and actual health. In their study, men's perceived health was predicted by both shape cues (specifically averageness, symmetry and adiposity) and a colour cue (skin yellowness); whereas women's perceived health only found to be associated with sexual dimorphism. However, in order for a cue to be considered a valid cue to health, it must be linked to both healthy/attractive appearance and to some aspect of physiological health (Coetzee, Perrett, & Stephen, 2009b). Though masculinity in male faces was found to be associated with semen quality, there was a negative association between averageness and semen quality. Further, there was no significant association between perceived health cue and actual health for female. Here, for the first time, we examine skin texture and colour's influence on perceived health in a single study.

Further, while the effect of skin colour on apparent health of faces has been replicated in black African (Coetzee et al., 2012; Stephen et al., 2012, 2011) and Asian populations (Tan, Graf, Mitra, & Stephen, 2017), skin texture has only been examined in Western Caucasian populations (Fink et al., 2012, 2006), apart from one study in a black African population that used rated skin homogeneity in place of subjective measurement of texture (Coetzee et al., 2012). Since previous studies have found differences in preference for ideal body size between individuals from different cultures (Swami & Tovée, 2005a, 2005b; Tovee et al., 2006), and variation in skin colour has been proposed be the evolved based on the needs of the individual living in a specific geograpical location, for example photoprotection and vitamin D production (Jablonski, 2004), cross cultural replications are required.

The purpose of this paper is to explore the relationship between perceived facial health and facial skin condition, in an East Asian setting. Study 1 investigated the relationship between perceived facial health and objective analysis of skin texture and colour. Study 2 was an extension (and improvement) to Study 1, whereby the associations between perceived facial health, perceived skin health, skin colour and texture were explored in a more controlled setting.

2. Study 1: The relationship between facial skin condition and perceived facial health

Based on the results of previous studies conducted in the West exploring the relationship between skin texture and attractiveness (Fink et al., 2006, 2001; Fink, Matts, Röder, Johnson, & Burquest, 2011; Jones, Little, Burt, et al., 2004; Matts et al., 2007; Samson, Fink, & Matts, 2010), it was predicted that there will be a relationship between perceived facial health and a measure of skin texture, such that smoother skin will be perceived as healthier.

2.1 Methods

This study was approved by the Ethics Committee at the University of Nottingham Malaysia Campus. All participants gave both verbal and written informed consent in advance. The current study was divided into two main parts. In Part 1, a group of participants were recruited for their facial photographs to be taken (henceforth referred to as “subjects”). In Part 2, the standardized photos collected in Part 1 were evaluated by an independent group of participants (“raters”) for their perceived facial health.

Asia is a large continent with a huge variation of ethnicities. To control for the variation in skin tones and the influences of confounding factors (such as of the difference in diet and activity level) between ethnic groups, we limited our study to a single ethnic group.

Chinese was selected, as one of the largest ethnic groups in Asia, and the second largest in Malaysia (Hirschman, 1980).

2.1.1 Stimulus production. One hundred and forty three Malaysian Chinese subjects were recruited (67 male, 76 female; mean age = 20.41, SD=1.24). All were undergraduate or postgraduate students at the University of Nottingham Malaysia Campus and did not have visible facial hair.

Subjects had their facial photograph taken with a Canon EOS 550D digital camera in a photo booth painted Munsell N5 grey and illuminated with nine Verivide F20 T12/D50 daylight stimulation tubes in high frequency fixtures to reduce the effects of flicker. Shutter speed, ISO, aperture and white balance settings of the camera used were held constant. Participants were requested to sit on a chair inside the photo booth. Hair was held back from the face with a black head band, and participants were asked to pose with a neutral expression while holding a Munsell N5 painted board over their shoulders to obscure clothing.

2.1.2 Analysis of skin texture and colour. Psychomorph (Tiddeman & Perrett, 2001) was used to delineate facial images with a total of 179 coordinate landmarks plotted on each face. The size of the facial photos used was then standardized by aligning the eyes of the images to the same locations. Skin patches (226 x 361 pixels) were cropped from the left cheek area of each of the 143 facial photographs, using Matlab (Figure 1). The area cropped was selected by trial and error to ensure that a patch of skin was cropped without including any portion of the features (eyes, nose or mouth) or background.

Gabor wavelet analysis was performed, using Psychomorph (Tiddeman & Perrett, 2001), on the 143 skin patches, to obtain objective measurements of skin texture. Gabor wavelet analysis divides the data into different frequency components, and studies each component with a resolution matched to its scale (Kumar & Shreyas, 2006). Thirty two outcomes (indices) were produced (four levels of spatial frequency, where the filter of the final scale was 8 times larger than the first), over 4 different orientations (0 degrees, 90 degrees, 45 degrees, -45 degrees). While a number of techniques are available for assessing the texture of skin from images, Gabor Wavelets are well established, having been used successfully for this purpose in the machine vision (Manjunath & Ma, 1996; Jain & Farrokhnia, 1990) and medical imaging (Zhang & Ma, 2007; Ou, Pan, Zhang, & Xiao, 2016) literature. Indeed, it has been suggested that Gabor Wavelets may be more successful at quantifying skin texture from images than Haralicks' GLCM method (Haralick, Shanmugan, & Dinstein, 1973), which is used in some previous papers examining the effects of skin homogeneity on perceived health/attractiveness of faces (Fink et al., 2012).

Principle component analysis was then performed using SPSS v22 to reduce these 32 indices into a smaller set of factors. Three factors (named as Gabor wavelet factor 1, Gabor wavelet factor 2 and Gabor wavelet factor 3) were selected, with eigenvalues higher than 1.00, which together accounted for 97.18% of the variance.

Skin colour (sRGB) was measured from the skin patches using the Color Picker Tool in the Gnu Image Manipulation Program (GIMP Development Team, International). These values were converted to the CIELab colour space using Colour Conversion Centre v4.0a (Boronkay, 2007).

2.1.3 Rating of perceived facial health. Facial images were presented in Qualtrics, a web based data collection software. Raters were asked to rate the faces presented on a scale from 1 (very unhealthy) to 7 (very healthy), and key in 9 if they know the face in real life (though no rater indicated that they recognised any face). Seventy two Malaysian Chinese raters (28 male, 44 female; mean age = 23.54, SD=2.19; all with normal colour vision) were allowed to take as much time as they want to rate the images. All facial images were presented in a random order.

2.2 Results and Discussion

2.2.1 Preliminary test of normality. Tests of normality were performed. According to the test of Shapiro-Wilk, the perceived facial health rating and the facial redness and yellowness variables (all $p > .05$) were normally distributed. However, all the three Gabor wavelet factors and the three colour dimensions were not normally distributed ($p<.001$; positive skew) and could not be normalized using standard transformations (square root, log, reciprocal). Therefore, bootstrapping was used for all correlation and regression analyses (bias-corrected accelerated method, set to 1,000 samples), as this technique is robust to violations of normality.

2.2.2 Bootstrapped correlation analysis

Rated health was significantly correlated with Gabor wavelet factor 1, $r(143) = .30$, $p<001$; Gabor wavelet factor 2, $r(143) = -.39$, $p < .001$ and Gabor wavelet factor 3, $r(143) = -.23$, $p = 006$ (Figure 2), and marginally positively correlated with L* (lightness), $r(143) = .14$, $p = .092$ and b* (yellowness), $r(143) = .16$, $p = .058$ (Figure 3). Rated health was not significantly correlated with a* (redness), $r(143) = -.09$, $p = .309$.

2.2.3 Bootstrapped regression analysis

Bootstrapped regression analysis was performed, with rated health as the criterion variable, and the three Gabor wavelet factors, plus CIELab L*, a* and b* variables as predictor variables. A significant model was produced, F(6,142) = 10.477, $p < .001$, explaining 28.6% of variance ($R^2_{adj} = .286$). Coefficients of the model are presented in Table 1. While the three Gabor factors remain significant in the same direction as the correlations, L* is no longer significant, and b* is no longer significant with the standardised coefficient (β) is reversed, suggesting that a suppression relationship is present in the data (Chen & Krauss, 2004). To examine this possibility, the analysis was repeated using a hierarchical design in which the three Gabor wavelet factors were entered in the first step and the three CIELab variables were entered in the second block. The effects of the Gabor wavelet factors on rated health strengthened, supporting the presence of a suppression effect (Table 1)

2.3 Correlation and Regression Discussion

Consistent with results from the West (Lefevre, Ewbank, Calder, von dem Hagen, & Perrett, 2013; Lefevre & Perrett, 2015; Stephen, Coetzee, et al., 2009; Stephen, Law Smith, et al., 2009; Stephen et al., 2012), Study 1 found significant correlations between skin condition and perceived face health. The three outcomes of the Gabor Wavelet analysis obtained from the facial skin patch were all significantly correlated with the perceived face health ratings, and faces that were lighter and yellower were marginally perceived as healthier.

