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Reducing Children's Obesity in the Age of Telehealth and AI/IoT Technologies in Gulf Countries

Mohammed Faisal [1,*], Hebah ElGibreen [2,3], Nora Alafif [4] and Chibli Joumaa [1]

[1] Center of AI and Robotics (CAIR), Kuwait College of Science and Technology (KCST), Kuwait City 35002, Kuwait
[2] Information Technology Department, College of Computer and Information Science, King Saud University, Riyadh 11543, Saudi Arabia
[3] Artificial Intelligence Center of Advanced Studies (Thakaa), King Saud University, Riyadh 4545, Saudi Arabia
[4] Department of Community Health Sciences, College of Applied Medical Sciences, King Saud University, Riyadh 11451, Saudi Arabia
* Correspondence: m.naji@kcst.edu.kw

Abstract: Childhood obesity has become one of the major health issues in the global population. The increasing prevalence of childhood obesity is associated with serious health issues and comorbidities related to obesity. Several studies mentioned that childhood obesity became even worse recently due to the effect of COVID-19 and the consequent policies and regulations. For that reason, Internet of Things (IoT) technologies should be utilized to overcome the challenges related to obesity management and provide care from a distance to improve the health care services for obesity. However, IoT by itself is a limited resource and it is important to consider other artificial intelligent (AI) components. Thus, this paper contributes into the literature of child obesity management by introducing a comprehensive survey for obesity management covering clinical work measuring the association between sleep disturbances and childhood obesity alongside physical activity and diet and comparatively analyzing the emerging technologies used to prevent childhood obesity. It further contributes to the literature by proposing an interactive smart framework that combines clinical and emerging AI/telehealth technologies to manage child obesity. The proposed framework can be used to reduce children obesity and improve their quality of life using Machine Learning (ML). It utilizes IoT devices to integrate information from different sources and complement it with a mobile application and web-based platform to connect parents and physicians with their child.

Keywords: children obesity; machine learning; Internet of Things

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1. Introduction and Background

Global health observatory data from the World Health Organization (WHO) in 2017 documented a total of 340 million children and adolescents between the ages of 5 and 19 with obesity [1]. Obesity in the Gulf countries among children and adolescents ranges from 5% to 14% in males and from 3% to 18% in females [2]. It was also reported by a systematic review of 18 articles (between 1998 and 2010) from the Saudi population of the age 6–21 years old, including 88265 children and adolescents, showing an average prevalence of being overweight and obesity of 26.7% [3]. More recently, it was found that the prevalence of obesity in children from 4 to 8 years old are around 19.2% in Saudi Arabia by 2016 [4]. As confirmed by several studies [5–10], obesity became even worse recently due to the effect of COVID-19 policies and regulation around the world. Other studies have also focused on the Saudi community during the pandemic and dove into their eating habits and weight progress [11,12]. These studies have agreed that the sample reported an improvement in the food quality as homemade cooking was consumed more, but the quantity of the food was compromised, which negatively affected obese and overweight children. It was concluded that obesity levels in children have increased more than adults during that period.

Physical activity is defined as the skeletal muscular movement of a body, which results in energy expenditure [4]. Low physical activity levels among schoolchildren increases their risk of long-term health problems such as heart disease and brittle bones. [13]. Another challenge in managing obesity is that it can be associated with other factors of a child's lifestyle. One important factor is sleep, where it was documented that children's sleep is an important marker for both well-being and health [12]. Sleep is essential to maintain children's health. Poor/irregular sleep or lack of sleep in early childhood can lead to excessive weight gain, which leads to obesity. Short durations of sleep can also worsen cognitive, cardiometabolic, and general function/ability of children [14]. According to the National Sleep Foundation in the United States [15], it is recommended that preschool (3–5 year) children require a minimum of from 10 to 13 h of sleep and that school-aged children (6–13 year) require from 9 to 11 h of sleep for optimal health [16]. Another factor causing childhood obesity among school children is the excessive using of technology, especially watching TV, playing digital games, and using computers. [17]. Therefore, the life pattern is an important factor and studies must be conducted with respect to the culture of Gulf countries to find the optimal clinical model to reduce child obesity. Moreover, public health must focus more on tracking the children's habits and increasing the awareness of healthy eating with the help of emerging technologies. Nevertheless, despite the significant escalation in the rate of obesity in children throughout the world during the past three decades, there is currently no clear treatment strategy [18].

