Intrareliability and Interreliability of Low-Cost Devices to Measure Skin Tone, Moisture, and Oiliness

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ABSTRACT

OBJECTIVE: To evaluate the intraexaminer and interexaminer reliability of low-cost commercial devices to measure skin tone, moisture, and oiliness; determine associations with the Fitzpatrick Scale; and compare results with those of widely used commercial equipment.

METHODS: Researchers bilaterally collected a total of 36 samples from 18 participants. For data acquisition, two experienced raters were considered for skin index assessment. Evaluations were conducted independently, with measurements taken at two different times with an interval between them, thus enabling intrarater and interrater reliability measures. The measurements were made with two low-cost devices and compared with those acquired using standard equipment for such analyses.

RESULTS: For the intraexaminer reliability results, the authors observed intraclass correlation coefficient ranging from moderate to high reliability between these tools (0.747-0.971). Regarding interexaminer reliability, intraclass correlation coefficient ranging from moderate to high (0.541-0.939) were observed. For the results of the correlations, a moderate to a large association was observed for skin tone. However, a small association for moisture was observed among the tools.

CONCLUSIONS: Evaluations of skin tonality, oiliness, and moisture showed moderate to excellent intrareliability and interreliability. These methods can be applied in different environments, especially clinics, because of their low cost and ease of use.

KEYWORDS: clinical evaluation, data accuracy, epidermis, moisture, oiliness, reproducibility of results, skin care, skin pigmentation, skin tone

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INTRODUCTION

The integumentary system performs substantial roles in organic homeostasis, including protecting the internal environment, regulating body temperature, maintaining cellular fluid, and perceiving somesthetic stimuli. Body-dependent factors, such as age, ethnicity, and sex influence the structural and biomechanical condition of the skin.[1,2] The interrelationships of different factors induce a cause-effect cycle and, consequently, repercussions on skin properties and performance.[3]

Skin assessment using noninvasive methods is an accessible and safe approach. The procedure measures intercellular properties related to barrier function, including hydration, phototype, temperature, and pH.[4] Further, water and lipid content is a subclinical biomarker in different dermatologic conditions, and melanin level indicates the degree of sensitivity to erythema, immunosuppression, and photoaging from UV radiation.[5–8] Equipment for measuring the stratum corneum uses technology based on capacitance, conductance, and impedance, depending on the electrical properties of the skin.[9,10] There is a positive relationship between different types of skin measurement devices.[11–13]

The variety of equipment points to the need for discernment based on reliability with different examiners, time intervals, anatomic sites, and clinical protocols. Evaluating inexpensive, easy-to-use equipment for determining intrinsic characteristics of the skin will provide evidential support to the scientific and clinical community for the use of noninvasive methods in planning a therapeutic approach in different contexts of health. Using this type of technology with patients with moisture-associated skin damage may assist in the prevention of a complex and heterogeneous condition. For these previously mentioned conditions, older adults may be particularly affected and would benefit from such noninvasive skin assessments.[14,15]

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In this study, the authors assessed the intraexaminer and interexaminer reliability of low-cost commercial devices to measure skin tone, moisture, and oiliness; determined associations with the Fitzpatrick Scale; and compared results with those of widely used commercial equipment.

METHODS

Study Design and Procedures

The authors followed the Guidelines for Reporting Reliability and Agreement Studies in conducting this reliability study.[16] The researchers responsible for the measurement of skin indices were blind to the clinical characteristics of each participant evaluated. The ethics committee of the Clinical Hospital of the Ribeirão Preto Medical School, University of São Paulo, approved the study procedures (protocol no. 2.748.430).

The authors performed a sample size calculation to detect a moderate intraclass correlation coefficient (ICC = 0.75)[17] with an a priori calculation based on available scientific literature.[18] For a coefficient of confidence of 0.95 and amplitude of the CI for the ICC of 0.30, the authors determined that a minimum sample size of 34 participants was needed.

Two experienced raters who were trained in data collection and familiarized with the equipment performed all skin index assessments. The raters were considered trained after they were familiarized with the equipment and completed the pretest execution before the valid tests for the study. After the end of the training protocol, the two raters independently performed the index measurements at two different time points.

Participants

Eighteen participants (13 women and 5 men) with a mean age of 21.44 (SD, 3.22) years and no history of systemic or localized skin lesions on the forearm or thigh were evaluated. Researchers conducted evaluations bilaterally, for a total of 36 samples (36 forearms samples and 36 thigh samples). Participants were required not to use any topical agents on their skin for 3 hours prior to the evaluation.

Evaluation Procedure

Participants were positioned in dorsal decubitus with the areas to be evaluated exposed. For the forearm, a midpoint was determined between the lateral epicondyle and the ulnar styloid process. For the thigh, a midpoint was determined between the anterosuperior iliac spine and the superior border of the patella. The environment was controlled at 22 °C (± 2 °C) and 50% humidity. The flowchart of the study is depicted in Figure 1.

