Study on Health Monitoring Systems Based on Correction Mode

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Abstract: Current health monitoring systems often do not concern about the needs of the elderly, leading to inaccurate health status monitoring and delayed treatment for emergency health conditions. Similarly, they do not consider the variable factors affecting each patient, resulting in discrepancies between the measured values and real health status. To solve the problems, we propose a new health monitoring system with physiological parameter measurement, correction, and feedback. The study collects clinical samples of the elderly to formulate regression equations and statistical models for analyzing the relationship between gender, age, measurement time, and physical signs. After multiple adjustments to measurements of physical signs, the correction algorithm compares the data with a standard value. The process significantly reduces the risk of misjudgment while matching users' health status more accurately. The application case of this paper proves the validity of the method for measuring and correcting heart rate results in the elderly and presents a specific correction procedure. Additionally, the correction algorithm provides a scientific basis for eliminating or modifying other influencing factors in future health monitoring studies.

Key words: health monitoring; correction mode; algorithm design; heart rate

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0 Introduction

The aging of population is one of the significant social problems in the world today. The proportion of the elderly suffering from chronic diseases is high, requiring regular disease monitoring and timely warning. When coupled with the increase in the number of empty-nesting elderly people, the old solitary people are more likely to increase the risk of developing other complications or significant illnesses due to inadequate chronic disease surveillance and delayed prevention and control. The imbalance between the continuously increasing health care needs of the elderly population and the insufficient number of health care personnel is growing[1]. Medical treatment has evolved to focus on prevention and self-monitoring, and health monitoring products have gradually become necessary for ordinary families rather than public medical resources[2]. Health monitoring is a cross-cutting research field involving medicine, computer science, information, and communication. With the development of technology, traditional medical monitoring products are developing toward intelligent and remote.

Parsons' first use of telemedicine opened communication technology in medicine[3]. Similarly, with the development of technology such as computers, the Internet, and virtual reality in the 1990s, various smart medical models such as health monitoring mini-devices and electronic medical records emerged[4]. In the 21st century, the emergence of the Internet of things (IoT) has provided more modes of information collection and transmission for health monitoring systems and improved product intelligence and humanization through IoT technology. With the advent of 5G era, human physiological

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parameters can be transmitted faster and more steadily. Big data's use in health monitoring systems for the elderly enables artificial intelligence to maintain the ability to process information individually and determine physical health conditions more accurately[5].

Human vital signs gauging is closely related to physiology, time, and environmental factors which will affect the accuracy of human signs' values to varying degrees. The exclusive use of the values instrument-derived measured as the basis for health judgments leads to inaccuracies due to individual and environmental differences. This paper proposes an innovative health monitoring mode based on individual user information and different measurement times for differential correction. Here, we specifically address the shortcomings of the existing monitoring products that incapable of making differential judgments for different users based on shifts in their influencing factors. The new measurement and correction monitoring mode can effectively reduce interfering factors and accurately reflect the user's real health status. It has a positive impact on disease prevention, reducing the risk of disease deterioration, and saving medical resources. This study also provides an essential basis for subsequent research on reducing the influence of interfering factors in health monitoring.

1 Analysis of Health Monitoring Correction Mode

Vital signs directly reflect physiological health status, and their patterns are often used in medicine to prevent certain diseases. Among the influencing factors, subjects' gender, age, and measurement time are more common and typical, and these factors are uncontrollable compared with the exercise status and measurement position of the subjects. Therefore, this paper uses the influences of these three types of factors as the basis for the correction of physiological measurement values.

The health monitoring system's workflow in this study measures the physiological parameter values through the biosensors and then corrects the measurement values three times to obtain the correction value that matches the actual health status. The correction value is compared with the basic judgment conditions, and finally, returns the accurate judgment result or warning. The workflow of the monitoring system is shown in Fig.1.

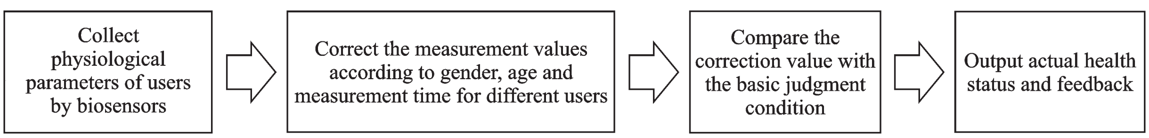

Fig.1 Workflow of health monitoring system

In terms of physiological significance and equipment monitoring conditions, the human body temperature, heart rate, blood pressure, and other representations are more apparent[6] and are commonly used to assess human physiological health conditions. In this paper, the heart rate correction process is used as an application case of this method, mainly consisting of the following two aspects.

