iFeliz: An Approach to Control Stress in the Midst of the Global Pandemic and Beyond for Smart Cities using the IoMT

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***Abstract*—Being able to live happily and peacefully should not be as difficult as it is in today's world. There is always so much happening around with the global pandemic and other current events that every human being is affected one way or another. Having emotions and reacting to events is good as long as there is a healthy stress response. When a person does not know how to cope with stress, technology should be able to provide a solution. Often, people don't realize that they are under stress until the very last moment. In order to avoid these mishaps, iFeliz a stress control system is proposed. iFeliz proposes different approaches to address on-spot or live sudden fluctuations in stress: a day-end method to allow the user understand the changes in daily physiological fluctuations, and weekly and monthly approaches to analyze the variations in stress for a certain period to predict any further health issues. Post traumatic disorder is a significant issue and life after COVID-19 will not be the same. Keeping this in mind, iFeliz is proposed to improve the smart healthcare domain thereby improving the smartness in smart cities.**

***Index terms*—** Human Stress Control, Smart Cities, Chronic Stress, Anxiety, PTSD, Human Stress Monitoring, Pandemic, COVID-19

I. Introduction

Technological innovations provide the solid foundations for experiencing higher economic growth and human progress [1]. The Internet of Things (IoT) and specifically, the Internet of Medical Things (IoMT), is the means with which devices or things are connected for timely communication in any smart infrastructure [2].

A smart city can be envisioned as a technology paradigm in which traditional networks and services are made more flexible by improving its operations. The components of smart cities include smart transportation, buildings, infrastructure, energy, healthcare etc. [3]. There are many applications for improving the operations of smart cities which include branches like environment monitoring, smart parking, etc., [4]–[6] which have been used in many real life scenarios such as offices and universities [7]–[9].

Still, there are a few questions that need to be answered, such as how much smart is too much smart and how do we define smartness of a component or a city. Though there is not a specific answer for how much is too much, there is a significant rather slow adoption of new smart devices, appliances, technology, wearables etc., by humans [10]. Though a city has every smart component that is in order to be called a smart city, the true state of smartness can be achieved when both the users and the technology benefit. For example, in the smart healthcare domain, the users who use wearables should be educated on how to get control over their bodies while the data that is collected by the wearables must be used to analyze any future issues the users may have.

Keeping this in mind, this research proposes iFeliz, an approach to stay happy and calm by addressing chronic stress through everything that is happening in today's life. Stress is considered as an important factor for many chronic diseases. Prolonged stress can cause fatal diseases like cancer, anxiety, depression, obesity, PTSD, PCOS, Type II diabetes, osteoporosis, and memory problems [11]. Through iFeliz, the idea is to be potentially happy and relaxed during pandemics like COVID-19 or even after it. The pictorial representation of idea behind iFeliz is shown in Fig. 1.

Fig. 1. Pictorial representation of iFeliz.

The organization of this paper is as follows: Section II summarizes the existing state-of-the-art literature for stress detection and control. Section III lists the novel contributions along with the motivation behind this research. Section IV represents the broad perspective of iFeliz. Section V represents the system level perspective of the proposed iFeliz. Section VI explains the different approaches iFeliz is proposing. Section VII contains the implementation and validation details of iFeliz followed by conclusions and future research in Section VIII.

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II. Related Prior Research

There are many wearables that are readily available in the market for monitoring purposes. Table I summarizes the name of the wearable, the sensors used in it, its features and drawbacks.

Aside from wearables, there are many research articles that address stress monitoring methods. Some of the state-of-the-art literature is presented in Table II.

Though there are number of applications for stress detection and monitoring, the concept of stress control is still not well developed.

III. Novel Contributions

iFeliz attempts to propose a solution that is user friendly and helpful for users without having to sacrifice convenience over health. The following are the novel contributions that are presented in this research:

- A mobile application interface completely dedicated for stress management with no user input.
- Provides an interface which uses real time location of the user to provide appropriate remedies.
- A potential extension of any product that gathers the data from the user.
- Four different approach methods which have the ability to address immediate and analyzed stress.
- A protocol to analyze stress states and stress levels to suggest remedies and actions to control stress.
- Provides user access to the analyzed data.
- Allows users to understand the fluctuations of stress and get back their control over their body.

IV. iFeliz: A Broad Perspective of Stress Control using the IoMT

The broad idea behind iFeliz is to allow the users to understand the importance of stress. In order to understand the importance of stress, the user has to know the way stress affects the human body.