Skin Index Measurements. Researchers used Doctor Skin Phototype (Doutor da Estética, Hortolândia) to analyze skin tone indices and Doctor Skin (Doutor da Estética, Hortolândia) to measure moisture and oiliness. The Doctor Skin device measures the moisture, oiliness, and elasticity levels of the skin using biological impedance, with measurements of moisture and oiliness given as percentages and elasticity described as unbalanced, slightly balanced, or fully balanced. This evaluation tool is inexpensive compared with the standard equipment used for these analyses.

The assessment took place in two parts. First, one rater took three consecutive measurements at each of the two measurement locations, and then the second rater conducted the same measurements. Each rater conducted the measurement individually and without the other rater present. After a 40-minute interval, the raters repeated the measurement process using the same method previously imposed, in order to analyze the intrarater and interrater reproducibility and reliability. See Figure 2 for a description of the positioning, evaluation method, and technical specifications of the equipment as presented in the manufacturer's manual.

Fitzpatrick Skin Type Scale. A single expert rater classified the skin tone of the participants based on the Fitzpatrick Scale.[19] The scale comprises six different tone classifications, with type I being a pale white skin, type II being a white skin, type III being a light brown skin, type IV being a moderate brown skin, type V being dark brown skin, and finally type VI being a black skin.[19] The classification was performed during the participant's initial skin assessment.

MoistureMeterD. To evaluate the reliability of the indices obtained using the low-cost commercial equipment, researchers also used the MoistureMeterD (Delfin Technologies Ltd) to evaluate participants' relative skin moisture indices. The MoistureMeterD measures the dielectric constant of the skin and subcutaneous tissues to determine the water content. The device includes multiple probes for measuring different depths; the researchers

Figure 1. FLOWCHART WITH CHRONOLOGICAL REPRESENTATION OF EVALUATION

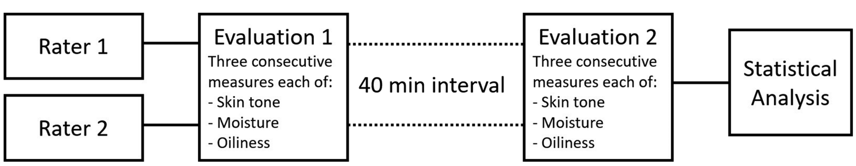

Figure 2. POSITIONING AND EVALUATION METHODS

A, Upper and lower limb skin tone and B, moisture and oiliness measurements.

Technical Reference	
Moisture measurement	0.1 - 99.9%
Oiliness measurement	0.1 - 99.9%
Elasticity measurement	
Measurement intervals	0.1%
Error range	2%
Accuracy	98%

used the probe with an effective depth of up to 2.5 mm (Figure 3). A single researcher who was experienced in evaluations with such equipment performed measurements for all participants. Evaluation with this type of equipment is considered the criterion standard for measurement in human biological tissues.

To evaluate the relative moisture of the limb, two assessment points were considered, one on the anterior face of the medial region (anteromedial) of the lower limb and a second point on the medial face of the distal region (medial-distal) of the lower limb (Figure 3).

Statistical Analysis

The authors included all collected data in the statistical analysis and calculated means and SDs for the different raters and equipment. They used ICC to determine intrarater and interrater reliability, with the respective 95% CI, standard error of measurement (SEM), and minimum detectable change (MDC). In interpreting the ICC values, reliability was considered low for values less than 0.40; moderate for values between 0.40 and 0.75; substantial for values between 0.75 and 0.90; and excellent for values greater than 0.90.[17]

For the correlation analysis, the authors first conducted a normality test of the data using the Kolmogorov-Smirnov test. Next, they checked the association between the tools (low-cost devices and Fitzpatrick Scale or standard evaluation equipment) using Kendall tau (τ). They used the classification established by Cohen[20] to interpret the magnitude of the correlations: 0.10 was considered small, 0.30 was moderate, and 0.5 was large. Statistical processing was performed using SPSS software (version 20.0; IBM Corp).

RESULTS

Eighteen participants were evaluated bilaterally, totaling 36 samples analyzed. Participant characteristics, Fitzpatrick Scale scores, and standard evaluation equipment measurements are outlined in Table 1. The means and SDs of all analyzed indices are described in Table 2.

In terms of intraexaminer reliability, ICC values ranged from 0.747 to 0.971, the SEM was between 0.292 and 0.921 (percentage: 2.5 and 5.1), and the MDC was between 0.808 and 2.554 (Table 3). Regarding the interexaminer reliability, the authors observed ICC values ranging from 0.541 to 0.939, SEM between 0.280 and 1.263 (percentage: 2.4 and 6.9), and MDC between 0.777 and 3.500 (Table 4). Thus, intrarater reliability had substantial to excellent ICC values, whereas interrater reliability had moderate to excellent ICC values. Low error percentages were found for intrarater and interrater reliability.

