International Journal of Advanced Culture Technology Vol.11 No.1 363-369 (2023)
DOI https://doi.org/10.17703/IJACT.2023.11.1.363

IJACT 23-3-44

A Study on the Relationship between Ultraviolet Rays and Skin Color Using a Photoplethysmography Sensor

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Abstract

In this study, to check the function of managing the severity of ultraviolet rays with a smart watch, a popular health care IT device, It was tested whether measuring heart rate using a PPG(Photoplethysmography) sensor representatively used in a smart watch could tell skin changes caused by ultraviolet rays.

Through this experiment, we examined the possibility that the skin color tanned by ultraviolet rays can be determined only by the heart rate measurement function of the PPG sensor. In addition, the possibility of expanding the heart rate measurement function of the PPG sensor to the use of skin condition management was considered. we used an Arduino-based reflective PPG sensor to measure changes in heart rate by selecting body sites with high and low UV rays exposure. A significant value was derived through tests considering factors such as gender, UV exposure, and age. As a result, the study identified the possibility of adding ultraviolet rays and skincare items to future smart watch healthcare items and the possibility of expanding skin measurement methods. It is also possible to suggest the direction of future research.

Keywords: *Smart Watch, PPG Sensor, Skin Tone, UV-rays, Heart Rate*

1. INTRODUCTION

With the popularization of smart watches, demand for health care has also increased. It is now possible to easily measure the heart rate with a smartwatch worn on the wrist, and use the related data to know the amount of exercise and sleep time. The key to these health management data is the ability to measure heart rate. This technology is called PPG(Photoplethysmography) sensor technology, and the technology using this sensor, called 'optical blood flow measurement', measures blood flow by reflecting or transmitting light using the transparency of the skin. By attaching a green LED to the back of the smartwatch, it is possible to measure the heart rate when the smart watch is worn and active.

People around the world are using it due to the popularization of smart watches, but there is a research result that dark-skinned people have difficulty recognizing the PPG sensor as the amount of light reflection decreases [1]. Under the assumption that information on the skin can be obtained by using the principle of the PPG sensor, based on previous research, we want to find out whether it is possible to study the darkened skin color due to ultraviolet rays.

Manuscript received: February 16, 2023/ revised: March 3, 2023/ accepted: March 13, 2023
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Ultraviolet(UV) rays, which are strengthened due to the destruction of the ozone layer, have a direct effect on the skin, and damage such as skin burns, skin damage, and skin cancer is increasing. Awareness of the risk of exposure to these ultraviolet rays has increased, but there is no way to know how much damage the skin exposed to ultraviolet rays is damaged. If it becomes easy to measure skin damage caused by such UV rays, it will be a way to reduce damage to skin damage.

Using the PPG sensor's ability to measure heart rate through blood flow measurement, it is expected to show differences in measurement results for changes in skin color tanned by ultraviolet rays. In the process of measuring the blood flow using the PPG sensor, it is expected that there will be a difference depending on the degree of exposure to ultraviolet rays on the individual's skin. In addition, we want to study whether the PPG sensor can indicate the degree of UV exposure of tanned skin exposed to UV rays by checking the correlation between the change in the measured result value and the degree of UV exposure.

2. THEORETICAL CONSIDERATIONS

2.1 UV-rays and Skin

UV light is light with a shorter wavelength than visible light. As shown in Figure 1, there are also types of these UV rays, including UVC of 200-290 nm, UVB of 290-320 nm, and UVA of 320-400 nm [2]. It corresponds to 90%, and it is harmful to the skin enough to be classified as a carcinogen.