A. Why is Stress an Important Factor?

Stress can be defined as a reaction of the human body to a situation. The common elements to stress are *Novelty* for something a person has never experienced before, *Unpredictability* of the situation that may occur, *Threat* to the ego when a person's competence is questioned and *Sense* of not having control over the situation [23]. Under these situations, a stress hormone called cortisol is released in the human body. The circumstances which allow the secretion of cortisol are called stressors. There are four types of stressors [11]:

- Physiological Stressors - which put the strain physically on the body.
- Psychological Stressors - which have an impact on the mental health of a person.
- Absolute Stressors - Effect on humans because of natural calamities, such as 9/11 or COVID-19, and
- Relative Stressors - Effect on specific humans because of work pressure, exam pressure, traffic, insomnia, etc.

B. How to Recognize Stress?

Stress is broadly categorized into distress, which is negative stress and eustress, a positive stress. Stress can be be further classified in three different categories: acute stress, episodic acute stress and chronic stress. Acute stress is short-term while episodic acute stress is the repetition in the frequency of occurrence of acute stress. Chronic stress is the result of prolonged exposure to stressors. When a stressful situation occurs, the levels of stress hormones rises to meet the demands of the situation and fall once it is dealt with [24]. However, with prolonged exposure to chronic stress, the human body experiences:

- The wear and tear of stress response - for being activated more than once for a small period of time.
- Habituation - where the human body is habituated to function under stress.
- Prolonged Response - human body fails to go back to its base state.
- Inadequate Response - Human body loses its ability to respond to stress in future.

Chronic stress is categorized in three different stages. These stages along with the changes in the human body are presented in the Table III. The symptoms of stress are in a variety of form, a selected of which are are shown in Fig. 2.

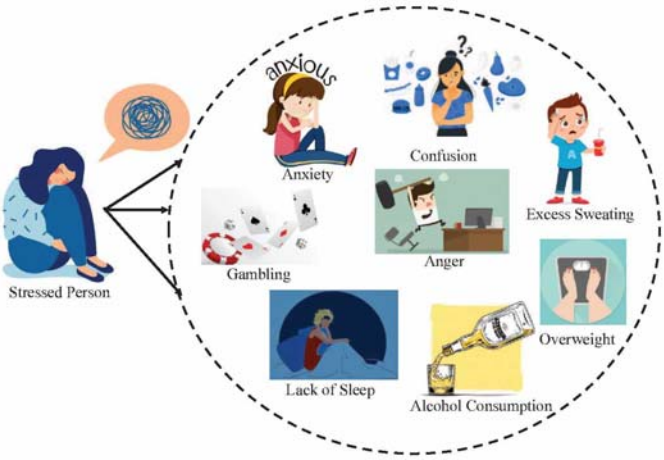

Fig. 2. Symptoms of Stress.

C. How to Control Stress?

A way to tackle stress is to find ways to cope up with it. There are two types of coping strategies: problem-focused and emotion-focused. Problem-focused strategies deal with analyzing the situations, accepting the outcomes, working harder, etc., while emotion-focused strategies are based on improving the mental health of the person by imagining, visualizing success or generating happy thoughts. As noted in Section II, there are very few applications or products which allow stress management and control. Incorporating self monitoring methods for stress in the IoMT provides a way to lay a strong foundation for developing a smart city. A way of

TABLE I
NOTABLE WEARABLES AVAILABLE IN THE MARKET

Wearable	Sensors Used	Features	Drawbacks
Xiaomi Mi Band 4 [12]	Heart Rate sensors; When connected to a phone, alerts will be sent by the device which tracks sudden increases in heart rate.	Tracks the number of hours slept and makes suggestions based on the calories burned.	No stress monitoring or control suggestions; Generalized application. Slow response to spikes in heart rate.
Garmin viviosmart 4 [13]	Sensors which monitor the amalgamation of sleep movement, heart rate, and pulse oxymeter sensor	A function that tracks stress levels based on previous activities; GPS function which notifies the user of the locations that increase stress levels.	No stress control suggestions or remedies. Price could deter consumers as market value is high.
Moodmetric Smart Ring [14]	Electrodermal activity	Uses an algorithm that maps stress data into a number between 1-100. Displays a round diagram that notifies the users stress fluctuation over a 12-hour period	No stress control suggestions or remedies. Not very affordable for everyone as the market price is high.
Muse 2 [15]	EEG	Sound therapy: the user will hear peaceful weather sounds when calm and thunderstorm sounds when the sensor picks up a wandering mind.	User is always required to wear the band, does not consider other physiological parameters.
Thync Relax Pro [16]	EEG	Deep sleep and relax modes by emitting higher and lower electric pulses to maintain the relaxed state.	High market price for the device plus an additional monthly charge for app usage. Sleep quality data cannot be accessed by the user thereby questioning the effectiveness of the device. Restricted usage for pregnant woman or individuals with a pacemaker.
Lief Smart Patch [17]	Heart Rate Variability (HRV).	When stress levels reach a high value, the app plays soothing sounds and sends vibrations through the patch.	Sticker underneath the sensor is not reusable thereby increasing the price. Does not measure cortisol levels in perspiration. User is not allowed data access.

