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Research Article

Investigation of the Effects of a Self-Heated Vest on Vital Values of Individuals: A Case Study on Public Health

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Abstract:

With the adaptation of portable and harmless technological devices to clothing products, self-heating outdoor products are becoming more common in the market. These products can produce heat energy on their own, unlike standard thermally insulated products. In this way, it contributes to the thermal comfort of people in situations where the environment cannot be conditioned. In this study, the effects of these products, which are in close contact with the human body, on human health were measured through vital values. Measurements were collected from the same group of individuals at three different time intervals over 30 minutes. Significant differences between the obtained data were examined using the Friedman test and detailed using Wilcoxon Signed Rank test. While a significant difference was observed in systolic blood pressure, diastolic blood pressure and body temperature data, no significant difference was found in oxygen saturation and pulse data. As for the actual changes, no serious effects on human health were observed based on the vital values presented in the study.

1. Introduction

Wearable technologies are increasingly entering daily life. These technologically updated products have a wide range of uses. One of these innovations is the combination of wearable products with lightweight and innovative heating units. While self-heated products meet people's daily needs especially in winter, they are in close contact with people's bodies. The development of these innovative designs is recent and still developing. For instance, in the initial applications thermal blankets have been studied for space flight [1]. Technological products in close contact with human body that produce heat are directly related to thermal comfort research area. According to the definition of thermal comfort, it is intended that a person feel thermally balanced in an outstanding setting and that the environment adapts to this balance [2]. That is, in an environment where thermal balance exists, the heat transfer between the person's body and the environment changes balancedly per unit time, and there is also balance in the change in the difference between the core temperature of the person's body and the temperature of the person's skin per unit time. In this way, people can continue their daily routine comfortably in terms of in terms of thermal comfort perspective while preventing their health from being affected by the effects of too cold and too hot ambient temperatures. Standard type materials can be used to construct coats and vests that will increase a person's thermal comfort both indoors and outside in cold climates. Thermal insulation can be provided by the standard fabrics of coats and vests, but also self-heating pads can be added to the fabrics to produce external heat to ensure thermal comfort in cold environments. These heated vests work by connecting flexible metallic and non-metallic wire pads to a power unit, which activates the heating inside the coat or vest (Joule heating) [3]. Different types of thin wires with different resistance characteristics can also be applied as a heating element for heated vests and coats [3, 4]. As a result of these pads actively providing heat, people working in stagnant jobs such as guard or security or those working in cold environments can adapt to ambient better and their health will be less affected. Heat pads are simply placed on the chest and back parts of these wearable products and heat the middle part of the body almost evenly [5, 6]. Within this framework, thermal comfort can be defined as the state in which a healthy individual's body requires the least amount of physiological exertion in the given environment. Because the body's skin temperature may vary and the body tries to thermally adapt to the environment by using some internal effort [7]. Veins in the body can dilate (vasodilate) or constrict (vasoconstrict) blood vessels in response to environmental changes [8]. As the ambient temperature rises, so does the body temperature. It is known that temperature increase has an effect on the body's vital values [9]. Moreover, seasonal temperature drops are known to trigger heart diseases [8]. While blood pressure increases in cold environments due to the response of the vessels in the body, blood pressure tends to decrease in hot environments. As the veins adapt to the environment, the veins narrow in cold weather conditions, and the heart tries to increase blood pressure to ensure full blood pumping to the body.

Thermal comfort can be achieved either by conditioning the environment or achieved through the selection and design of proper clothing. Clothing directly affects heat transfer between the body and the environment by acting as an insulating and conducting element. In cases where the environment cannot be conditioned, proper clothing must be provided. Since self-heated clothes are in direct contact with the body, their health effects need to be examined. While vital effects may not be obvious in cases of inactivity or low mobility, they may become more important as their effects on the body in conditions that require more movement, such as doing sports or military operations. In this study, the effects of a commercial self-heated vest equipped with heating pads on vital values of individuals will be examined. In order to quantify changes in vital values statistical methods will be performed by using Statistical Software SPSS version 27.