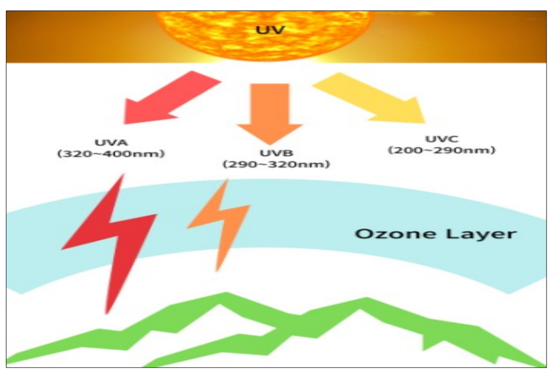

Figure 1. Types of ultraviolet rays (UV)

If you continue to be exposed to these UV rays, aging occurs. Skin aging caused by UV rays is called “photoaging”. It includes a phenomenon in which the elasticity of the skin decreases, becomes dry, becomes rough, and pigmentation such as freckles, melasma, and blemishes, and reddening due to the expansion of capillaries of the skin.

Skin tanning after being exposed to ultraviolet rays is the action of the skin to protect the body from ultraviolet rays. When sunlight hits the skin, melanogenesis occurs, in which the amount of melanin secreted from the epidermis increases to prevent ultraviolet rays from entering the dermis. Because of this protective action of the skin, the skin darkens [3].

2.2 PPG Sensor

PPG(Photoplethysmography) sensor is also called 'optical blood flow measurement'. It is a compound word of Photo (light), Plethysmos (change), and Graphos (record), which uses light to record and measure changes in body parts where arteries pass. Pulse waves are changes in blood vessels that occur during the process of blood circulation due to contraction and relaxation of the heart. PPG is a method of recognizing and recording these pulse waves as waveforms. It detects the amount of reflected or transmitted light by irradiating light to the skin by recognizing the increase and decrease in blood flow in the blood vessels during contraction and relaxation of the heart [6]. It measures blood flow by reflecting or transmitting light using the transparency of the skin is shown in Figure 2.

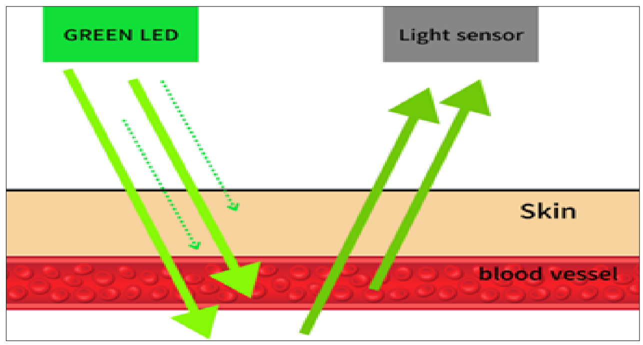

Figure 2. Reflective PPG sensor Logic

2.3 PPG Sensor and Skin Tone Research Case

There are many ways to study the skin. Since smart watches became popular, studies related to skin tone and PPG sensor signals have been published. As a result of a study on the amount of light absorption using a PPG sensor in a commercial wearable device, it was found that when the skin is dark due to high obesity and high melanin concentration, the level of light reaching the blood is low [1].

In a study that measured the PPG sensor in relation to skin type and gender, it was investigated whether the PPG signal performed equally well by dividing the skin into light and dark cases into the female and male experimental groups, and the light skin type had a higher blood volume pulse signal volume came out[4].

There is also a paper that studies the effect of skin color and activity on the PPG sensor worn on the wrist. In this paper, the study was conducted by measuring the PPG signal after performing the same activity for each skin tone. A wrist-worn optical heart rate monitor was used to study the effect of skin color and physical activity on heart rate, and it was found that skin tone influenced the percentage of heart rate intervals obtained with the PulseOn Aini OHR device. A need for improvement in heart rate accuracy was shown in the darker skin tone group, and no difference occurred in the lighter skin tone [5].

3. STUDY SUBJECT AND METHOD

3.1 Research Content

In the theoretical review, when heart rate was measured with the PPG sensor according to skin color, the noise level was different, resulting in a difference in the graph [4]. Therefore, since the skin is tanned by ultraviolet rays, when the heart rate is measured using the PPG sensor in the same environment by dividing the area that is not covered with clothes or applied with sunscreen and the area that is relatively exposed to sunlight and is tanned, In the case of a type PPG sensor, the darker the skin, the more light is absorbed, so the less light that reaches the bloodstream, the lower the noise and reflection, the lower the heart rate, and then proceed with the experiment.