When entered into a regression analysis to predict rated health, the Gabor wavelets remained significant. However, the effect of L* was reduced, and the effect of b* was reversed. When this pattern of results is seen, it is often the caused by multicollinearity amongst the predictor variables. This was not the case in the current dataset, since all collinearity diagnostics were well within the acceptable range (all VIFs < 2.35; mean VIF 1.63; intercorrelations between predictors all < .7). In this case, it may be tempting to conclude that this means that L* and b* are not important predictors of rated health. However, this pattern of results is better interpreted as the result of a negative suppression effect. This effect, in which the effect of the suppressor variable(s) on the outcome variable is reduced or reversed, while the effect of the predictor variable(s) on the outcome variable is strengthened, is caused when there is no multicollinearity between the predictor and suppressor variable(s), but the variance that is shared between them is also shared with the outcome variable. In this case, the suppressor variables are positively related to the outcome variable (as revealed by the correlation analysis), but do not appear to be so in the regression model.

2.3.1 Relationship between perceived facial health and Gabor Wavelet factors. Examples of the three skin patches with highest (which the overall face were perceived as relatively healthier) and lowest values of Gabor wavelet factor 1 are presented in Figure 4. It can be seen that those skin patches with lower GW1 values display a number of red spots, as compared to those high in GW1 values, which are relatively smoother. Additionally, skin patches with the highest Gabor wavelet factor 1 (GW1) values look lighter and yellower. T-tests on the 10 skin patches with highest GW1 vs the 10 skin patches with lowest GW1 show that those high in GW1 are lighter (high GW1 M = 64.75, SD = 4.09; low GW1 M = 59.98, SD = 3.22; t(18) = 2.90, p = .010) and yellower (high GW1 M =26.85, SD = 1.53; low GW1 M = 21.25, SD = 3.76; t(18) = 4.36, p < .001) as compared to those low in GW1. There was no significant difference in redness (high GW1 M = 12.04, SD = .48; low GW1 M = 11.79, SD = 1.70; t(18) = .34, p = .736).

The top row of Figure 5 shows examples of the three skin patches with highest values of Gabor wavelet factor 2 (of which the overall faces were perceived as relatively less healthy), while the bottom row of Figure 5 shows patches with the lowest GW2 values. As found in the analysis, skin patches with higher Gabor wavelet factor 2 (GW2) values are perceived as less healthy. It can be seen that those skin patches with highest values have more scarring and holes, as compared to those scoring the lowest in GW2. There is no significant colour difference between the 10 patches with the highest and 10 patches with the lowest GW2 patches (all p > .05).

Results also showed that skin patches with higher Gabor wavelet factor 3 (GW3) values are perceived as less healthy. Top row of Figure 6 shows the three skin patches with highest values of Gabor wavelet factor 3 (for which the overall face were perceived as relatively less healthy), while bottom row of Figure 6 shows patches with the lowest GW3 values. Again, we can see that images with low GW3 values look smoother as compared to those with highest values. There is also a colour difference between high and low GW3 patches, with the 10 patches with the highest GW3 values being darker (high GW3 M = 61.15, SD = 4.35, low GW3 M = 66.74, SD = 3.43, t(18) = 3.20, p = .005), redder (high GW3 M = 12.09, SD = 1.56, t(18) = 3.78, p = .001) and less yellow (high GW3 M = 22.50, SD = 2.86; low GW3 M = 27.76, SD = 1.64; t(18) = 5.05, p < .001).

By comparing the skin pacthes obtained from the two extreme ends of the three Gabor wavelet factors, it is apparent that skin condition, including its smoothness and colour homogeneity, is associated with the perceived health of human faces. Individuals preferred smooth skin with even colouration, suggesting that these traits may act as cues to underlying physiological condition, including the level of degeneration and photodamage due to UV radiation (Kammeyer & Luiten, 2015; Naylor et al., 2011) or hormone levels (Essah, Wickham, Nunley, & Nestler, 2006; Karrer-Voegeli et al., 2009) which can reflect the person’s reproductive health.

Further, the Gabor wavelet factors were associated with colour differences, such that for GW1 and GW3, skin patches with healthy Gabor wavelet factor scores tended to be lighter and yellower. There were also marginally significant correlations between skin yellowness (b*) values measured from the patches and perceived health. However, the colour results from this study should be treated with caution since we do not have spectrophotometry data for these images, and the monitors on which the participants completed the task were not colour calibrated. Study 2 was therefore performed to replicate and clarify the role of skin colour and texture in perceptions of health in Malaysian Chinese faces.

3. Study 2: Predicting apparent health from skin patches

3.1 Introduction

Study 2 was conducted as an extension and replication of Study 1. There are three major improvements in this study as compared to the previous one. Firstly, Study 2 measured the actual skin colour of a sample of individuals with a spectrophotometer. Second, the experiments were conducted on a colour-calibrated computer, to minimize noise introduced by the monitor settings. Third, in addition to whole face ratings of apparent health, a subjective judgement of facial skin health was obtained from an independent sample of raters, to examine if perceived facial skin health (cropped from the cheek area) can be a reliable predictor of perceived facial health, as suggested by Jones et al (2004).

3.1.1 Hypotheses

We hypothesized that*:*

1. There will be a positive correlation between perceived skin health and perceived face health.

2. There will be a correlation between the Gabor Wavelet factors, and subjective ratings of skin health, such that smooth skin with homogenous colour distribution will be perceived as more healthy.

3. There will be relationships between skin colour variables and subjective ratings of skin and facial health, such that higher skin yellowness, skin redness, and skin luminance will be perceived as healthier.

3.2 Methods

The current study was divided into two main parts. In Part 1, a group of subjects were recruited and skin colour measurements were made using a spectrophotometer. Standardized photos were taken, colour calibrated and analysed using Gabor wavelet analysis and then evaluated by a group of raters for their perceived facial (whole face photos) and skin (skin patches) health in Part 2 of the study. A colour calibrated computer monitor was used to present the images to the participants.

3.2.1 Photography session and skin pigmentation. Fifty three Malaysian Chinese participants (24 male, 29 female; mean age = 20.62, SD=1.32) volunteered to participate in this study. They were all students from University of Nottingham Malaysia Campus. Facial photographs were taken under the same controlled conditions as described in Study 1. All images were taken with a Gretag Macbeth Mini ColorChecker colour chart included in the frame, and were colour-calibrated using a least squares transform from the colours represented in the image to published values of the patches on the colour card, in Psychomorph (Tiddeman, Stirrat, & Perrett, 2005).

Subjects' skin colour was measured using a handheld Konica Minolta CM2600D spectrophotometer. This is a painless, non-invasive method utilising the Commission International de l'Eclairage (CIE) L*a*b* colour system measuring the luminance (L*), redness (a*) and yellowness (b*) of the skin.

Three facial regions of participants were measured: the right cheek, left cheek and forehead. Two sets of measurements were taken for each region, and scores were averaged across repetitions and regions for analysis. The spectrophotometer was calibrated each time it was switched on.

All facial photographs were aligned on eye location using Psychomorph (Tiddeman & Perrett, 2001). Matlab was used to create a skin patch by cropping the left cheek part of the photos as described in Study 1. Gabor wavelet analysis was performed, using Psychomorph (Tiddeman & Perrett, 2001), on the 53 skin patches created, as in Study 1. Principle component analysis was then performed, within the same software, to reduce these 32 indices into a smaller set of factors. Three factors (named Gabor wavelet factor A, Gabor wavelet factor B and Gabor wavelet factor C) were selected, with eigenvalues higher than 1, which together accounted for 96.87% of the variance.

3.2.2 Rating of perceived facial health. Forty eight Malaysian Chinese were recruited as the raters of perceived facial health, with 21 males and 27 females (mean age = 21.96, SD=2.81). All raters were students pursuing undergraduate or postgraduate degrees at two private institutions of higher education in Malaysia - University Putra Malaysia (UPM) and Universiti College Sedaya International (UCSI). All raters had normal or corrected vision; and normal colour vision.

Colour calibrated facial images were presented using Psychopy (Peirce, 2009), on a computer attached to a 15” TFT monitor that was colour calibrated with a DataColor Spyder3 Pro. All the facial images were presented once to the participants, one at a time, for one second, during the Preview Phase. No rating was made during the Preview Phase. Raters were then presented with the same facial images again, one image at a time, during the Rating Phase where they were asked to rate the faces shown on a scale from 1 (very unhealthy) to 7 (very healthy). Raters were requested to key 9 if they knew the pictured individual in real life (though no rater indicated that they recognised any face). They were allowed to take as much time as they wanted for each trial. The images were presented to the participants in random order.