Firstly, studying the association between each influencing factor and heart rate. By collecting user samples, a statistical regression model is established to analyze whether typical factors such as gender, age, and measurement time of elderly users have influence and the degree of influence on heart rate, calculate the degree of influence of each factor separately, and then quantify the degree of influence. Finally, present complete and accurate correlation data tables.

Secondly, designing the process and core algorithm for health measurement value correction. The correction algorithm's overall idea is to increase or decrease the instrument's actual value according to the values in the correlation table, aiming to offset or weaken the influence degree of the correlation factors. The algorithm includes establishing the benchmark and variation values in the correction process, and the results provide the theoretical basis for the design of the system software program.

2 Application Case Study

In order to validate the accuracy and innovation of the health monitoring correction mode, heart rate measurement and correction process in the elderly is used as a case study in this study.

Heart rate is a crucial indicator for assessing physiological health status. Resting heart rate is closely related to the physical condition of the elderly and requires regular monitoring and timely warning. In the case study, firstly, the basic conditions for judging heart rate are set up. Secondly, the relationships between gender, age, measurement time, and heart rate are calculated, and the regression equation and correlation tables are derived. Finally, complete algorithm formulas for heart rate correction are designed, and the corrected values are used to provide feedback on the user's actual health status.

We collect 505 valid samples from the clinical heart rate values of 565 elderly people aged 60—90 years in the Jiangyin People's Hospital, China. It is used as sample data to calculate the correlation between influencing factors and heart rate. Measurements are taken using the Mindray PM-60 heart rate monitor in the subjects' resting state and are performed by hospital nurses or doctors to ensure the data acquisition accuracy and professionalism.

2.1 Setting basic judgment conditions

Internationally, the average adult heart rate is 60—100 beats per minute. However, some recent clinical medical practices have proven that the upper and lower limits of this range are both slightly exaggerated[7]. By monitoring the heart behavior of 5 541 healthy elderly people aged 60—79, Bryan et al.[8] found that the heart rate of people in this group ranged mostly between 53—93 beats/min. The big data of domestic health survey on relevant population[9] also revealed that the average value would be 50—95 beats per minute.

We divide the resting heart rate status of the elderly into five stages and two-level warnings according to the recognized health standards. These include heart rates in the medical field, the possible adverse consequences and the severity of complications caused by abnormal heart rate. Here, these standards are used as warning criteria for the monitoring system. Deep warning and shallow warning are categorized based on the magnitude beyond the normal range. The specific judgment conditions are shown in Table 1.

Table 1 Basic conditions for judging heart rate

Condition	Low-deep warning	Low-shallow warning	Normal	High-shallow warning	High-deep warning
Heart rate /($beats \cdot min^{-1}$)	⩽45	46—54	55—90	91—99	⩾100

2.2 Analysis of correlation factors

2.2.1 Correlation between gender and heart rate

The individual heart rate varies among different stages of life. For example, during adolescence, the heartbeat is generally fast and tends to slow down in adulthood and old age[10]. Notably, heart rate changes more significantly in females than in males. Similarly, a survey on the topic conducted with healthy people in China by Wu et al.[11] shows that the resting heart rate of men is generally 2—7 beats/min slower than that of women, and this difference gap is reduced in the old age. Women's faster heart rate is related to the thick layer of breast tissue and the small heart organ[12].

As a result, a statistical regression model is produced using samples on this measurement. It aims to establish the relationship between gender and heart rate and the influence of gender. According to the measurement samples collected in the previous stage, the heart rate is the dependent variable set to y, and the gender is the independent variable set to x. Using statistical product and service solutions (SPSS) for analysis, the correlation coefficient r is calculated to be greater than 0 and less than 1 in this model, indicating a degree of linear correlation between the two variables of heart rate and gender. The results of the variance analysis are shown in Table 2.