TABLE II
STATE-OF-THE-ART LITERATURE.

Research	Sensors Used	Action	Drawbacks
Anusha et al. [18]	Electrodermal Activity (EDA)	Stress Monitoring	No Stress Control
Can et al. [19]	Heart Rate, Skin Conductance, Accelerometer and Skin Temperature	Stress Monitoring	No Stress Control
Delmastro et al. [20]	Physical Activity	Stress Detection	No Stress Control
Cheong et al. [21]	Heart Rate and Temperature Sensors	Stress Detection	No Stress Control
Hao et al. [22]	PPG and Accelerometer	Stress Detection	No Stress Control
iFeliz (Current Paper)	PSG, Food Images, Body Temperature, Accelerometer, Humidity	Stress Detection	Stress Control

TABLE III
STAGES OF CHRONIC STRESS

Stages	Effects on Human Body
Stage 1	Increase in Heart Rate, Breathing, Blood Sugar Levels, Blood Pressure Levels and Problems with Digestion.
Stage 2	Continuous Anxiousness and Worry, Overwhelming Feelings, Lack of Concentration, Increase of Alcohol Consumption, Uncontrollable Smoking, often Flu and Cold, Imagining the Worst of Everything and Memory Loss.
Stage 3	Heart diseases, Insomnia, Depression, Cancer and Burnout.

controlling the human body and gaining back control over it by monitoring physical activity data is provided in [25]. As over eating or binge eating is another main important factor for various health issues, a self monitoring system to analyze and differentiate stress-eating vs normal-eating is proposed in [26]. A similar method to tackle insomnia, a very important factor of stress, is proposed in [27].

iFeliz includes ways to analyze stress behavior as well as provides suggestion to control depending on the level of stress of the user. iFeliz can be an add-on to the wearables proposed for physical activity, stress-eating and smart-sleeping as well as can be a stand-alone device. The data from the many available smart devices is taken for suggesting stress control remedies through a mobile application interface to the user.

V. ARCHITECTURE FOR STRESS CONTROL IN IFELIZ

The architecture of iFeliz has all the physiological data that is collected by the various sensors, the sleep cycle data and the food consumption data for analyzing and monitoring stress level fluctuations. This raw physiological sensor data is fed to deep learning edge models where the data processing and analysis is performed. After the analysis, the stress level is characterized. This characterized data is sent to the user for visualization through a mobile application interface. The feedback through short-term and long-term advice is provided to the user through iFeliz as represented in Fig. 3.

The system level representation of iFeliz is shown in Fig. 4. The classified stress level data from the edge devices using deep learning models is sent to the cloud platform. From here, the database interconnected with the platform has the stress control remedies, both short-term and long-term. This control remedy data from the database is taken when required by the approaches. The suggested remedies are then displayed to the user through a mobile application.

VI. Proposed Approaches for Stress Control

iFeliz proposes short-term and long-term feedback mechanisms, as seen in Fig. 3. The short-term mechanisms are again classified in live or on-spot remedy approaches and day-end analysis of stress levels and remedies. The long-term mechanisms are analyzed in weekly and monthly approaches. The pictorial representation of the approaches proposed in iFeliz is shown in Fig. 5.

The four approaches are related as the decision of the analysis of each stress level along with the remedy are linked with the previous approach. The approaches in Fig. 5 follow Algorithm 1. Studies show that the mood of a person is directly proportional to the amount of time the person has spent in that mood [28], [29].