Statistical methods are frequently preferred in scientific studies involving experimental design. Particularly, repeated measures designs, when participants in the same group are tested repeatedly at more than one factor level (longitudinal), are frequently used in many areas of science such as studies related with clinical trials and nutrition [10, 11]. The advantages of repeated measurements designs over cross-sectional designs, i.e. increase in statistical power, makes them popular. Data obtained from these studies are often characterized by sample sizes and numbers of factor levels of the within-subjects factor(s). In a given application, the differences in the means of selected group obtained before and after the application can be examined by statistical method such as paired t-test. However, generally same group of individuals are tested more than twice on same independent variable over some time. Then repeated measures Analysis of Variance (ANOVA) is preferred to analyse differences in group means obtained from different observations at different points in time. While descriptive statistics provide information about the characteristics of the data, the graphical image of the distribution of the values in the data as a series of bars can be visualized by the histogram plots [12]. The repeated measures ANOVA comes with F-statistic that is used to determine statistical significance.

$$F = \frac{MS_{betweentreatments}}{MS_{error}} \quad (1)$$

and

$$MS_{betweentreatments} = \frac{SS_{betweentreatments}}{df_{betweentreatments}} \quad (2)$$

Calculating effect size for Repeated Measures ANOVA can be expressed as;

$$\eta^2 = \frac{SS_{betweentreatments}}{SS_{betweentreatments}+SS_{error}} \quad (3)$$

Whether the data obtained shows a normal distribution is important for the statistical approach to be chosen. Normally distributed data is usually believed to follow a symmetric, bell-shaped curve [13]. By investigating the normality of the statistical distribution, it can be determined which parametric or non-parametric analysis is preferred. It can be decided whether a distribution is normally distributed or not by examining histogram plots or examining skewness and kurtosis values. The normal distribution plot must have a structure similar to a bell curve or the skewness and kurtosis values must be below a certain limit. It has been stated that normal distribution can be accepted when the skewness and kurtosis values are between -1.5 and +1.5 [14, 15]. Non-normal distributed data is frequently encountered in areas such as health and social sciences [16]. Friedman test, a nonparametric test, can be used to test differences for non-normal data [17]. When the number of groups is more than two, the use of the Friedman test alone cannot determine which groups the

differences are between. In this case, the Wilcoxon Signed Rank test should also be used for pairwise comparison of groups. Significance value can be set to 5% (p value < .05) or Bonferroni correction can be applied.
Sample size is an important parameter for the accuracy of statistical analysis. Insufficient sample size in a study can lead to incorrect outputs to identify substantial variations and insufficient statistical power. Conversely, a study that uses an enormous sample size will waste money and put study participants at unnecessary risk. Studies on selecting proper sample sizes were conducted to obtain reliable statistical results for a given experimental design [18]. Estimations can be made on selected parameters by using different software, articles and tables. In these studies, power consideration is the main basis for determining sample size along with specified statistical distance any pair of treatment means [19]. Sample sizes for a given experimental design can be calculated in advance and given at the end of the study in terms of the statistical reliability of the results of the study [18, 20]. Sample size can vary with respect to pre-defined reliability factors but its value is dependent on group population mean and standard deviation.
Sample sizes can be very high or low depending on the type and purpose of the study. Several examples can be given from the literature. Hendrickx et. al. surveyed 27,224 individuals to investigate stress levels of individuals due to sexual difficulties [17]. Singh et. al. examined Hemoglobin values of 423 participants at 15-day intervals [10]. Samplings were repeated four times for the same group and group averages were compared with Repeated Measures ANOVA. Kassim et. al. conducted an exploratory study on the behaviours of the dentists toward screening for medical conditions [21]. Their questionnaire was given to 143 participants. Swan et.al. investigated lab mice groups to understand their psychological state from their facial expressions [22]. They reported their samples size was 10. Cho et. al. conducted study on mice in order to investigate the effects of high folate gestational and post-weaning diets [23]. They had 10-12 animals in each group. Guetterman et. al. investigated seminar scores of cancer patients to see the effect of virtual humans (VHs) simulation [24]. During their study, they used two groups of 12 and 15 people each. As seen from the literature studies related with clinical trials and surveys are frequently published and results are validated with statistical methods. Different types of study designs seeking effects of treatments on the outcomes of the study are started to take place in numbers in the literature. Sample size selection is strongly related to the concept of power [12]. For example, in order to detect small variations, i.e. very low dose of drug or a component in a blood sample, larger sample sizes are needed. Small sample sizes are effectively used especially if there is a significant statistical distance within-subject study means. It should be kept in mind that research with as little as one sample size might occasionally yield ground-breaking results [25].