Table 2 Gender-heart rate variance analysis

Parameter	Sum of squares	df	Mean square	F	Sig.
Regression	503.032	1	503.032	13.225	0
Residual	19 131.629	503	38.035		
Total	19 634.661	504			

We focus on the significant value Sig.(P) first. Table 2 shows that P is close to 0; thus, it can be considered that the gender-heart rate model is statistically significant at the significance level of 0.05. This value indicates a linear correlation between the dependent variable heart rate and the independent variable gender, meeting the basic assumption that simple linear regression analysis can be used.

The regression results displayed in Table 3 prove that the regression model of gender-heart rate is also relevant. It can be considered that gender is significant at the level of 0.05 and is an influencing heart rate factor. The regression equation is organized as

$$y = -2.206x + 76.239 \tag{1}$$

From the above analysis, it can be concluded that the heart rate of women aged 60 to 90 is 2.026 beats/min faster than that of men on average when other conditions remain unchanged. The heart rate of old-aged men is set to HR, so the heart rate of elderly women is HR+2.026. The relationship between gender and heart rate is closely exhibited in Table 4.

Table 3 Results of gender and heart rate regression analysis

Parameter	Unstandardized coefficients		t	Sig.	95% confidence interval	
	B	Std.error			Lower bound	Upper bound
Constant	76.239	0.427	178.714	0	75.401	77.077
Gender	−2.026	0.557	−3.637	0	−3.121	−0.932

Table 4 Correlation between gender and heart rate

Gender	Male	Female
Heart rate/(beats•min^{-1})	HR	HR+2.026

2.2.2 Correlation between age and heart rate

Valentini et al.[13] discovered that while the individual gets old, the heart rate in a tranquil state shows a slight downward trend, dropping a 0.13 beat/min per year. The confirmation that the heart rate slows down with age is mainly attributed to the heart system's degeneration as time passes, and hyperfunction and increased tension of the vagus nerve can also collaborate for this phenomenon.

Consequently, to further determine the influence of age on heart rate and its extent, a statistical regression model is established based on samples for analysis. According to the measurement samples collected in the early stage, the dependent variable heart rate is set to y, and the independent variable age is set to x. In this model, the calculated correlation coefficient r is between 0 and 1, indicating a degree of linear correlation between the two variables of heart rate and age. The results of the variance analysis are shown in Table 5.

Table 5 Age-heart rate variance analysis

Parameter	Sum of squares	df	Mean square	F	Sig.
Regression	557.769	1	557.769	14.707	0.00
Residual	19 076.892	503	37.926		
Total	19 634.661	504			

Table 5 shows that P is close to 0. Thus, it can be considered that the age-heart rate model is statistically significant, indicating a linear correlation between the heart rate and age. This value meets the basic assumption that a simple linear regression analysis can be used.

The regression results in Table 6 prove that the regression model of age-heart rate is statistically significant, and age is an influencing factor of heart rate. Thus, the regression equation is

$$y = -0.156x + 85.934 \tag{2}$$

It can be concluded from the above analysis of the correlation between age and heart rate that the heart rate slows down by an average of 0.156 beats/min for every increase of one year in age, when oth-

Table 6 Results of age and heart rate regression analysis

Parameter	Unstandardized coefficients		t	Sig.	95% confidence interval	
	B	Std. Error			Lower bound	Upper bound
(Constant)	85.934	2.851	30.143	0	80.333	91.535
Age	−0.156	0.041	−3.835	0	−0.236	−0.076

er conditions remain unchanged. Set the heart rate at the age of 60 as HR, thus the relationship between age and heart rate of the population aged 60—90 is shown in Table 7.

Table 7 The correlation between age and heart rate

Age	60	61	62	…	90
Heart rate/(beats•min^{-1})	HR	HR−0.156	HR−0.312	…	HR−4.68

2.2.3 Correlation between circadian time and heart rate

Circadian change in regular heart rate is mainly affected by neurohormones, daily schedules, and emotions. The fluctuation rate manifests as a relatively fast heart rate with a large increase and decreases during the day, along with slow, small changes at night.

Ben-dov et al.[14] reported that the average heart rate of the elderly at night is usually 10% to 20% slower than the rates during the day. When asleep, the heart can beat around 14 times/min slower than during the waking state on average. Conversely, the average heart rate in the afternoon is about five beats/min faster than in the morning. Also, the minimum heart rate usually occurs in the second half of the night.