3.2.3 Rating of skin health. Another 42 raters (22 male, 20 female; mean age = 22.5, SD=3.022) were recruited to judge the apparent health of the skin. All raters were Malaysian Chinese university students, with normal colour vision.

Skin patches were presented the same way as the full face images. Participants were asked to rate the skin patches shown on a scale from 1 (very unhealthy) to 7 (very healthy), and to key in 9 if they thought that the patch presented was not clear (though no rater indicated that any patch was unclear). The skin patches were presented in random order.

3.3 Results and Discussion

One participant's skin luminance (L*) value was more than 3 standard deviations above the mean. Excluding her data from the analysis did not change the pattern of results, so she is included in the results reported here. Since Shapiro-Wilk tests of normality were performed on the two ratings (perceived facial health, and perceived skin health), the three facial colours (luminance, redness and yellowness), and the three Gabor wavelet factors. Results showed that both perceived facial health and perceived skin health are normally distributed, together with Gabor wavelet factor A, and facial skin yellowness (all p>.05). All the other factors: facial luminance (positive skew, leptokurtic) facial redness (negative skew, leptokurtic), Gabor wavelet factor B (positive skew, leptokurtic) and Gabor wavelet factor C (positive skew, leptokurtic) were not normal, and could not be normalized with standard transformations (square root, log, reciprocal). Bootstrapping was therefore used for all analyses, since this produces results that are robust to violations of normality.

3.3.1 Correlation analyses

Pearson correlation was conducted to investigate the relationship between perceived facial health and rated skin health. As expected, we found a significant positive correlation, r =.678, p<.001, between perceived face health and rated skin health.

As predicted, results indicated significant correlations between rated skin health, rated facial health and Gabor wavelet factor B (skin health r (53) =-.80, p<.001; face health r (53) = -.57, p < .001; Figure 7) and between rated skin health, rated face health and Gabor wavelet factor C (skin health r (53) =-.35, p =.011; face health r (53) = -.30, p = .032) (Figure 8).

There was no significant correlation between rated skin health and Gabor wavelet factor A, (r (53) = .12, p=.411), though it was marginally significant for rated face health r (53) = .24, p = .090).

These results were consistent with Jones and colleagues' (2004) previous finding that faces with healthier skin were judged as more attractive. Here, we found an agreement between the perceived health of cheek skin patches and facial images, in an Asian sample. This suggests that, even when no facial structure information is visible, the condition of skin patches can be used to predict the apparent health of human faces.

We found a significant correlation between perceived face health, skin health and facial yellowness, (skin health r (53) = .36, p = .008; face health r (53) = .307, p = .025), between perceived skin health and facial luminance, (r (53) = .43, p = .002), but not perceived face health and skin luminance (r (53) = .02, p = .87), and no significant relationship between skin redness and perceived skin health (r (53) = -.22, p = .123) or face health (r (53) = -.02, p = .91; Figure 9).

Skin yellowness was found to be positively correlated with both skin health and facial health ratings, while skin luminance was positively correlated with skin health. This result is consistent with previous studies in Western, African and Asian populations (Stephen et al., 2011; Stephen, Law Smith, et al., 2009; Tan et al., 2017).

3.3.2 Regression analyses

For the bootstrapped regression analysis predicting perceived face health, the model was significant (F(6,52) = 7.02, p < .001), predicting 41.0% of the variance (R^2_{adj}=.410). Gabor factor B was a significant predictor of perceived face health, Gabor factor A, lightness and redness were marginally significant. Gabor factor C and yellowness were not significant predictors (Table 2), despite their zero-order correlations with perceived face health being significant. All VIFs were within the acceptable range (all < 2.10), indicating that this effect was not due to multicollinearity, and suggesting that a suppression effect is present in the data.

For the bootstrapped regression analysis predicting perceived skin health, a significant model was produced (F(6,52) = 16.65, p < .001), predicting 64.4% of variance ($R^2_{adj} = .644$). Gabor factor B was a significant predictor in the model, lightness was marginally significant. Gabor factors A and C, and redness and yellowness were not significant predictors, despite yellowness and Gabor factor C having significant zero order correlations with perceived face health. All VIFs were within the acceptable range (all < 2.10), indicating that this effect was not due to multicollinearity, and suggesting that a suppression effect is present in the data.

4. General Discussion

4.1 The importance of skin texture as a predictor of perceived facial health.

The current studies (Study 1 and 2) found an association between skin condition and perceived face health. By using only skin patches extracted from the left cheek part of the face images, Study 2 found agreement between perceived skin health rated from skin patches and perceived facial health, showing that one can make inferences about another person's apparent health merely by assessing the skin condition of the cheek. A similar finding has previously been observed in the West when Jones et al. (2004) found that skin patches which were rated as healthiest by the Caucasian raters belonged to faces that were rated as most attractive. This suggests that skin condition is an important predictor of perceived health in human faces of different ethnicities.

Both Study 1 and Study 2 found associations between perceived facial health, perceived skin health and the Gabor Wavelet factor measures of skin texture, with smoother skin perceived as healthier. The result of Studies 1 and 2 are consistent with previous studies in Western samples. Fink and colleagues (Fink et al., 2012; Fink et al., 2008; Matts et al.,

2007) also showed that faces with even colouration were judged as healthier and more attractive in Caucasian samples, and previous studies have shown associations between even skin colour distribution and perceived age (Fink et al., 2012; Matts et al., 2007).

Previous research (Roberts et al., 2005) has found an association between the apparent health of skin patches and heterozygosity at three key loci in the major histocompatibility complex (MHC). Heterozygosity in the MHC is thought to be associated with enhanced immune function. Roberts and colleagues (2005) also found agreement between rated skin health and facial attractiveness, suggesting that apparent skin health may be a valid cue to human health. Future studies should examine links between skin texture and underlying measures of physiological health, since such associations would suggest that smooth skin texture acts as a valid cue to human health (Coetzee et al., 2009b).

4.2 Skin colour as a predictor of perceived health

Skin yellowness and lightness were significantly positively correlated with perceived skin health in colour calibrated images in Study 2 and marginally positively correlated with the perceived skin health in uncalibrated images in Study 1. In Study 2, skin yellowness also predicted perceived face health. This is in line with previous studies finding that skin colour is associated with perceived health and attractiveness in Caucasian (Lefevre, Ewbank, Calder, Hagen, & Perrett, 2013; Lefevre & Perrett, 2015; Pezdirc et al., 2017; Stephen et al., 2011; Stephen, Law Smith, et al., 2009), African (Coetzee et al., 2012; Stephen et al., 2011) and Asian (Tan et al., 2017) faces, using experimental manipulations and colour calibrated stimuli and monitors.

Previous studies have established the relationship between carotenoid consumption and skin yellowness via both correlational and experimental research. Stephen et al. (2011) showed that individuals with higher dietary carotenoid intake tend to have slightly yellower skin tone than those with low dietary carotenoid intake. It was found in an interventional study that supplementation with a smoothie rich in carotenoids enhances skin yellowness (Tan, Graf, Mitra, & Stephen, 2015), in turn increasing perceived health (Tan et al., 2017). Carotenoids have been found to be beneficial to the immune (Friis et al., 2001) and reproductive systems (Forman et al., 1996), suggesting that skin yellowness, associated with carotenoid colouration, may be a valid cue to health.

However, it should be noted that some more recent studies have found mixed results relating to the relationship between facial skin yellowness and perceived health and attractiveness. First, one correlational study failed to find a significant relationship between skin yellowness (b*) and rated attractiveness of faces using uncalibrated images and monitors (Jones, 2018), and a second found significant positive correlations between skin yellowness (b*) and perceived health and attractiveness for male but not female faces in colour calibrated images presented online on uncalibrated monitors. While it has been suggested that online data collection via participants' own uncalibrated monitors is suitable for studies examining the role of colour in face perception, it should be noted that this claim rests on a single comparison of 43 online and 13 laboratory-based participants in an experimental design (Lefevre, Ewbank, Calder, von dem Hagen, Perrett, et al., 2013). It may be the case that, for less sensitive correlational designs, colour calibration of images and monitors may be more important. This is supported by the weaker relationship found in Study 1 (in which images and monitors are uncalibrated) compared to study 2 (in which images and monitors are calibrated).