2. Material and Methods

2.1 Study Design

A study was conducted with a total of 15 participants, 11 males and 4 females. Participants are between the minimum age of 19 and the maximum age of 44 (mean value 25.6 and std. deviation value 7.68). Participants sit still throughout the study in a conditioned room. Participants wore a Monthermo brand size L self-heating vest (Model: MH34001, 100% polyamide and micro silicon) where the vest was compatible with most 5V/2.4A power banks available in the market. The appearance of the experimental setup where male and female participants wear the jacket is presented in Figure 1. The heated vest is temperature controlled and has three operating temperatures: 25, 35 and 45^0C. Experiments were conducted while the vest was operated at 45^0C, which is the highest operating temperature. The vest heating was powered by a standard 10000 Mah portable powerbank. The vest has a total of three heating pads, one on the back and two on the front abdominal area, and the heating units are placed in the simplest way compared to equivalents on the market. Two thermometers with probes were attached to the two fabric surfaces of the vest directly over the heated pads one the back and second on the front. In this way, it was observed whether the heating pads worked effectively and what the temperature levels were between the vest and the clothing. Moreover, the humidity and temperature of the environment were observed during the experiments using a smart room thermometer to ensure that these values do not change significantly during the experiments.

Figure 1. *Representative view of experimental design and data collection from female and male participants.*

2.1 Experiments

Before each participant put on the vest, the fully charged powerbank was connected to the heating units. And body temperature, systolic and diastolic blood pressure, oxygen saturation, and pulse rate of each participant were measured five times consecutively. Polygreen (model KI 8280) brand thermometer was used to measure body temperature (forehead measurement), Omron (model M2) brand digital blood pressure meter was used to measure blood pressure. Comfort Plus Pulse Oximeter (model M170) was used to measure the oxygen level (oxygen saturation) of the blood and pulse rate. After that participants wore the vest and they sat motionless in a soft leather chair for half an hour. In this way, vitals are not affected due to movement. All measurements were sampled repeatedly at the 15th and 30th minutes. Thermal comfort studies showed that significant differences between mean skin temperatures and thermal stabilization fully occur by the 15th minute [26, 27]. The data of the participants at the first moment (0th minute), the second moment (15th minute) and the last moment (30th minute) were recorded for statistical analysis. For the ambient conditions, temperature and relative humidity were measure as 20^0C $\pm 3^0$C and 41±4%, respectively.

3. Results and Discussions

3.1 Normality Check

Skewness and kurtosis values of systolic blood pressure, diastolic blood pressure, body temperature, oxygen saturation and pulse rate datasets higher than the limits determined for normal distribution. In addition, the histograms of each data set and their distribution on the normality line were also examined. The histogram of any data set does not exactly follow the normal distribution curve. Since the data did not show normal distribution, the non-parametric Friedman test was used. Non-parametric Wilcoxon Signed Ranks test was used for pairwise comparisons.

3.2 Non-Parametric Tests

The results of the Friedman test, which was conducted to examine whether there is a significant difference between the data sets collected at selected time intervals, are presented in Table 1. In addition, the results of the Wilcoxon Signed Ranks test performed for pairwise comparison of different groups are presented in Table 2. As can be seen in Table 1 and Table 2, there is a significant difference over time in the systolic

Table 1. *Friedman test results*

Data Name	**N**	**Percentiles**			**Ranks**	**Asymp. Sig.**
		25th	**50th (Median)**	**75th**		
SBP (min 0)	15	109	112,8	120,8	2,6	0,008*
SBP (min 15)	15	107,8	112,2	115,8	1,93	
SBP (min 30)	15	104,2	106,2	113,6	1,47	
DBP (min 0)	15	68,8	71,8	73,4	2,37	0,033*
DBP (min 15)	15	66,4	70,8	75	2,17	
DBP (min 30)	15	60	65	72	1,47	
BT (min 0)	15	36,44	36,6	36,8	1,53	0,002*
BT (min 15)	15	36,48	36,66	36,8	1,77	
BT (min 30)	15	36,68	36,76	36,9	2,7	
OS (min 0)	15	96	96,8	98	2,03	0,802
OS (min 15)	15	96,2	97,6	97,8	2,1	
OS (min 30)	15	96,2	97,2	97,8	1,87	
PR (min 0)	15	76,8	84,4	92,4	2,23	0,516
PR (min15)	15	76,8	83,6	90,2	1,93	
PR (min 30)	15	72	85	88,2	1,83	

**Significant difference (p value <.05) SBP: Systolic blood pressure, DBP: Diastolic blood pressure, BT: Body temperature, OS: Oxygen saturation, PR: Pulse rate, min: minute.*