Through this experiment, it will be possible to find out that skin tanned by ultraviolet rays can be distinguished only by the heart rate measurement result using the reflective PPG sensor.

3.2 Research Method

The experimental method used for this study was to select three body parts with high UV exposure and three body parts with low UV exposure using the PPG sensor, and measure the heart rate 5 times for 1 minute for each part. Calculate the average heart rate and mark it.

The experimenters proceeded with different skin colors and ages. Heart rate was measured 5 times for 1 minute for each part in the lying down, resting state, and then another part was measured after a 5-minute break.

3.3 Experiment Environment

Arduino UNO R3 and ROHM Co., Ltd.'s BH1790GLC were used as experimental tools to measure heart rate for each body part with a reflective PPG sensor. Arduino IDE was used for the program displayed during heart rate measurement, and ROHM The company's BH1790GLC manual [7] OPEN source was used. The body parts selected for the experiment were measured by dividing them into arms, neck, and face with high UV exposure (dark skin), abdomen with low UV exposure (light skin), ankles, and thighs.

Heart rate was measured in a way that the experimenter measured each part 5 times for 1 minute in a stable state, and then measured the other part after a 5-minute break. The heart rate measured for 1 minute was indicated as the minimum value, maximum, and average values.

3.4 Result

The heart rate measurement results for each pigmented body by ultraviolet rays using the PPG sensor are shown in a table. The arms, neck, and face in front of the horizontal axis of the experiment result table show dark skin areas with high exposure to UV rays, and the next belly, ankles, and thighs show light skin areas with low UV exposure. The vertical axis represents the minimum, maximum, and average values of the heart rate for each experiment and each experiment. The graph shows the total average heart rate by body part. The red graph is where UV exposure is high, and the blue graph is where UV exposure is low.

The heart rate measurement results of the experimenter M1 are shown in Table 1.

Table 1. Experimenter M1 heart rate measurement results

		Arm	Neck	Face	Abdomen	Ankle	Thigh
1	Min	59	58	57	58	62	60
	Max	67	67	57	62	68	63
	Avg	63	62.5	57	60	65	61.5
2	Min	59	57	56	57	63	58
	Max	63	64	62	63	64	65
	Avg	61	60.5	59	60	63.5	61.5
3	Min	59	57	56	60	64	61
	Max	67	61	58	62	69	65
	Avg	63	59	57	61	66.5	63
4	Min	62	57	57	58	65	60
	Max	65	59	64	64	70	65
	Avg	63.5	58	60.5	61	67.5	62.5
5	Min	62	56	58	59	63	61
	Max	65	63	62	61	65	62
	Avg	63.5	59.5	60	60	64	61.5

Experimenter M1 showed a lower average heart rate in the darker skin area.
The heart rate measurement results of the experimenter M2 are shown in Table 2.

Table 2. Experimenter M2 heart rate measurement results

		Arm	Neck	Face	Abdomen	Ankle	Thigh
1	Min	66	62	56	66	65	70
	Max	70	69	64	70	68	71
	Avg	68	65.5	60	68	66.5	70.5
2	Min	65	63	64	70	67	64
	Max	69	76	78	76	74	78
	Avg	67	69.5	71	73	70.5	71
3	Min	68	65	66	68	67	68
	Max	70	71	82	75	73	75
	Avg	69	68	74	71.5	70	71.5
4	Min	63	65	69	67	71	69
	Max	70	69	72	77	78	80
	Avg	66.5	67	70.5	72	74.5	74.5
5	Min	60	81	63	70	68	70
	Max	68	83	68	73	72	75
	Avg	64	82	65.5	71.5	70	72.5

Experimenter M2 showed a lower average heart rate in the darker skin area.
The heart rate measurement results of the experimenter W1 are shown in Table 3.