Telehealth and emerging technologies can be utilized to overcome the challenges discussed previously and provide care from distance to improve the health care services for obesity [19,20]. Through IoT, sensors can be used to monitor biomedical variables of the child, such as sleep, heart rate, activities, and temperature. This causes it to be easier to connect with the child and track their activities and health condition even if they are not at home. However, IoT by itself is a limited resource and it is important to consider other AI components to analyze the data and interact with the child accordingly [21]. This is of particular importance because children requirements are more difficult and challenging than those of adults [22,23]. They need encouragement, surprise elements, and engagement to affect them. Traditional obesity management systems face difficulties in which users reported discomfort and loss of motivation in using non-personalized systems [23]

Chau et al. [24] measured the utility and acceptability of children to an obesity prevention system to find that more than 90% of the children and parents have agreed that the system was encouraging and can help in reducing the brief clinical encounters. A study was conducted in [25] over 11 elementary schools to find that 44.3% of the children preferred using gaming applications while 63.2% preferred Japanese animated characters rather than traditional obesity management applications. Thus, it is important to utilize AI and create an interactive community for both children and parents. Even though smart IoT applications have been introduced to the literature of obesity m-health systems and are important to track daily activities, these applications need to be complemented with AI components that alert the parent/health care provider while engaging the children with the system to accept the given recommendations. The current literature needs further development with respect to obesity management for children, especially when considering Saudi culture. Most of the current systems are in English and do not consider the calories of Gulf food. The interactivity and motivation are still underrated, even though they can produce a huge difference when it comes to children acceptance. Not to mention, the parents' social community and connection with a health care provider were rarely introduced.

Due to the clinical and technical challenges discussed before, this study is proposed with an ultimate goal of increasing children/parent awareness, regulating sleep, reducing obesity, and increasing physical activity. In particular, this study contributes to the literature of obesity management as follows: First, a comprehensive survey for obesity management from the research and commercial perspective will be introduced. The published work measuring the association between sleep disturbances and childhood obesity alongside with physical activity and diet will be discussed from the clinical perspective and a comparative

study about technologies used to prevent childhood obesity will also be presented. We have already conducted a preliminary investigation to study the relationship between sleep and obesity among Saudi children [26] to find that sleeping problems are prevalent, in which 94.4% of children with obesity were found to have sleeping problems.

Second, a novel framework that combines clinical and emerging AI/telehealth technologies to manage obesity in Gulf countries will be introduced to improve their quality of life. The main purpose of this smart framework is to promote healthy life patterns for children. The framework will consider three main factors: sleep, diet, and physical activity. The proposed framework includes an interactive AI model to predict the best recommendation based on children lifestyle and utilizing the IoT devices to integrate information from different sources and complement it with a mobile application and web-based platform that connect parents and physicians with the child.

This paper is organized as follows. First, a comprehensive literature review is presented in Section 2. Second, the proposed framework is described in Section 3. Third, the discussion has been introduced in Section 4 and the conclusion is discussed in Section 5.

2. Related Work

This section will introduce a comprehensive survey for obesity management from two different aspects: research and commercial. From the research aspect, the published work measuring the association between sleep disturbances and childhood obesity alongside physical activity and diet will be discussed from the clinical perspective and then how technology has been used to prevent childhood obesity will also be presented. On the other hand, the commercial aspect will cover the software and hardware available in the market (free/non-free) that manage obesity.