From the analysis of the results above, we combine the routines of elderly persons over 24 h, which are subsequently divided into six time periods according to the heart rate's speed and the difference in the range of variation per hour. Here, 0:00—2:00 and 2:00—4:00 is the sleep stage, 4:00 to 6:00 the morning wake up period, 6:00 to 14:00 the morning and noon stage, 14:00—22:00 the afternoon and evening stage, and 22:00—0:00 the sleep stage. The heart rate variation per hour in each time period is displayed in Table 8.

Table 8 Correlation between day and night time and heart rate

Time period	2:00—4:00	4:00—6:00	6:00—14:00
Heart rate variation per hour/(beats•min^{-1})	+1	+2	+1
Time period	14:00—22:00	22:00—0:00	0:00—2:00
Heart rate variation per hour/(beats•min^{-1})	−1	−2	−1

2.3 Correction algorithm design

The design of the correction process and the specific heart rate correction algorithm are based on the research of the influence of multiple factors. After the heart rate value is corrected three times in terms of gender, age, and time, the corrected results that are more consistent with the user's real condition are returned, and are finally compared with the basic judgment standard of heart rate to obtain an accurate evaluation of health status.

Considering the relationship between gender and heart rate mentioned, the average heart rate of women aged 60 to 90 is 2.026 beats/min faster than men's. Therefore, the heart rate value of women should subtract the corresponding gender difference during the correction. The heart rate is corrected according to the user's gender as the user's heart rate value measured by the sensor is set as HR and the user's gender variable as HRsex. For men, HRsex =0, otherwise HR_{sex}=2.026. Then the HR value is updated by

$$HR = HR - HR_{sex} \tag{3}$$

where it is observed that the average heart rate of people aged 60—90 tends to slow down by 0.156

beats/min for every increase of one year in age. Therefore, during the correction, the corresponding step value should be added to the heart rate value for every new year of life. The heart rate is corrected according to the user's age where the user's age variable is set as HR_{age}, considering HR_{age}=(user's age−60) ×0.156 beats/min, and the HR value is updated again by

$$\begin{cases} HR_{age} = (\text{user's age} - 60) \times 0.156 \\ HR = HR + HR_{age} \end{cases} \tag{4}$$

Through the analysis of this specific data, it can be said that the heart rate variations prove its rhythmical fluctuating and changing during the day and night, presenting an overall situation of fast heart rate during the day and slow heart rate at night. During the period of 2:00 to 14:00, the heart rate value increases by different degrees every hour, and the maximum value appears around 14:00. Additionally, from 14:00 to 2:00, the heart rate value is reduced by different degrees every hour, and the minimum value appears around 2:00.

The heart rate is corrected according to the measurement time. The minimum value of heart rate is set as 0 at 2:00 and reaches a peak as 14 at 14: 00, and the median 7 corresponds to a time point of 7:00. The heart rate at 7:00 is used as the reference value to establish functions for different periods, and then the value is increased or decreased according to the variation value in each period. After setting the time variable of heart rate as HR_{time}, the interval is accurate to one hour, and a function HR_{time}=hr (time) for the heart rate-time transformation curve is established. The corresponding HR_{time} of measurement time is then obtained, and the HR is updated again by

$$hr(\text{time}) = \begin{cases} 7 - (\text{time} - 2) \times 1 & 2{:}00 \leqslant \text{time} < 4{:}00 \\ 5 - (\text{time} - 4) \times 2 & 4{:}00 \leqslant \text{time} < 6{:}00 \\ 1 & 6{:}00 \leqslant \text{time} < 7{:}00 \\ 0 & \text{time} = 7{:}00 \\ -(\text{time} - 7) \times 1 & 7{:}00 \leqslant \text{time} < 14{:}00 \\ -7 + (\text{time} - 14) \times 1 & 14{:}00 \leqslant \text{time} < 22{:}00 \\ 1 + (\text{time} - 22) \times 2 & 22{:}00 \leqslant \text{time} < 0{:}00 \\ 5 + (\text{time}) \times 1 & 0{:}00 \leqslant \text{time} < 2{:}00 \end{cases} \tag{5}$$

$$\begin{cases} HR_{time} = hr(\text{time}) \\ HR = HR + HR_{time} \end{cases} \tag{6}$$