Table 3. Experimenter W1 heart rate measurement results

		Arm	Neck	Face	Abdomen	Ankle	Thigh
1	Min	62	60	59	65	58	57
	Max	65	63	61	70	64	59
	Avg	63.5	61.5	60	67.5	61	58
2	Min	68	62	60	58	55	58
	Max	69	66	71	68	60	62
	Avg	68.5	64	65.5	63	57.5	60
3	Min	60	61	61	61	61	60
	Max	68	65	63	70	63	68
	Avg	64	63	62	65.5	62	64
4	Min	64	67	63	56	56	59
	Max	73	73	66	60	61	64
	Avg	68.5	70	64.5	58	58.5	61.5
5	Min	62	59	62	61	56	59
	Max	66	73	63	70	59	63
	Avg	64	66	62.5	65.5	57.5	61

In the graph of the total average heart rate of experimenter W1, the average heart rate in darker skin areas was higher.

The heart rate measurement results of the experimenter W2 are shown in Table 4.

Table 4. Experimenter W2 heart rate measurement results

		Arm	Neck	Face	Abdomen	Ankle	Thigh
1	Min	69	63	71	68	80	74
	Max	71	73	73	73	88	84
	Avg	70	68	72	70.5	84	79
2	Min	70	65	66	69	78	75
	Max	74	79	71	74	87	81
	Avg	72	72	68.5	71.5	82.5	78
3	Min	71	66	67	64	80	69
	Max	75	72	74	73	85	73
	Avg	73	69	70.5	68.5	82.5	71
4	Min	68	69	69	66	76	67
	Max	73	71	74	74	86	73
	Avg	70.5	70	71.5	70	81	70
5	Min	68	63	67	67	75	71
	Max	77	75	81	75	84	75
	Avg	72.5	69	74	71	79.5	73

Experimenter W2 showed a lower average heart rate in the darker skin area.

As expected, the average heart rate was lower in darker skin areas exposed to UV rays, as expected for 3 out of 4 experimenters. The heart rate in the darker skin area differed from the average heart rate in the light area at least by 2 and at the most by 5. However, the results of experimenter W1 came out opposite. This means that the average heart rate was measured higher in places with darker skin due to a lot of UV exposure, and even in the overall average, the place with the highest heart rate was also found in dark places.

4. CONCLUSIONS

As a result of heart rate measurement, the test results of 3 out of 4 experimenters show that, as assumed, the average heart rate is lower in body parts exposed to UV rays. Although there was some variation in the heart rate result of each experimenter, the heart rate measurement result of the darker skin area was lower than that of the total average heart rate of the body area. However, the heart rate measurement result of experimenter W1 showed that the heart rate was higher in the darker skin area.

Experimenter W1's measurement results showed that the difference between the total heart rate in a dark place and the total heart rate in a bright place was more than 3.13, which was higher in the dark place.

The reason for the exceptional appearance is different from the assumption that the boundary between areas affected by ultraviolet rays and areas affected by ultraviolet rays is relatively unclear due to the habit of applying sunscreen relatively frequently compared to other experimenters in the behavioral characteristics of experimenter W1.

As shown in the research results conducted in this study, it can be seen that the PPG sensor has limitations in clearly indicating the degree of skin tanning caused by ultraviolet rays through the heart rate measurement function. In future studies, it is thought that increasing the number of test subjects and selecting subjects with clear boundaries in the degree of tanning by ultraviolet rays in selecting experimenters will clearly show the results of assumptions. In addition, it is thought that proper control of the subject's behavior is necessary in conducting the experiment. This is because the pulse characteristics are relatively greatly affected by the subject's body movement and physical condition. In addition, for the experimental results expressed in this study, it is difficult to distinguish the difference in the effect of ultraviolet rays only with the heart rate expression graph, so in future studies, the PPG sensor's light reflection measurement result for blood flow is expressed as a graph and the difference we think it needs to be analyzed.

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