2.1. Research Aspect

This section will investigate the research study from two different interventions, Clinical and Technology-Based intervention, and discuss recent studies related to obesity management to highlight the current open research areas and needed contribution.

a. *Clinical Intervention*

In the last 30 years, obesity and the number of overweight have increased in children. Several studies found that there is an inverse relationship between body mass and sleep duration during childhood [27]. Childhood obesity is considered as a major health problem because it may lead to many diseases such as cardiovascular diseases, hypertension, and diabetes. Sleep duration is not the only cause of obesity, as many factors such as food eating habits and the level of physical activity can cause it, but it is one of the major causes [28].

Physical activity is defined as the skeletal muscular movement of a body that results in energy expenditure. A lack of physical activity can lead to obesity, which is a commonly known risk-factor associated with low levels of physical exercise. A strong link was identified between health and education, which is associated with schools promoting physical activity to their students [29]. Physical education plays a major role in an advantageous position for endorsing leisure benefits of physical activities [30]. The WHO has stated that, globally, nearly 1.9 million deaths are accredited to physical activity and they recommend that school children should participate in 60 min per day physical activity [31].

Schools play an important role in creating a safe and caring environment that sustains healthy practices and also provides opportunities for students to learn and practice healthy eating habits and encourage regular physical activity. Physical inactivity combined with sedentary factors and poor diet can lead to weight gain in children [32]. Schools have a significant impact on the development of a secure and nurturing atmosphere that supports healthy behaviors and offers kids the chance to learn and put into practice good food and frequent physical activity. According to the WHO, physical inactivity is the fourth greatest cause of death worldwide and 57% of Saudi Arabia's children are believed to be inactive at the moment. [33]. There are few studies regarding physical activity and other relevant factors in Saudi schoolchildren [34]; there are few studies about a combination of physical

activity factors in adults, children, and expatriate populations from various regions of Saudi Arabia [35]. Therefore, more research is still required to evaluate the impact of physical exercise and determine its relationship to obesity. Healthy nutritional diets protect improved adult health status in school-aged children [36]. Preventing the onset of NCDs and chronic diseases in adolescence and adulthood can be achieved by instilling the habit of eating a balanced and healthy diet in children [37].

From 2005 to 2009, three studies on Saudi Arabia were carried out. The first study, which sought to evaluate sleep issues in Saudi elementary school students aged from 5 to 13, was proposed by BaHammam [38]. The analysis included 1012 fully completed questions in total. The findings of this survey indicated that daytime weariness (37.5%), bedtime resistance (26.2%), and sleep-onset delay (11.8%) are the most common sleep issues. In the second study [39], sleep duration was calculated for Saudi primary school students aged from 6 to 13 and the results were compared to published data from other societies. They discovered that Saudi schoolchildren's nighttime sleep duration was less than what had previously been reported. A different study by Bawazeer [40] looked into the connection between obesity and sleep duration in Saudi students between the ages of 10 and 19. According to this study, boys and girls who slept for fewer than 7 h had a considerably higher chance of becoming obese. More than 71% of schoolchildren did not get enough shut-eye at night, according to Al-Hazzaa [41]. Additionally, he discovered that among Saudi schoolchildren, having insufficient sleep at night was very common and was linked to eating breakfast as well as numerous sociodemographic and lifestyle factors.

Al-Hazzaa [41] found that more than 71% of school children did not sleep at night sufficiently. He also found that the popularity of insufficient sleep at night based on the Saudi school children was high, associated with breakfast and several socio-demographic and lifestyle behaviors.