Table 2. *Wilcoxon Signed Ranks test results*

Pairs	**Neg. Ranks**	**Pos. Ranks**	**Ties**	**Total**	**Asymp. Sig. (2-tailed)**
SBP (min 15-min 0)	11	4	0	15	0,069
SBP (min 30-min 15)	10	5	0	15	0,041*
SBP (min 30-min 0)	13	2	0	15	0,006*
DBP (min 15-min 0)	8	6	1	15	0,638
DBP (min 30-min 15)	11	4	0	15	0,047*
DBP (min 30-	12	3	0	15	0,02*

min 0)					
BT (min 15-min 0)	6	7	2	15	0,278
BT (min 30-min 15)	3	11	1	15	0,008*
BT (min 30- min 0)	0	13	2	15	0,001*
OS (min 15-min 0)	6	8	1	15	0,729
OS (min 30- min 15)	8	7	0	15	0,442
OS (min 30- min 0)	9	6	0	15	0,608
PR (min 15- min 0)	8	7	0	15	0,887
PR (min 30- min 15)	7	8	0	15	0,495
PR (min 30- min 0)	10	4	1	15	0,3

**Significant difference (p value <.05) SBP: Systolic blood pressure, DBP: Diastolic blood pressure, BT: Body temperature, OS: Oxygen saturation, PR: Pulse rate, min: minute.*

blood pressure, diastolic blood pressure and fever data. However, no significant difference was observed in oxygen saturation or pulse values. When pairwise comparisons are examined, it can be said that temperature effects occur as early as the 15th minute. These results are in agreement with previous thermal comfort studies [26, 27]. In fact, in pairwise comparisons of systolic blood pressure, diastolic blood pressure and body temperature data, it is seen that the ranks increase or decrease in harmony as time progresses. As seen in Table 2, the significance value decreases harmoniously over time, showing group differences.

3.3 Mean Graphs

The changes over time in the group means of vital values with error bars taken at different time intervals are presented from Figure 2 to Figure 6. As seen in Figure 2 and 3, there is a decrease in systolic and diastolic blood pressure values. On the other hand, as seen in Figure 4, there is an increase in body temperature. Although oxygen saturation and pulse data are close to linear, which can be seen from Figure 5 and Figure 6, it is difficult to say anything clear about them.

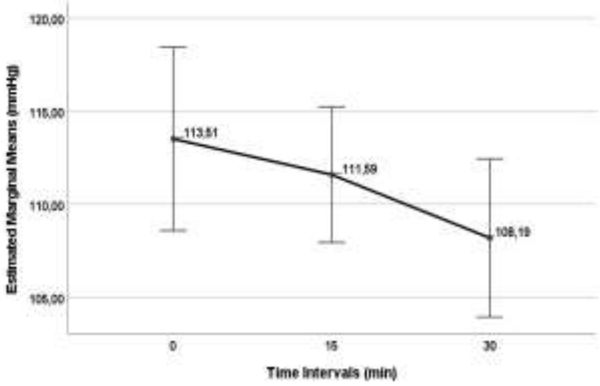

Figure 2. *Estimated marginal means of systolic blood pressure values over time.*

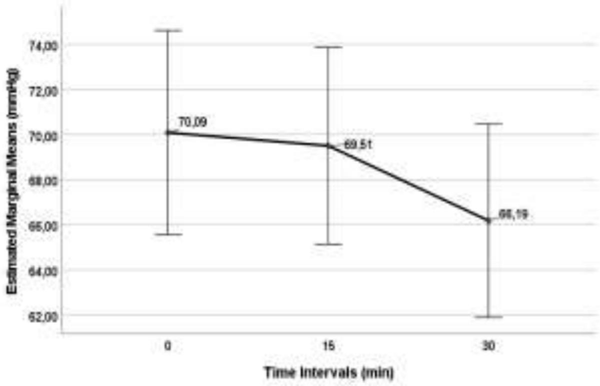

Figure 3. *Estimated marginal means of diastolic blood pressure values over time.*