A further related study using calibrated images and monitors asked mainland Chinese and UK-based Caucasian participants to choose which is more attractive from pairs of Caucasian and Chinese faces in which one was increased in yellowness by 3 units of b* and one was decreased in yellowness by 3 units of b*. While Caucasian participants preferred the increased yellowness faces, mainland Chinese participants preferred the decreased yellowness faces, suggesting cross-cultural differences in colour preferences (Han et al., 2017). Relatedly, Tan et al (2017) asked Malaysian Chinese participants to manipulate the skin colour of colour-calibrated Malaysian Chinese face photographs along an axis associated with consumption of a carotenoid-rich fruit and vegetable smoothie to make the faces look as healthy as possible. Participants chose a significant increase in smoothie-induced colour change (equivalent to L* -0.31 units; a* +0.37 units; b* +1.15 units). Two potential explanations are offered for this apparent conflict. First, the forced choice methods used by Han et al (2018) do not allow the measurement of the amount of colour change that participants perceive as healthiest, nor for the characterisation of the shape of the preference curve associated with changes in skin colour. While it is clear that the preferred level of skin yellowness in the mainland Chinese population is reduced compared to UK-based Caucasians, it is not clear to what extent this preference is reduced. The optimum may even be positive if the rate at which attractiveness reduces is steeper as skin yellowness is increased above the optimum than when skin yellowness is reduced below the optimum. Second, if culture influences people’s preferences for skin colour, it should be noted that Malaysian Chinese participants have been shown in face recognition tasks to use a fixation pattern intermediate between that of mainland Chinese participants (who fixate preferentially on the centre of the face) and Western Caucasian participants (who fixate preferentially on the eyes and the mouth) (Tan, Stephen, Whitehead, & Sheppard, 2012). It has been suggested that, since Malaysian Chinese people are ethnically Chinese but have extensive exposure to Western culture and Caucasian faces, that their perceptions of faces, and cognitive style more generally) are intermediate between Western and mainland Chinese. Our results are in accordance with this pattern, with participants showing a moderate preference for skin yellowness.

Lighter skin tone was positively correlated with perceived skin health, but not perceived face health. This is consistent with the finding by Stephen et al. (2011) which found that lighter skin tone was perceived as healthier by Caucasians and Han et al (2018) who found that mainland Chinese prefer faces with lighter skin. Melanin which contributed to skin darkness, filters a large amount of UV radiation, making limited amounts of UV reach the dermis and be available for the synthesis of vitamin D (Hochberg & Templeton, 2010). Lack of Vitamin D may increase risk of having musculoskeletal pain (Heath & Elovic, 2006), and has been found to give impact on one's emotional wellbeing and cognitive ability (Wilkin et al., 2006).

We did not find a relationship between perceived health and skin redness in either study. Previous studies using experimental methods have found that increased skin redness (Stephen, Law Smith, et al., 2009), particularly redness associated with oxygenated blood colouration (Re, Whitehead, Xiao, & Perrett, 2011; Stephen, Coetzee, et al., 2009) is perceived as healthy. However, a number of previous correlational studies have failed to find this relationship (Foo, Simmons, & Rhodes, 2017; Scott et al., 2010; Stephen et al., 2012), and Han et al (2018) found a reduced preference for facial redness in a mainland Chinese sample. While experimental methods typically manipulate a single variable in isolation, correlational studies have large numbers of appearance variables visible simultaneously. It may be the case that this additional information, as well as potential relationships between appearance variables reduces or eliminates the importance of redness as a predictor of perceived health in correlational studies.

4.3 Suppression effects

A number of the skin quality variables that showed significant, positive zero-order correlations with perceived skin health (Studies 1 and 2) and perceived face health (Study 2) were not significant predictors of the perceived health variables when entered into a regression analysis with the other skin quality variables. In particular, yellowness (Studies 1 and 2), lightness (Study 1) and Gabor factor C (Study 2) became nonsignificant predictors in the models. Multicollinearity was not an issue in the dataset, with all VIF scores within the acceptable range. It may be tempting to conclude from this that these predictor variables are not important predictors of perceived health. However, this pattern of results is more correctly understood as a suppression effect (Chen & Krauss, 2004). In a suppression effect, the predictor variables share some portion of variance, and part of the portion of variance that is shared between predictor variables is also shared with the outcome variable. This causes an inflation of the predictive value of one or more of the predictor variables, while reducing the observed predictive value of the suppressor variables, often reducing their apparent predictive value to non-significance, or even reversing the direction of the relationship between the suppressor variable(s) and the outcome variable. Researchers should be vigilant for this effect in future studies, and ensure that this pattern of results is not erroneously interpreted as lack of predictive power.

Russell and colleagues (2016) found in their study that facial contrast, specifically the luminance and colour contrast between facial features and their surrounding regions serve an important cue for perceived health, and is dimorphic in Caucasian and Asian faces (Jones, Russell, & Ward, 2015; Russell, 2009). Jones and colleagues (Jones, Porcheron, Sweda, Morizot, & Russell, 2016) found that luminance in periorbital areas, redness in cheek, and overall facial yellowness enhanced apparent health. However, the current studies assessed colour and texture globally, without assessing the contribution of skin colour distribution to perceptions of health. These should be addressed in future work. Further, since recent correlational studies using single colour estimates in the absence of homogeneity data have failed to find significant relationships with perceived health of Caucasian faces (Jones, 2018), our results highlight the importance of considering colour homogeneity and distribution.

4.4 Conclusion

Both skin texture and skin colour were found to contribute to the judgment of perceived face health and rated skin health in an Asian sample. One can spontaneously make inferences about another person’s health status by attending to the subtle clues obtained from the face. Previous studies (Baudouin & Tiberghien, 2004; Coetzee, Perrett, & Stephen, 2009; Jones & Little, 2001; Little, Apicella, & Marlowe, 2007; Penton-Voak et al., 2001; Rhodes et al., 2003b; Swaddle & Cuthill, 1995) have highlighted the significance of facial structure in the perception of apparent health and attractiveness. Whilst some recent research (Coetzee et al., 2012; Fink et al., 2012, 2001; Jones, Little, Burt, et al., 2004; Lefevre & Perrett, 2015; Samson, Fink, & Matts, 2010; Stephen, Coetzee, et al., 2009a; Stephen et al., 2011) has started giving more emphasis to the importance of skin condition in the judgement of health and attractiveness, no such study has been conducted in an Asian setting. In line with what was observed in the West, the current study showed that Malaysian Chinese participants’ perception of facial and skin health is predicted by skin texture and colour. Specifically, smooth skin with homogenous colouration, and slightly yellower was perceived as healthier.

Open Practices

The data associated with this research are available at DOI: 10.6084/m9.figshare.5848164

Sufficient data is provided for an independent researcher to reproduce all reported results.

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Figure 1: Examples of three skin patches produced by cropping the left cheek area of 143 facial photographs with Matlab.

Figure 2. Correlation between health rating and Gabor wavelet factors 1 (top), 2 (middle) and 3 (bottom).

Figure 3. Correlation between health rating and luminance (top), skin redness (middle) and skin yellowness (bottom).

Figure 4. Skin patches from the left check of subjects with highest (top row) and lowest (bottom row) Gabor wavelet factor 1 values

Figure 5. Skin patch from left check with highest (top row) and lowest (bottom row) Gabor wavelet factor 2 values

Figure 6. Skin patch from left check with highest (top row) and lowest (bottom row) Gabor wavelet factor 3 values

Figure 7. Correlations of Gabor wavelet factors A (top), B (middle) and C (bottom) with rated skin health (left) and rated face health (right)

Figure 8. Correlation between skin luminance (L; top), redness (a*; middle) and yellowness (b*; bottom) and rated skin health (left) and rated face health (right) in Study 2.*

Figure 9.