Health education initiatives must be introduced at levels including people, families, communities, organizations, and agencies in Gulf nations to address childhood obesity. The risk, negative effects, and prevention of obesity should be made known to the general public. Children should eat breakfast that is high in nutrients, make good food choices, stay away from sugary drinks, and drink more water. Children should also limit non-physical activities such as watching television or playing video games, among others. The children must be encouraged and counseled by the health care professionals to implement these suggestions made by the institute for enhancing the clinical system.

b. *Technology-Based Intervention*

In the sphere of obesity prevention programs, technologies have been utilized in the past decade. It started with mobile health (m-health) systems in which mobiles were used to monitor the user's activities. SapoFit was proposed in [42] as a mobile application for diet monitoring and assessment. The application was designed to allow the user to keep a daily Personalized Health Record (PHR) of their food intake and daily exercise using their mobile to share it in social networks. The system collected the user's weight, calorie intake, and physical activities and customizes the alerts depending on the data inserted. Another mobile-based application was proposed in [43] to motivate adults in losing weight. The application collected the time of drinking water, calorie intake, and physical activities but it has not yet been tested on one user. Taçyıldız, Özgü et al. [44] proposed a mobile-based obesity tracking application that is targeting children and teenagers. It is an ontology-based obesity tracking system that uses predefined knowledge based on medical semantic rules to infer the recommendations. It tracks obesity and suggests treatments or activities depending on the age. It has an inferencing engine model to suggest the personalized activities. The system has a mobile interface used by the health providers, parents, and children to allow them to connect together and provide consultation via the mobile. An m-health application was developed in [45] to manage children obesity. The system increases the user's awareness about their intake by allowing them to scan food tags that they will eat and the system will automatically record the calories intake and send proper notification based on their food choices. It was designed to motivate children to learn good nutrition

habits with the help of their parents and teachers. Similarly, an application called So'rah [46] was developed as an m-health application but it was dedicated for Saudi dietary evaluation. The application allows the user to record their calorie intake and educate them about the number of calories in Saudi food. The food would be associated with a customized barcode and the mobile is used to scan the code and tell the user what the food name is and how many calories there are. The users can create a diet plan using the system and track their calorie and water intake.

The main drawback of m-health systems resides in the incapability of automating the tracking of user activities and burdening the user with entering all information, which causes it to be impossible for children to efficiently use it. Thus, IoT devices were introduced into the literature, where telehealth technology was sometimes provided, and certain vital signs were automatically collected using sensors.

Mohamed Alloghani et al. [47] proposed an educational tool for children, in which IoT is used to connect parents and a health provider with the child activity. The system proposed the use of IoT devices to collect the child intake using QR-code reader and vital/activity signs using a fitness tracker. The data are monitored by the parents and physicians to increase the child awareness of the consequences of being obese. It also allows both parents and physicians to provide recommendation on how to sustain a balanced and healthy diet. On the other hand, Wibisono and Astawa [48] proposed an m-health application that is connected to a special weight scale that upload weight reading to a server. The collected data are then used to provide a recommendation through a web page. This recommendation is concerned with the type of food that should be consumed to reduce weight and follow a healthy diet.

A ML with IoT-based smart health platform, called PISIoT, was proposed in [21]. This system is used to prevent, detect, treat, and control obesity and being overweight. ML algorithms were used in this system to classify patients to infer the right recommendation. The system was tested with elderly subjects, where their biomedical signs were collected through wearables and smart devices. The collected data are fed into the ML model to identify critical variables and produce the correct recommendation. Cloud computing and data analytics have also been used with IoT in [49] to monitor users' lifestyles (including food habits, physical activities, and sleeping habits) and help them adopt a healthier dietary lifestyle. The system collects the user's weight using the IoT sensors and sends it to the server on the cloud. Then, based on the collected data, the system shows the user's BMI progress using graphs and tables, allows the users to set up smart alarms on their mobile, and adds goals, diet plans, and exercise schedule. A new type of sensors was proposed in [50], in which the data are collected from different type of sources, including a wearable vest, sensors and devices, and user-reported data. The collected data are deployed into a smartphone application to assess the risk of obesity by using a rule-based algorithm that can infer the right recommendation by measuring the current activity level. After assessing the risk, the system will provide a personalized recommendation on the most suitable exercises and low-calorie plan.

In addition to smart obesity management system targeting adults, some research has been conducted to develop new applications for children. In [51], smartwatches were used as a tool to record children's heart rate variability to diagnose the child as overweight or obese. The smartwatch is connected to a smartphone and an online monitoring system so that the physician can monitor and analyze the child's cardiovascular parameters.