A moderate-to-large association was observed between the Fitzpatrick Scale and the low-cost tool for skin tone. Small associations were observed among the tools for moisture (Table 5).

DISCUSSION

The authors are not aware of any previous research comparing this type of inexpensive equipment with commonly used tools or the reproducibility indices of the same. However, Westermann et al[13] demonstrated a positive correlation between another low-cost device similar to the one used in the present study (SkinUp; Doutor da Estética) and another skin-index-measuring device (Corneometer; Courage & Khazaka). However, the authors emphasize that they did not apply reliability tests.

Figure 3. METHOD FOR POSITIONING AND ASSESSING THE RELATIVE HUMIDITY OF THE SKIN OF THE UPPER AND LOWER LIMBS

Technical Reference
Effective measuring depth 0.5 mm, 1.5 mm, 2.5 mm, and 5 mm
Sensor contact diameter 10 mm, 20 mm, 23 mm, and 55 mm

Table 1. **PARTICIPANT CHARACTERISTICS AND STANDARD EVALUATION EQUIPMENT MEASUREMENTS**	
Variables	**Mean (SD)**
Age, y	21.44 (3.22)
Weight, kg	61.89 (14.25)
Height, m	1.66 (0.09)
Body mass index, kg/m^2	22.47 (4.19)
Fitzpatrick Scale	
Type 2	56%
Type 3	33%
Type 4	11%
MoistureMeterD—assessment 1	
Anteromedial	32.32 (6.61)
Medial-distal	31.63 (5.35)
MoistureMeterD—assessment 1	
Anteromedial	31.74 (5.94)
Medial-distal	30.72 (4.88)

The application of different scales and tests such as the Fitzpatrick Scale or spectrophotometry measurements can be difficult, with divergent conclusions and definitions. Eilers et al[21] reported significant difficulty with applying the Fitzpatrick Scale. Their data suggest that dermatologist-determined tone is more accurate than patient self-reporting for types III through VI. Thus, a tool with moderate-to-large correlations and reliability is a great clinical option.

In addition to ease of use and reliability, the cost of these devices is another facilitator. Device acquisition costs and availability need to be considered, particularly in a clinical environment. Equipment such as DermaLab (Cortex Technology) and the Courage & Khazaka detectors (models CM 820 or CM 825) is well represented in the literature and clinics, but their higher market values are impediments to clinical use. As reported by Hua et al,[22] these devices show a significant correlation for the measurements of the skin physiologic properties and high quality, but their use is not the reality of every clinician worldwide.

The integumentary system plays a substantial role in the body. The interrelationship of different factors induces a cause-effect cycle. Consequently, repercussions on skin properties and performance[3] are an important evaluation tool. The methods presented here are an affordable and safe approach with significant reliability. Considering that the skin acts as a protective barrier and as a means of interaction with therapeutic procedures, such as light, it is extremely important to use reliable tools for its evaluation. Technology applied to health services is constantly evolving. For skin oiliness, for example, Kohli et al[23] and Mercurio et al[24] addressed techniques involving image analysis and computer interaction, indicating a strong correlation between such findings and those presented in clinical tests.

Effective interpretation of the intrinsic physiologic conditions of the skin is also important for therapies that interact with these dermal conditions and characteristics. For example, photobiomodulation therapy involves the direct application of light to promote biological effects. Because the skin is the first barrier and sometimes the target of intervention, conditions such as moisture and tone are determining factors in a successful therapeutic outcome.[25] These skin characteristics may also play a role in photodynamic therapy for cancer analysis and intervention[26] and the evaluation of superficial blood oxygenation, because recent discussions indicate a direct relationship with skin tone.[27] Thus, precise measurements are necessary. Consequently, more research should be encouraged for better and more accessible assessment.

Limitations

Future research should involve a variety of age groups to observe if skin assessment responses differ by age. Further, researchers should consider skin in nonideal conditions that may alter the moisture or oiliness, such as skin that is dehydrated or injured (as long as evaluation by touch is not precluded). Finally, this study sample did not include participants with Fitzpatrick Scale skin tone I, V, or VI, so future research should aim to include all skin tones.