Table 1: Coefficients of the regression model from Study 1. DV = Perceived skin health. *** p < .001

Model	Predictor	β	VIF
1	Gabor factor 1	.30***	1.00
	Gabor factor 2	-.39***	1.00
	Gabor factor 3	-.23***	1.00
2	Gabor factor 1	.32***	1.36
	Gabor factor 2	-.41***	1.10
	Gabor factor 3	-.34***	2.22
	L*	.05	1.28
	a*	.14	1.49
	b*	-.09	2.35

Table 2: Coefficients of the regression models from Study 2. *** $p < .001$, † $p < .01$

DV	**Model**	**Predictor**	**β**	**VIF**
Perceived skin health	1	Gabor factor 1	.03	1.00
		Gabor factor 2	-.80***	1.00
		Gabor factor 3	.01	1.00
	2	Gabor factor 1	.05	1.33
		Gabor factor 2	-.78***	2.07
		Gabor factor 3	.02	1.69
		L*	.17†	1.24
		a*	.14	1.27
		b*	.06	1.25
Perceived face health	1	Gabor factor A	.25†	1.00
		Gabor factor B	-.47***	1.00
		Gabor factor C	-.17	1.00
	2	Gabor factor A	.23†	1.33
		Gabor factor B	-.55***	2.07
		Gabor factor C	-.22	1.69
		L*	-.22†	1.24
		a*	.21†	1.27
		b*	.19	1.25

Figure 1

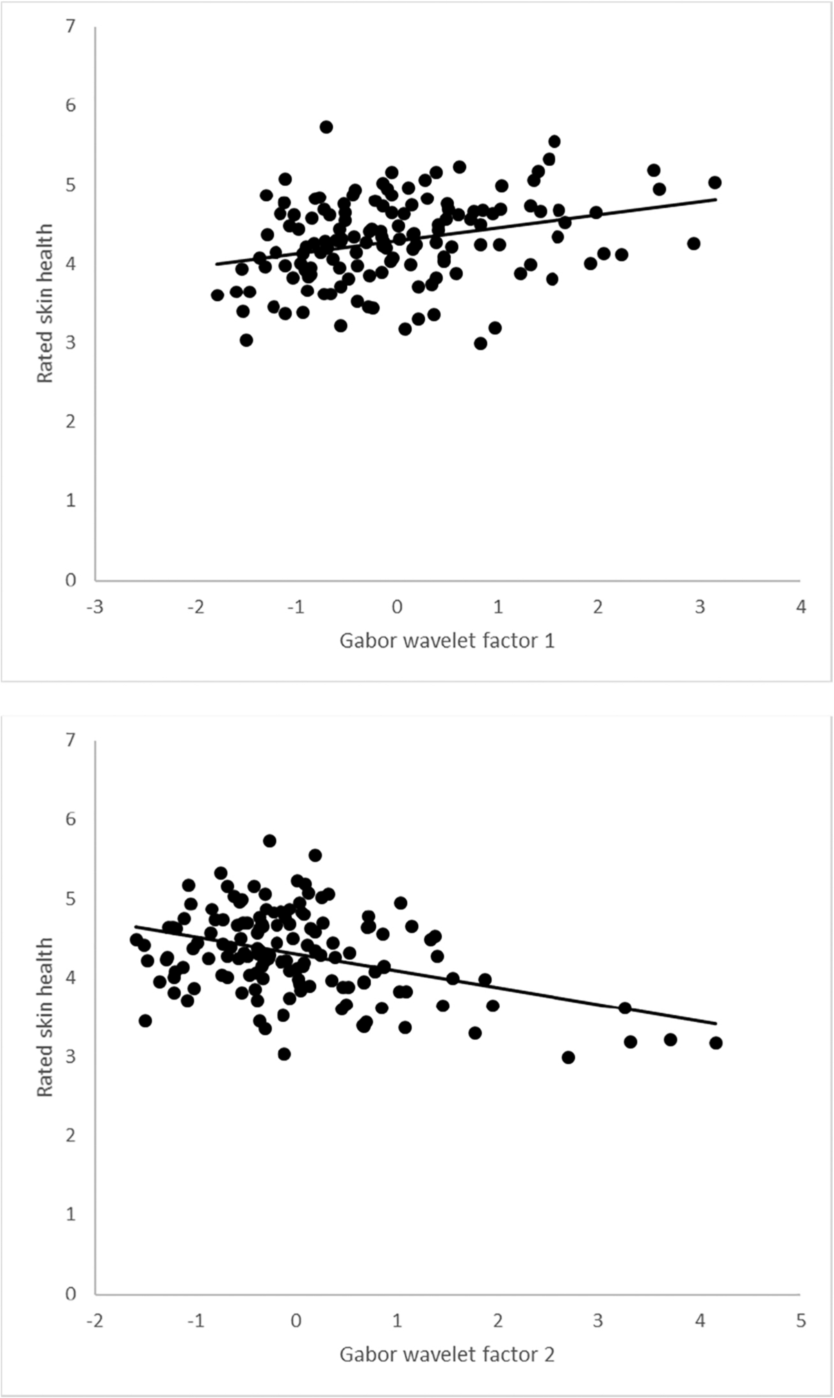

Rated skin health
7
6
5
4
3
2
1
0
-3
-2
-1
0
1
2
3
4
Gabor wavelet factor 1
Rated skin health
7
6
5
4
3
2
1
0
-2
-1
0
1
2
3
4
5
Gabor wavelet factor 2

Figure 2r1

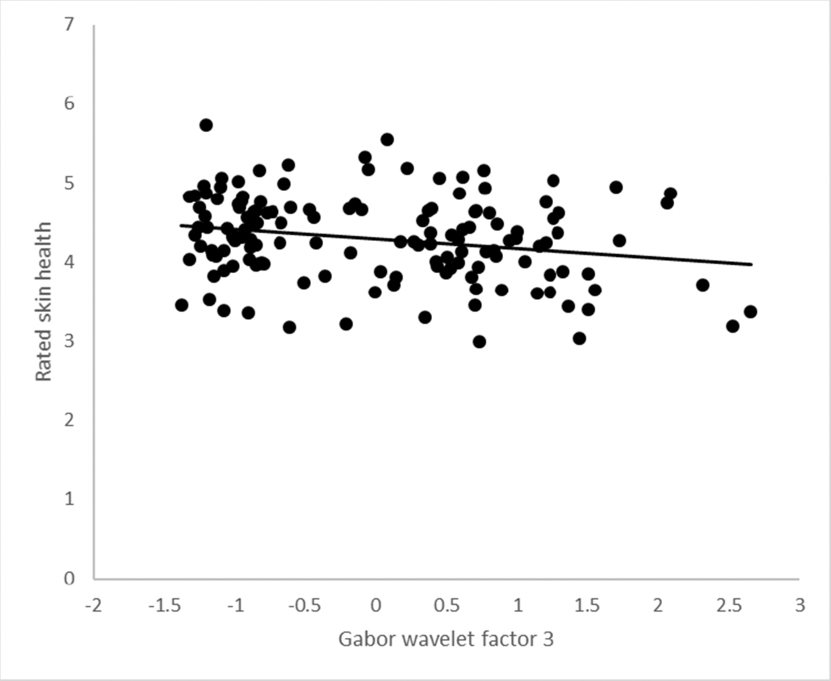
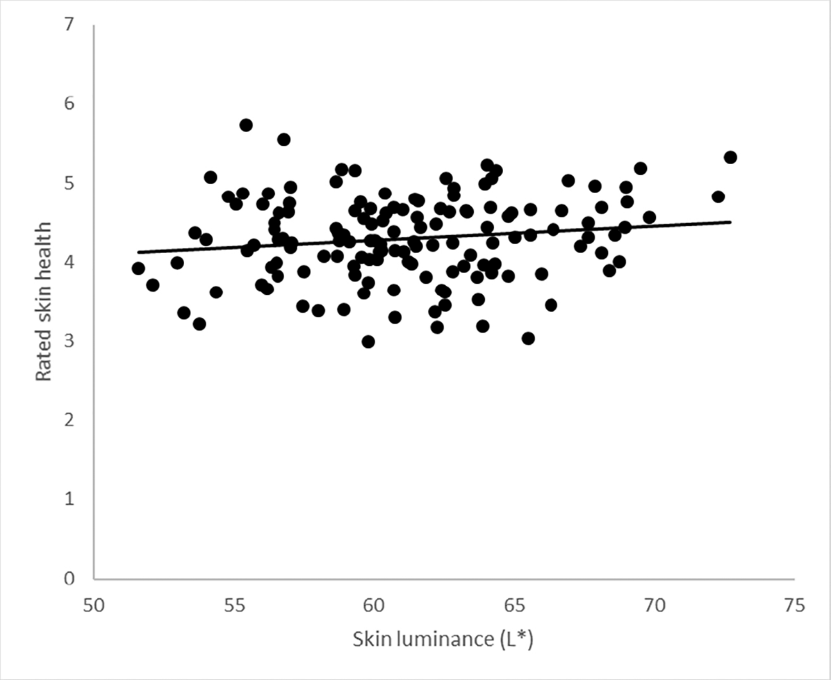

7
6
5
4
3
2
1
0
Rated skin health
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
Gabor wavelet factor 3

Figure 2r2


7
6
5
4
3
2
1
0
Rated skin health
50
55
60
65
70
75
Skin luminance (L*)