A study related to Saudis was published in [22], in which a social robot was developed and connected to IoT to help children overcoming obesity. This robot was designed for Saudi children and its ultimate purpose was to motivate children with obesity to monitor their daily activities and calorie intake. The robot is used to offer a set of activities for the obese child. A rest band is used to track the child movements and the mobile allows the child and parent to view their health record and keep track of their activities. The system also allows for health providers to track the child's activities, add recommendations and milestones, and connect to them when desired. Yet, the system does not autonomously

provide personalized recommendations and the system was not clinically tested yet. From all the literature discussed so far, important factors can be highlighted to compare the literature and highlight possible open research areas. In particular, the following criteria can be concluded and compared as shown in Table 1:

- Mobile (the system is supported with a mobile application).
- IoT (the system is supported with IoT sensors).
- Webpage (the system is supported with a webpage interface).
- Language (the supported language of the system proposed).
- Saudi Dietary (allow the user to know how many calories a Saudi dish has).
- Targeted User (what kind of obesity is the system designed for).
- Community (allow parents to communicate through the system platform).
- Connected Health Provider (allow the user to connect with a health care provider and allow the physician to keep track of the user progress).
- Recommender (support automatic recommendation that is not manually added).
- Interactive (support an interactive component to encourage and motivate the users to follow the given recommendations).

Table 1. Comparative analysis of technical-based publications.

Publication	[45]	[42]	[47]	[48]	[49]	[44]	[22]	[46]	[21]	[43]	[50]	[51]
Date	2012	2013	2016	2016	2017	2018	2018	2018	2019	2019	2020	2021
Mobile	√	√	√	√	√	√	√	√	√	√	√	√
IoT			√	√	√		√		√		√	√
Webpage	√		√	√			√		√		√	√
Language	English	English	English	English	English	English	Arabic	Arabic	English	English	English	English
Saudi Dietary								√				
Targeted User	Child	Public	Child	Public	Public	Child	Child	Public	Public	Public	Public	Child
Community												
Health care Provider	√		√			√	√		√			√
Recommend		√		√		√			√		√	
Interactive							√					

From the characteristics summarized in Table 1, it can be concluded that the literature has three main shortcomings. First, there is almost no contribution when it comes to Arab children. The current research is mostly focusing on obesity of the general public; additionally, Arab children are not familiar with the English language, which places a great burden on the parents to use and follow. Second, cultural diets are not considered, even though they play an important role if we want the user to log their calories intake accurately. Third, the social aspect of obesity management system is not highlighted in the literature. This aspect can be covered from two sides: social and intelligent interaction. When it comes to social, this component allows the parent to socialize in online communities and motivate each other when reading other parents' stories and discuss similar concerns. On the other hand, the intelligent interactivity is related more to the child, in which the system interactively provides their smart recommendation through an animated interface that engage the child and motivate them further.

2.2. Commercial Aspect

Several software and hardware have been developed to manage obesity either directly or indirectly. This section will summarize the most-known applications and conduct a comparative analysis to highlight the missing features in the current market.

2.2.1. Competitive Software

There are several m-health applications that try to reduce obesity. These applications can be categorized into three different types: sleep applications, weight loss applications, and activity applications.

a. *Sleep Applications*

Recently, several commercial applications have been introduced to deal with sleeping. The Sleep Cycle app [52] is used to monitor the user sleeping and wake them up when they are in light sleep to cause the user to feel better rested. The idea of this app is to wake up the user naturally, rather than with an alarm clock sleep cycle [52]. There are two different versions available: a free version and a premium version. The main feature of freemium version include a smooth wake up, detailed information, sleep visualization, setting alarms, snoozing, connecting to health apps, and exporting the user data. The main features of the paid version include: back-up, sleeping music, sounds, sleep thoughts, checking your mood, wake-up, weather forecasting, heart rate, and speed tracking. Another application called Pillow [53] analyzes the stages of the user sleep and wakes them up at the optimal time of their sleep.