VII. Implementation and Validation

A. Implementation of Proposed Approaches for Stress Control

The analyzed classified stress level data from wearables is taken. This classified data is compared to the ranges of the Control Remedies data available in the database, as shown in Fig. 4. The respective and appropriate stress control remedies are provided to the user as notifications whenever there is a match in the comparison. Google Flutter is used for developing the application and is shown in the Fig. 6. Depending upon the type of approach, the short-term and long-term are displayed.

TABLE IV
REMEDIES FOR STRESS CONTROL FOR SHORT-TERM APPROACHES

Low Stress (Alarm Reaction)	Medium Stress (Resistance)	High Stress (Exhaustion)
1 min meditation	3 min meditation	15 min meditation
1 min heavy breathing	3 min heavy breathing	15 min heavy breathing
30 sec smile	1 min smile	10 heavy laughter's
Scroll through photos	Read motivational quotes	Watch funny videos
Stretch your body	Read a book	Write how you feel

Algorithm 1 iFeliz and its Approaches

```
Initialize the input random variables l, d, w and m to zero.
Initialize the output random variables st and lt to zero.
Assign the input variables to live, day-end, weekly and
  monthly respectively.
Assign output variables to short-term and long-term re-
  spectively.
Assign classified stress level data to D with L, M and H
  as Low, Medium and High levels.
Declare a Boolean variable 'data' to 'true' for D from
  wearables.
while data==true do
  Move the contents of D to l.
  while l==L | | l==M | | l==H do
    Display st for L, M and H.
    while l !=0 do
      Move the contents of l to d.
      if 0.08*l == L then
        Display st for low stress.
      else if 0.08*l == M then
        Display st for medium stress.
      else if 0.08*l == H then
        Display st for High stress.
      end if
      while d !=0 do
        Move the contents of d to w.
        if 2*d >= H then
          Display lt for low stress.
        else if 4*d >= H then
          Display lt for medium stress.
        else if 5*d >= H then
          Display lt for High stress.
        end if
        while w !=0 do
          Move the contents of w to m.
          if 1*w >= H then
            Display lt for low stress.
          else if 2*w >= H then
            Display lt for medium stress.
          else if 3*w >= H then
            Display lt for High stress.
          end if
        end while
      end while
    end while
  end while
end while
```

B. Validation of Stress Control Remedies in iFeliz

The stress control remedies proposed in iFeliz are suggested in such a way that the user will be able to cope up with the situations. The division of short-term and long-term is made after considering the duration of a person experiencing stress and the impact of it. Yoga, and meditation are the go-