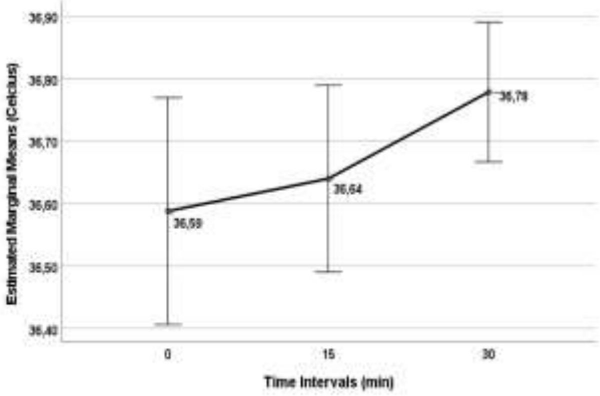

Figure 4. *Estimated marginal means of body temperature values over time.*

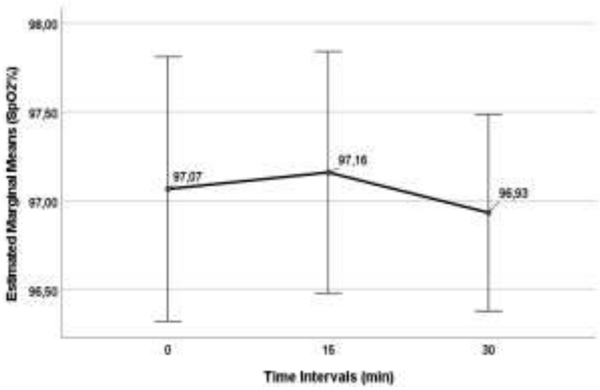

Figure 5. *Estimated marginal means of oxygen saturation values over time.*

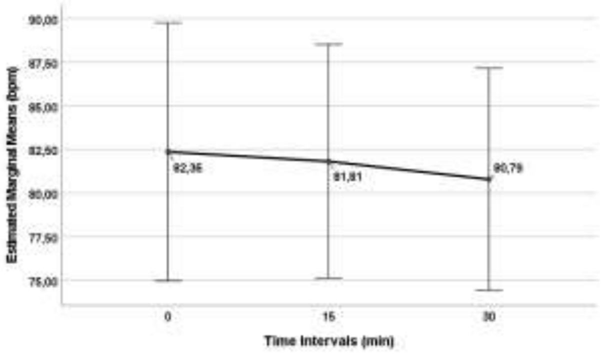

Figure 6. *Estimated marginal means of pulse rate values over time.*

4. Conclusions

In this study, the effects of a heated vest in close contact with human skin on vital values were investigated. It can be said that the results are expected. That is, while systolic and diastolic blood pressure data tend to decrease, body temperature data tends to increase. These changes also showed statistical significance. Although pulse data also tended to decrease, it did not show statistical significance. As expected, the vessels dilated as a result of thermal adaptation, reducing blood pressure. At the same time, body temperature also increased. Statistically, the effect of the heated vest on these three vital values is certain. Similarly, change patterns and statistical differences in outcomes were detected in a group consisting only of male participants [28]. For the other two vital values, the measuring devices may not have achieved sufficient sensitivity or these values may have been slightly affected by the heated vest. Moreover, these two results are not significant caused by a lack of power due to small sample size. When the average graphs are examined, it is seen that there is a change in vital values, but the changes are not physically serious. To summarize the results of the study, the effect of the heated vest on vital values is observed and statistically confirmed, but these changes are not at a level that will affect human health.

In order to roughly calculate minimum required sample size for this type of study solved with Friedman test. G*Power software was used for estimated calculations. In the program, repeated measures, within factors, ANOVA approach, three number of points in time (measurements) and medium effect sizes were set for calculations. f is the effect size index and can be calculated as;

$$f = \sqrt{\frac{\eta^2}{1-\eta^2}} \qquad (4)$$

where the value of f can be considered as 0.25 for medium effect sizes. If the value of f is 0 then it indicates that the population means are all equal.

The minimum number of sample size was calculated to be 12 for an alpha value of 5 percent and a power value of 80 percent. In the analyses mentioned here, the power values calculated for systolic blood pressure, diastolic blood pressure and body temperature were calculated as 0.937, 0,82, and 0.981 respectively. This shows that the study has statistical reliability.

When the data was examined further, it was observed that there was more separation in one person's data than others in terms of way of clustering. The initial values of this person's systolic and diastolic blood pressure were measured to be 87 and 49, respectively. It has been determined that the blood pressure values of this person, whose blood pressure values are lower than a normal individual, remain constant or increase slightly rather than decreasing further. The slight increase in the person's values may be due to the level of excitement during study. This can be interpreted as the heated vest having the expected effects, especially on individuals who are healthy and have standard vital values.

Author Statements:

- **Ethical approval:** Ethical approval was given by the ethics committee of Bayburt University with its decision dated Jan 17, 2024 and numbered 181168.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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