After three corrections in gender, age, and time, the HR obtains the user's final corrects heart rate value. This value is compared with the heart rate's basic judgment conditions to determine the user's interval of heart rate distribution and output corresponding feedback results. Considering the actual impact of the accuracy of the heart rate value, its value on the user interface can be rounded to a single digit. The corrected judgment method of HR is

$$\begin{cases} 55 \leqslant HR \leqslant 90 & \text{Normal} \\ 46 \leqslant HR \leqslant 54 & \text{Low-shallow warning} \\ 91 \leqslant HR \leqslant 99 & \text{High-shallow warning} \\ HR \leqslant 45 & \text{Low-deep warning} \\ HR \geqslant 100 & \text{High-deep warning} \end{cases} \tag{7}$$

3 Conclusions

Consequently, the processing method of physiological information in the health monitoring system is key to the analysis and correction of the collected information. This study is valuable for obtaining more accurate results, and proposes a new health monitoring model based on differences in the subjects' physiological factors and measurement time. The correlations between gender, age, measurement time, and vital signs are quantified and calculated according to the statistical analysis of the literature and clinical experiment data. This process is crucial in obtaining the detailed difference and step-change laws. Circadian time's influence, along with the median of the peak and valley values during the circadian time are used in the algorithm as the foundation for time interval divisions.

Furthermore, the study discusses and tabulates the changes in these time intervals and designs a correlation algorithm for the measured value of physical signs. The measured values are corrected three times for gender, age, and measurement to obtain values more consistent with the subjects' actual physical status. Finally, the corrected value is compared with the basic judgment conditions to obtain the evaluation result to reduce the influence of interference factors on the heart rate measurement.

In the case study, the monitoring mode is explained and verified in detail with the heart rate measurement and correction. The result shows that gender, age, and measurement time have specific influences on heart rate. Also, deviations in the influence of different factors may even result in misjudgment of health status and delay the potential rescuing operations. Therefore, we can reduce the influence of interference factors on heart rate measurement with the proposed algorithm.

Among the factors influencing the measurement of human body signs, gender, age, and time are universal and typical. This study only analyzes these three factors for their correlations with signs, as they are somewhat uncontrollable compared to the subjects' exercise status and measurement position. Consequently, in the future studies, more samples could be collected to expand on these factors' effects, including ambient temperature, light, and mood, on measuring body signs to obtain more comprehensive corrected results.

The proposed algorithm provides a scientific basis for correcting the deviation in measured physiological values caused by a myriad of factors in the field of health monitoring. The correction algorithm can be applied in the health monitoring products for the elderly. It has important practical significance for accurately and effectively assisting elderly group in health monitoring procedures, as well as mitigating the risk of disease deterioration.

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Author contributions Dr. ZHU Tianyang contributed to the ideas for this project, analyzed correlation factors and designed the correction algorithm. Prof. **ZHANG Yajun**

summarized the existing relevant studies and contributed to the methods of correlation analysis. Prof. **ZHOU Junliang** discussed the background and analyzed the heart rate characteristics. Mr. **ZHOU Aotu** collated and screened the sample data. All authors commented on the manuscript draft and approved the submission.

Competing interests The authors declare no competing interests.

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基于修正模式的健康监测系统研究

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摘要：现有的健康监测系统通常忽略了老年人真实健康需求并且缺少对不同被试者差异因素的考量，导致监测结果不准确，测量值与真实健康状态可能出现偏差，延误了对突发健康问题的救治。为解决这一问题，本文提出了一种新的健康监测系统，包括生理参数的测量、修正和反馈。本研究收集了老年人临床样本，建立回归方程和统计模型，分析性别、年龄、测量时间和体征值之间的关系。通过设计修正算法对体征测量值多次修正，将最终数据与标准值进行比较来判断是否正常。这一过程有效降低了误判风险，同时更准确地匹配用户实际健康状况。本文以老年人心率的测量及修正作为应用实例验证了该创新方法的有效性，并给出具体修正过程，为未来健康监测研究中其他影响因素的剔除或修正提供了科学依据。

关键词：健康监测；修正模式；算法设计；心率