Table 2. **SKIN INDEX MEASUREMENTS**

	Examiner 1		Examiner 2	
Skin Index	**Test, Mean (SD)**	**Retest, Mean (SD)**	**Test, Mean (SD)**	**Retest, Mean (SD)**
Upper Limb				
Skin type, n (%)				
Type 2	8 (22)	7 (19)	7 (19)	7 (19)
Type 3	24 (67)	24 (67)	23 (64)	23 (64)
Type 4	4 (11)	5 (14)	6 (17)	6 (17)
Moisture	11.5 (0.7)	11.6 (0.6)	11.8 (1.3)	11.9 (1.3)
Oiliness	17.2 (1.1)	17.3 (0.9)	17.9 (2.1)	17.8 (1.9)
Lower Limb				
Skin type, n (%)				
Type 2	8 (22)	8 (22)	12 (33)	17 (47)
Type 3	24 (67)	24 (67)	23 (64)	19 (53)
Type 4	0 (0)	0 (0)	1 (3)	0 (0)
Moisture	11.9 (1.5)	11.8 (1.0)	12.4 (2.2)	12.0 (1.2)
Oiliness	17.9 (2.1)	17.7 (1.6)	18.5 (2.8)	17.9 (1.9)

Table 3. INTRARATER RELIABILITY OF SKIN INDEX MEASUREMENTS

Outcomes	Cronbach α	Intraclass Correlation Coefficient	95% CI	Standard Error of Measurement, °	Standard Error of Measurement, %	Minimum Detectable Change, °
Upper Limb						
Examiner 1						
Skin type	.958	0.957	0.916-0.978	—	—	—
Moisture	.812	0.814	0.636-0.905	0.292	2.5	0.808
Oiliness	.826	0.828	0.663-0.912	0.418	2.4	1.159
Examiner 2						
Skin type	1	1	—	—	—	—
Moisture	.889	0.892	0.787-0.945	0.422	3.6	1.169
Oiliness	.888	0.888	0.782-0.943	0.672	3.8	1.864
Lower Limb						
Examiner 1						
Skin type	.971	0.971	0.944-0.985	—	—	—
Moisture	.758	0.759	0.529-0.877	0.622	5.2	1.723
Oiliness	.776	0.777	0.565-0.886	0.883	5.0	2.448
Examiner 2						
Skin type	.768	0.749	0.505-0.872	—	—	—
Moisture	.755	0.747	0.510-0.870	0.875	7.2	2.424
Oiliness	.852	0.842	0.687-0.920	0.921	5.1	2.554

Table 4. INTERRATER RELIABILITY OF SKIN INDEX MEASUREMENTS

Outcomes	Cronbach α	Intraclass Correlation Coefficient	95% CI	Standard Error of Measurement, °	Standard Error of Measurement, %	Minimum Detectable Change, °
Upper Limb						
E1 vs E2-A1						
Skin type	.941	0.937	0.876-0.968	—	—	—
Moisture	.633	0.615	0.262-0.801	0.626	5.4	1.734
Oiliness	.661	0.628	0.276-0.809	0.972	5.5	2.694
E1 vs E2-A2						
Skin type	.936	0.938	0.878-0.968	—	—	—
Moisture	.551	0.541	0.121-0.763	0.645	5.5	1.787
Oiliness	.558	0.548	0.134-0.767	0.957	5.5	2.653
Lower Limb						
E1 vs E2-A1						
Skin type	.772	0.771	0.554-0.883	—	—	—
Moisture	.762	0.753	0.520-0.873	0.930	7.6	2.577
Oiliness	.746	0.737	0.491-0.865	1.263	6.9	3.500
E1 vs E2-A2						
Skin type	.801	0.802	0.613-0.899	—	—	—
Moisture	.946	0.939	0.871-0.970	0.280	2.4	0.777
Oiliness	.945	0.939	0.875-0.970	0.426	2.4	1.182

Abbreviations: A1, assessment 1; A2, assessment 2; E1, examiner 1; E2, examiner 2.

Table 5. **CORRELATIONS BETWEEN THE LOW-COST DEVICES AND FITZPATRICK SCALE OR STANDARD EVALUATION EQUIPMENT**

Outcomes	Fitzpatrick Scale, *t* (*P*)	Standard Evaluation Medial-Distal, *t* (*P*)	Standard Evaluation Anteromedial, *t* (*P*)
Low-cost equipment—phototype			
Examiner 1—lower limb	0.307 (.007)[a]	—	—
Examiner 2	0.513 (.000)[a]	—	—
Grouped data for the tool	0.411 (.000)[a]	—	—
Examiner 1—upper limb	0.610 (.000)[a]	—	—
Examiner 2	0.508 (.000)[a]	—	—
Grouped data for the tool	0.558 (.000)[a]	—	—
Low-cost equipment—skin detector			
Examiner 1	—	0.225 (.006)[a]	0.242 (.003)[a]
Examiner 2	—	0.228 (.005)[a]	0.237 (.004)[a]
Grouped data for the tool		0.221 (.000)[a]	0.237 (.000)[a]

[a]$P < .05$.

CONCLUSIONS

Evaluations of skin tone, oiliness, and moisture showed moderate to excellent intrarater and interrater reliability. The studied devices can be used in different environments, with particular relevance for use in clinics, because of their low cost and ease of use. ●

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