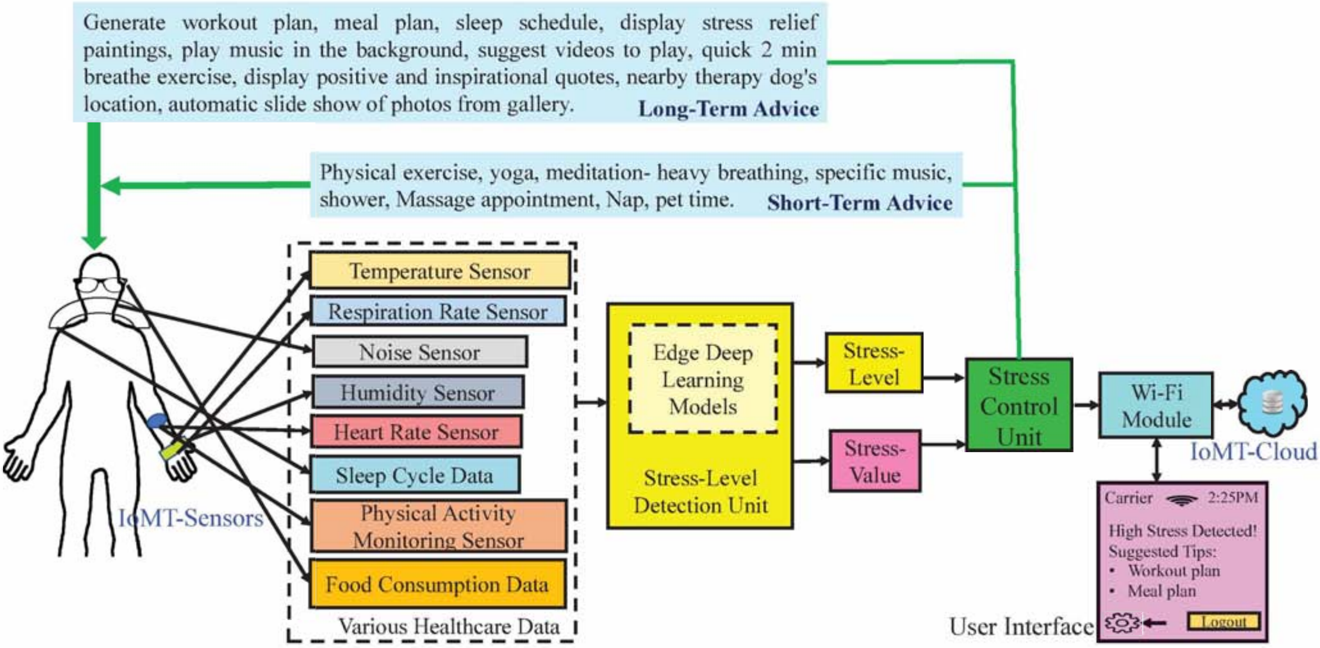

Fig. 3. An Architectural View of Stress Control in iFeliz.

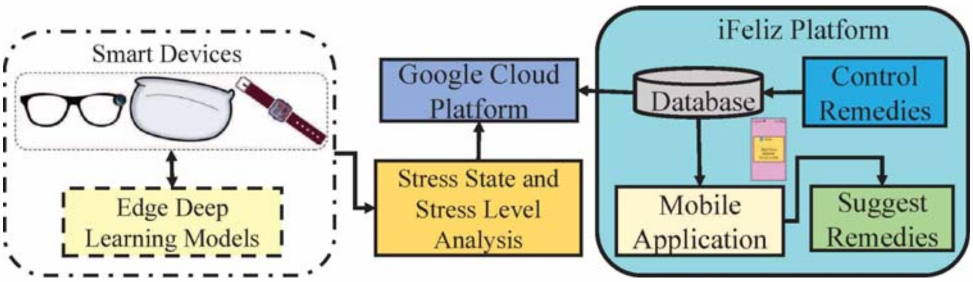

Fig. 4. System Level Modeling for Stress Control in iFeliz.

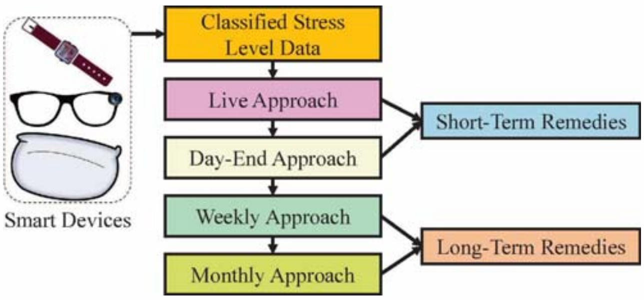

Fig. 5. Stress Control Approaches in iFeliz.

to remedies for even stage 3 chronic stress disorders [30], [31]. Studies also indicate that on exposure to certain pictures, or listening to music, there is a significant variation in the physiological response [32], [33]. Also, in our previous work [25]–[27] it has been shown that there is a significant effect of physical activity, food consumed and sleep quality on the physiological response.

1) Validation of Short-Term Remedies in iFeliz: The proposed stress control remedies in the dataset are compared to the classified stress level data from wearables. The Live and Day-End approaches are considered as short-term as the duration of a person during stress is relatively low when compared to prolonged exposure of stress. Typically, Live and Day-End approaches can be categorized under acute or stage 1 chronic stress which are not severe when compared to chronic stress stages 2 and 3.

Table IV shows the short-term remedies for alarm reaction, resistance and exhaustion, as explained in Sec. IV-A.

2) Validation of Long-Term Remedies in iFeliz: The Weekly and Monthly approaches are considered long-term as the time duration of the stress is much higher. Such prolonged exposures cause many health issues for the users. These approaches can be categorized under stages 2 and 3 of chronic stress, anxiety issues, post-traumatic stress and are very important to stay in control for a person to live happily and stay healthy.