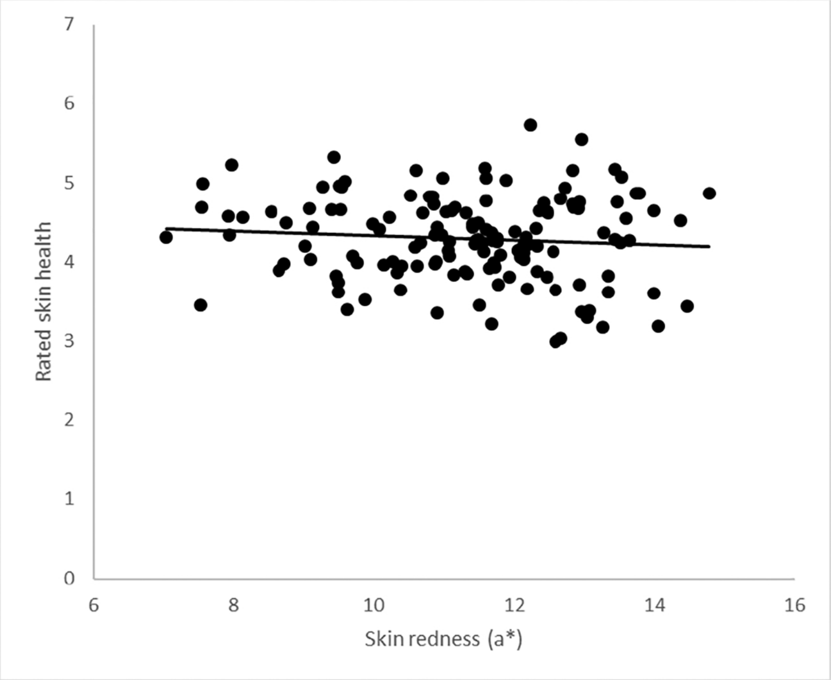

7
6
5
4
3
2
1
0
Rated skin health
6
8
10
12
14
16
Skin redness (a*)

Figure 3r1

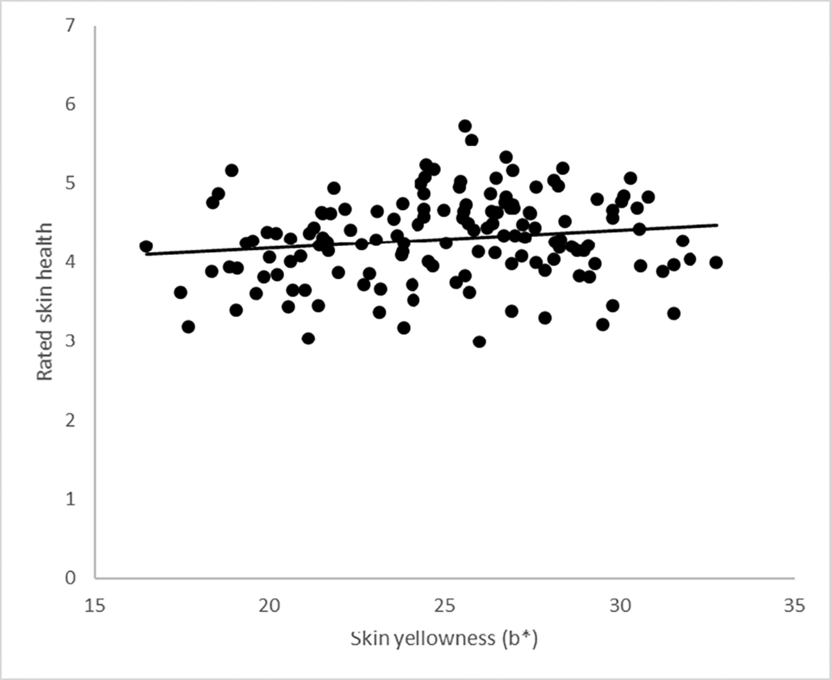


Figure 3r2

Figure 4

Figure 5

Figure 6

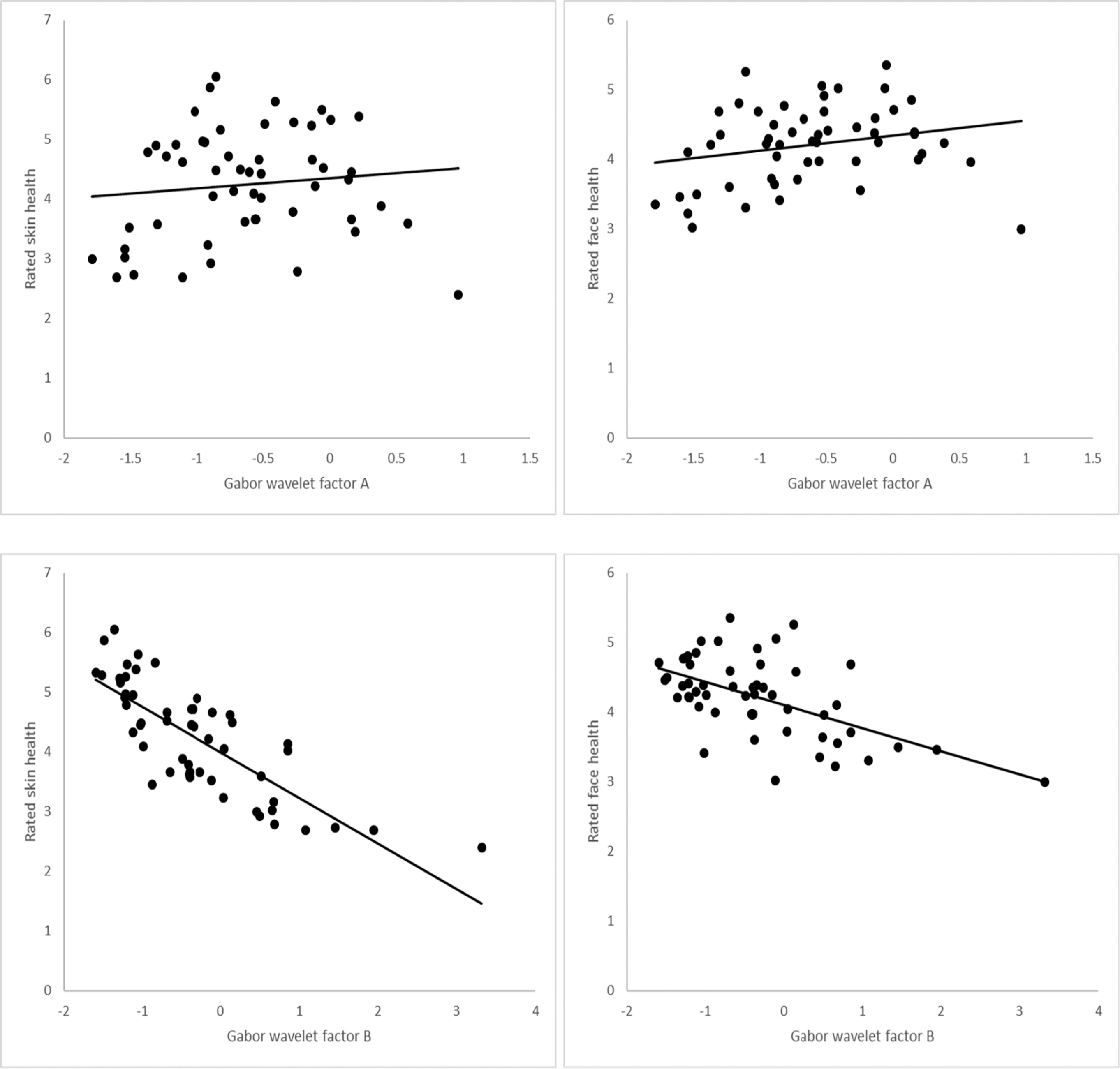
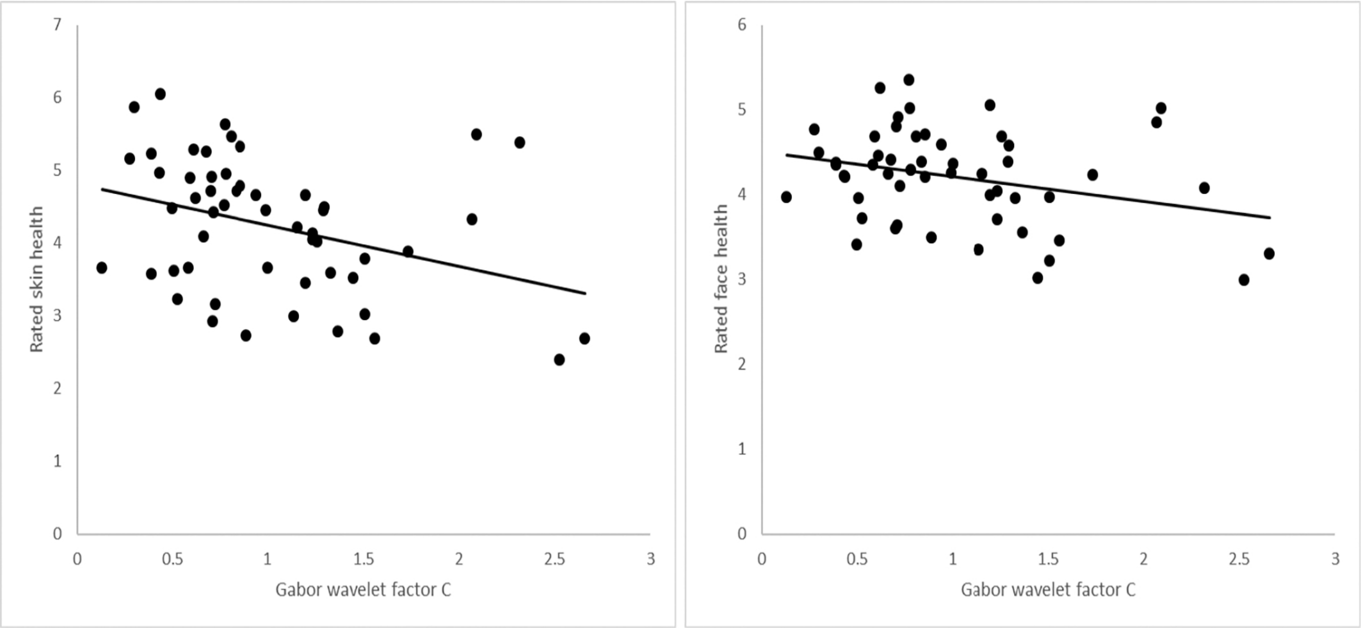