b. *Weight Loss Apps*

The MyFitnessPal app [54] is one of the most popular weight loss app. It calculates the user's calorie intake and allows them to log what they eat throughout the day and provides a breakdown of the calories and nutrients that the user consumed throughout the day [54]. It has many features including calorie calculating, logging what users eat throughout the day, and provides a breakdown of the calories and nutrients in the daily intake. The features of the premium version include macronutrients in grams, food analysis, quick add of macronutrients, different goals by day, exercise calorie settings, a home screen dashboard, priority customer support, data export, macros by meal, goaling the calorie by meal, food timestamps, and plans. Another weight loss app is the Fitbit [54]. It is used to help the user to track their physical activity. By connecting with Fitbit watches, it tracks the user's daily activity, nutrition, water, and sleep [55]. Fitbit also has strong community features such as checking a friend's progress, sharing in various missions with friends and sharing the user progress, setting the bedtime and wake up time, monitoring the users' goals, and achievement list with awards.

c. *Activity Apps*

RunKeeper [56] is used to track walking, running, and any physical activities. RunKeeper is able to save and discover new routes with GPS to record the user's workout. The RunKeeper app has many features such as community, motivation, planning, saving user's routes, missions, connected apps, Bluetooth pairing, timer, sharing users' activities, scheduling, activity summary, and time tracking. The JEFIT Workout Tracker Gym app [57] is an essential app for gym-goers. The user can write their notes easily such as weight, height, fat, and how many lifts and sessions they went through. This app enables the user to track their daily workout and off day and save and graph all body measurements as they are progressing. JEFIT has many features: training logs and progress, help from user's friends, detailed workout summaries, and training reports.

2.2.2. Comparison

The applications discussed before can be compared to highlight important attributes and missing features. In particular, the following attributes are compared as shown in Table 2:

- Monitoring sleep (allow users to track their sleeping habits).
- Monitoring activity (tracking user activity per day and showing statistics).
- Monitoring fitness (users can choose any schedule for sports to do).
- Heart rate (provide the users clear information about their heart rate).
- Language (the language supported by the system).

- Targeted user (what kind of obesity is the system designed for).
- Community (platform that allows users to share and communicate or contact with specialist).

Table 2. Applications comparison.

App Name	Monitor Sleep	Monitor Activity	Monitor Fitness	Heart Rate	Language	Targeted Users	Community
Sleep Cycle	✓	✓		✓	English	Adult	
Pillow	✓			✓	English	Adult	
MyFitnessPal	✓	✓	✓	✓	English	Adult	
Fitbit	✓	✓	✓	✓	English	Adult	✓
RunKeeper		✓	✓	✓	English	Adult	✓
JEFIT		✓	✓		English	Adult	✓

From the applications presented in Table 2, it can be concluded that the current market needs further development with respect to obesity management for children, especially when considering Saudi children. Almost all of the current apps are in English and do not consider the calories of Saudi food. There is no app dedicated for children as they are mostly designed for tracking adults.

2.3. Complementary Hardware

A smartwatch is a digital watch that provides many features aside from time. It can monitor heartrate, track your activity and sleep, and have different reminders throughout the day. Different smartwatches are available in the market and can be used to complement any obesity management system. The Apple Watch [58] is a smart watch that is designed and developed by Apple and has the ability of fitness and health tracking. It has many features including fitness tracking, heartrate detection, activity tracker, blood oxygen monitoring, ECG, sleep tracking, and loud noise detection. Another device is the Fitbit Versa [59]. The Fitbit Versa was designed with a fitness tracker, heart rate sensor, workout detection, and best sleep tracking feature. Another watch is the Galaxy Watch [60], which focuses on fitness tracking and notifications for Samsung mobiles. It has many features including tracking users' workouts, stress trackers, sleep trackers, heart rate trackers, and improving sleep quality. Polar Ignite [61] is another smartwatch that is balanced and personalized to generate workout partners and help the user to push their limits and their ultimate goal. It has many features including a daily training guide, sleep tracker and improver, breath exercises, activity tracker, and heart rate sensor. The smartwatches discussed before can be compared with respect to their IoT sensors and functionalities. The following attributes are important to consider when a developer needs to decide on what watch should be supported by their system (as summarized in Table 3):