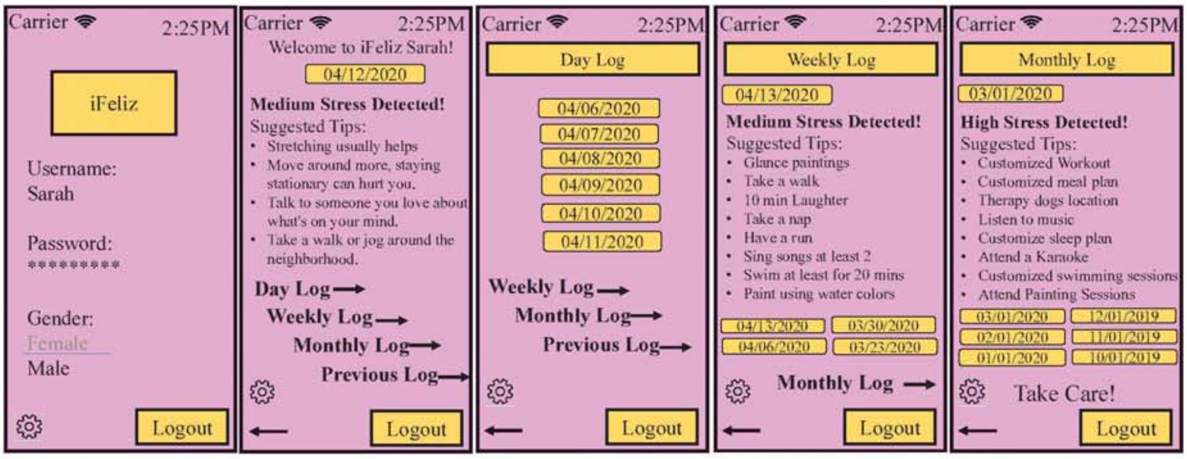

Fig. 6. User Interface of the Proposed iFeliz.

TABLE V
REMEDIES FOR STRESS CONTROL FOR LONG-TERM APPROACHES

Low Stress (Alarm Reaction)	Medium Stress (Resistance)	High Stress (Exhaustion)
15 min meditation	Glance paintings	Customized Workout
15 min heavy breathing	Take a walk	Customized meal plan
1 min smile	10 min laughter	Nearby therapy dog's location
Scroll through photos	Take a nap	Listen to music
Practice Yoga	Have a run	Customized Sleep Plan
Listen to Songs	Sing atleast 2 songs	Attend a Karaoke
Take a hot bath	Swim for atleast 20 mins	Customized swimming sessions
Practice Painting	Practice water color painting	Attend painting sessions

Table V displays the long-term remedies for alarm reaction, resistance and exhaustion.

3) Comparison of iFeliz with the state-of-the-art: The approaches proposed in iFeliz are compared with the state-of-the-art literature in Table VI.

VIII. CONCLUSIONS AND FUTURE RESEARCH

iFeliz is an attempt to lay a good foundation or to improve the operation for smart cities as healthcare is a very important domain for any smart city. We envision that the smartness of the city can be defined by the learning rate of both users and the equipment. Keeping this in mind, iFeliz has been proposed as a four-pronged application with no user input to analyze and control stress automatically. The mobile application can be interfaced with any wearable and can be made available for any mobile platform.

Increasing the scope of the application from smart cities to personalized user applications is one of our plans to investigate in the future. Creating personalized meal plans, workout plans, conducting virtual therapy sessions with the use of artificial intelligence, analyzing each and every situation of a person and informing the user about the chances of potential health hazards is the main objective of our ongoing research on this technical domain.

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TABLE VI
COMPARISON OF IFELIZ WITH STATE-OF-THE-ART

Research	Sensors	Features	Stress Detection	Stress Levels	Stress Control	Accuracy %
Anusha, et al. [18]	Electrodermal Activity (EDA)	57	Yes	3	No	85.06
Can, et al. [19]	Heart Rate, Skin Conductance, Accelerometer and Skin Temperature	NA	Yes	3	No	94.52
Delmastro, et al. [20]	Physical Activity	21	Yes	2	No	85
Cheong, et al. [21]	Heart Rate and Temperature Sensors	NA	Yes	NA	No	NA
Hao, et al. [22]	PPG and Accelerometer	NA	Yes	3	No	81.8
Rachakonda, et al. [26]	Image Data	4	Yes	2	Partially Yes	98
Rachakonda, et al. [25]	Body Temperature, Steps taken and Humidity	3	Yes	3	Partially Yes	98.3
Rachakonda, et al. [27]	Polysomnography, Sleep Duration and Snoring Range	8	Yes	5	Partially Yes	96
iFeliz (Current Paper)	PSG, Snoring Range, Sleep Duration, Images, Body Temperature, Steps taken and Humidity	15	Yes	3	Yes	97

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