Rated skin health
7
6
5
4
3
2
1
0
-2
-1.5
-1
-0.5
0
0.5
1
1.5
Gabor wavelet factor A
Rated face health
6
5
4
3
2
1
0
-2
-1.5
-1
-0.5
0
0.5
1
1.5
Gabor wavelet factor A
Rated skin health
7
6
5
4
3
2
1
0
-2
-1
0
1
2
3
4
Gabor wavelet factor B
Rated face health
6
5
4
3
2
1
0
-2
-1
0
1
2
3
4
Gabor wavelet factor B

Figure 7r1



Rated skin health
0
1
2
3
4
5
6
7
0
0.5
1
1.5
2
2.5
3
Gabor wavelet factor C
Rated face health
0
1
2
3
4
5
6
0
0.5
1
1.5
2
2.5
3
Gabor wavelet factor C

Figure 7r2

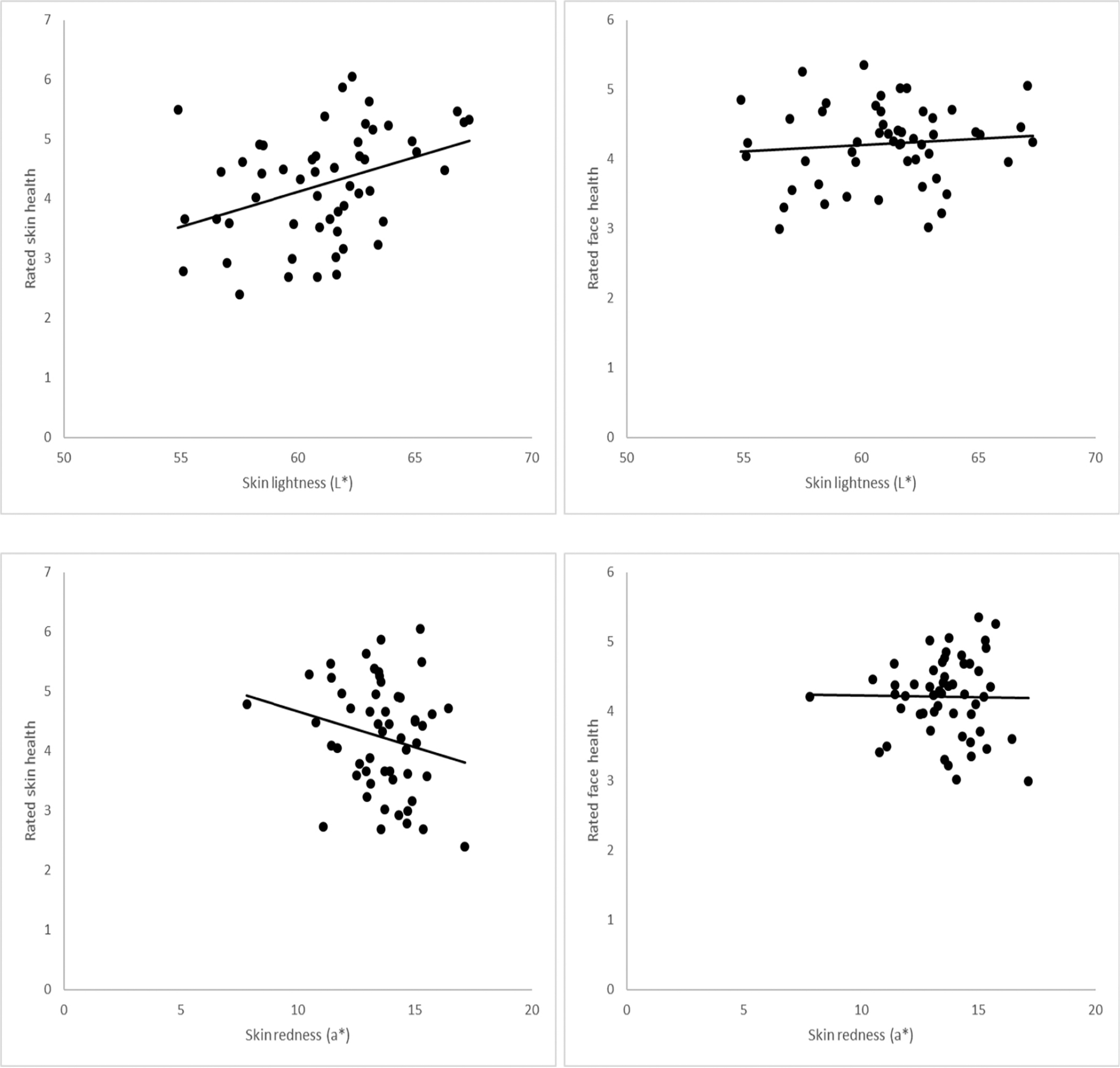

Rated skin health
Skin lightness (L*)
Rated face health
Skin lightness (L*)
Rated skin health
Skin redness (a*)
Rated face health
Skin redness (a*)
0
1
2
3
4
5
6
7
50
55
60
65
70
0
5
10
15
20

Figure 8r1

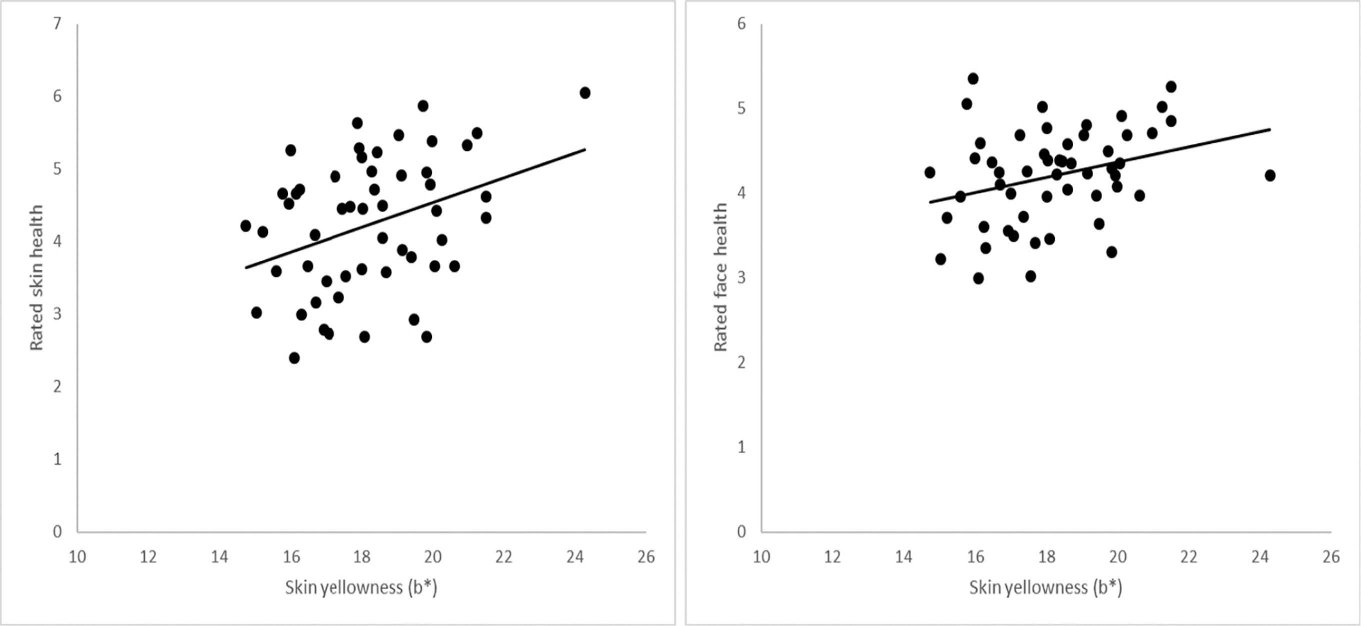

7
6
5
4
3
2
1
0
Rated skin health
10
12
14
16
18
20
22
24
26
Skin yellowness (b*)
6
5
4
3
2
1
0
Rated face health
10
12
14
16
18
20
22
24
26
Skin yellowness (b*)

Figure 8r2

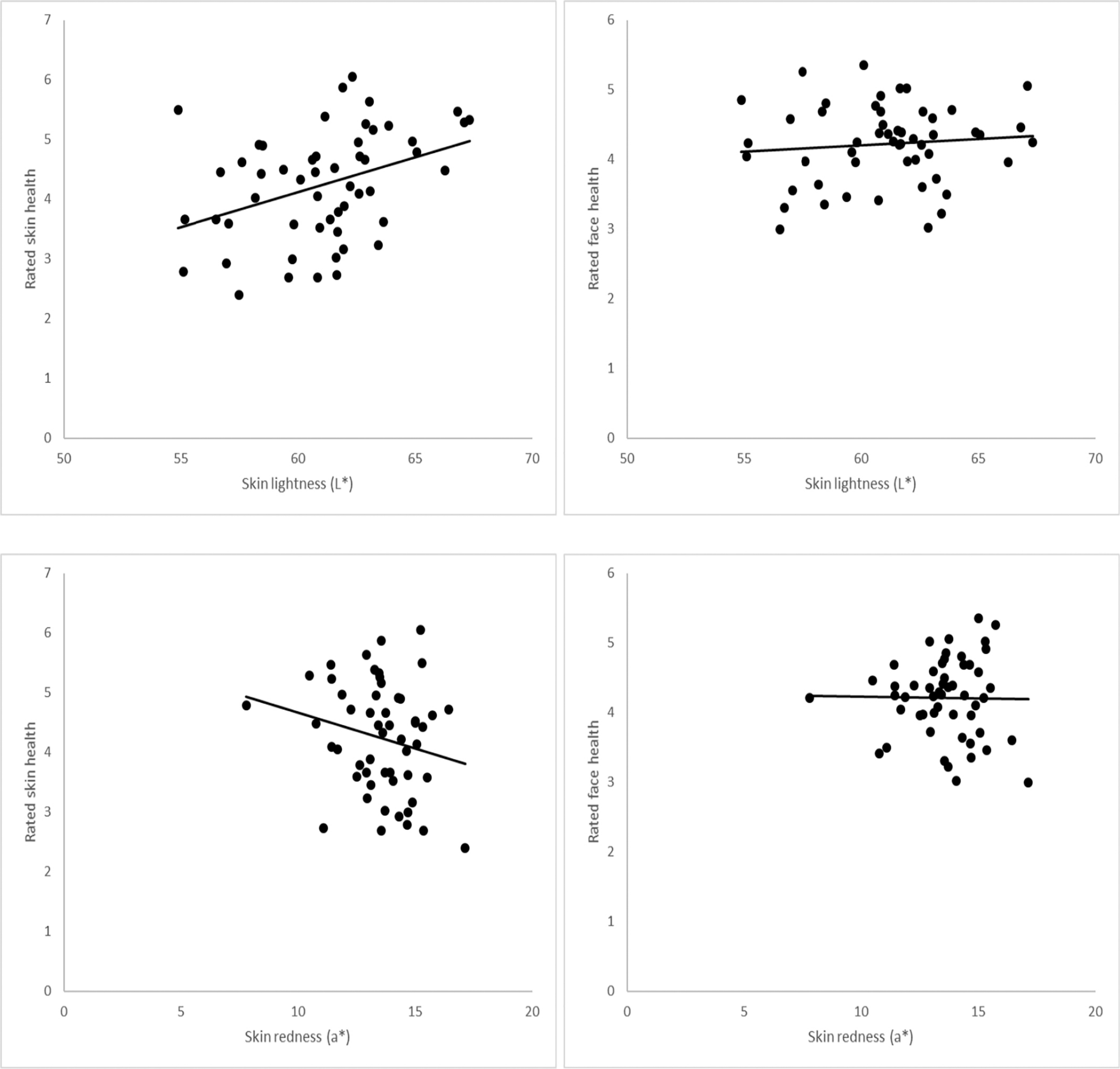

Rated skin health
Skin lightness (L*)
Rated face health
Skin lightness (L*)
Rated skin health
Skin redness (a*)
Rated face health
Skin redness (a*)
0
1
2
3
4
5
6
7
50
55
60
65
70
0
5
10
15
20

Figure 9r1

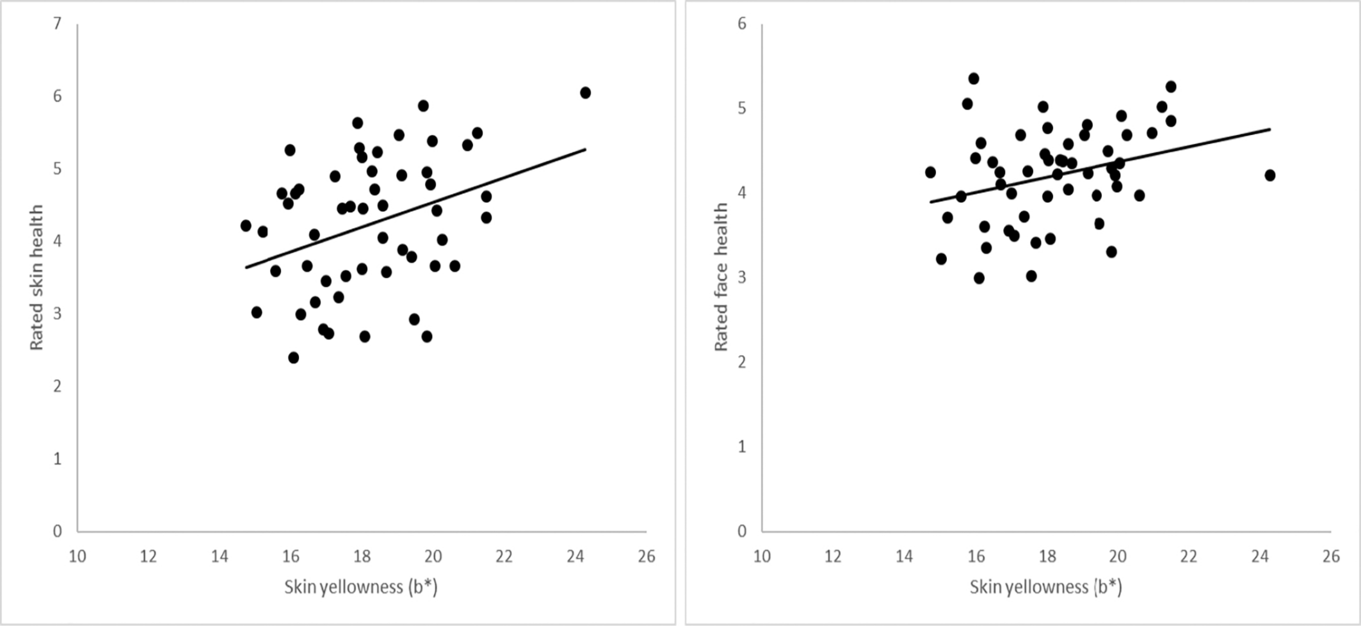

Rated skin health
0
1
2
3
4
5
6
7
10
12
14
16
18
20
22
24
26
Skin yellowness (b*)
Rated face health
0
1
2
3
4
5
6
10
12
14
16
18
20
22
24
26
Skin yellowness (b*)

Figure 9r2