- Battery life (the number of hours in which the watch is working without charging).
- Activity (tracking daily activities).
- Fitness (tracking workout activity such as cardio or strength training).
- Heart rate sensor (have sensors that listen to the user's heart rate).
- Sleep (tracking how many hours the user sleeps).
- Price (the cost of the smart watch).

From Table 3, there is no watch better than the other. Depending on the needed sensors and available budget, the decision can be made. New prototypes can also be built to have an open-source access to the data and reduce the cost.

Table 3. Smart device comparison.

Device Name	Battery Life	Activity	Fitness	Sleep Tracker	Heart Sensor
Apple Watch	18 h	✓	✓		✓
Fitbit Versa 2	3 day	✓	✓	✓	✓
Galaxy Active 2	24 h	✓	✓	✓	✓
Polar Ignite	17 h	✓	✓	✓	✓

From the characteristics summarized in the comprehensive survey, we can realize that the literature has many main shortcomings. First, there is no solution that connects sleep, diet, and physical activity and utilizes the AI and IoT. Second, there is almost no contribution when it comes to Arab children. Third, cultural diets were not considered, and these play an important role if we want the user to log their calorie intakes accurately. Fourth, the social aspect of an obesity management system is not highlighted in the literature. From the applications aspect, it can be concluded that the current market needs further development with respect to obesity management for children, especially when considering Arab children. Almost all of the current apps are in English and do not consider the calories of Gulf food. There is no app dedicated for children as they are mostly designed for tracking adults. Thus, new solutions are still needed in children obesity management.

3. Proposed Framework

Child obesity is one of the most challenging problems in society. The kids' desires to use electronic devices force them to face the problems of weight gain, low physical activities, and short sleep duration. Parents being busy with their work leads to children spending longer hours on devices. Therefore, this study seeks to understand the clinical aspect of children with obesity and relevant factors that are of high impact. Based on the *social aspect* and clinical data, emerging IoT and AI technologies are utilized to monitor children's lifestyles (sleep, physical activity, and calories) and involve parents and health providers to know their children's pattern and encourage the children to change for a healthier lifestyle. We are proposing an interactive smart framework to reduce children obesity and improve their quality of life by using ML and utilizing the IoT devices to integrate information from different sources and complement it with a mobile application and web-based platform that connects parents and physicians with the child. This framework can be divided into two main phases (Figure 1): clinical phase and technical phase. Each phase consists of several overlapped tasks. The main purpose of the clinical phase of the proposed framework is to generate a clinical model by understanding the *social aspect*, the correlation between childhood obesity and sleep, diet, and physical activities. We have already conducted a preliminary investigation and published the results in [26]. It was conducted in national and international schools in Riyadh, Saudi Arabia, and a total of 122 children (age range: 5–13 years) were recruited. The results of this study showed that sleeping problems are prevalent, in which 94.4% of children with obesity were found to have sleeping problems.

In the clinical phase, an observational study has to be conducted to (1) gather quantitative/qualitative data (anthropometric, clinical, diet history, sleep, and physical activity) from children with obesity through their parents (a preliminary observational study has been conducted); (2) set the threshold of sleep, calorie intake, and activity according to recommended daily requirements based on their gender, age, and anthropometric measures.

The proposed framework's aim is to use the key attributes and quantitative results of the clinical phase to develop a preliminary clinical model. This model will be proposed to improve children's healthy life patterns including sleep, diet, and physical activities to ultimately reduce obesity. The critical findings will be fed into the second layer of the project and different educational activities will be conducted for the public to educate the community about the importance of tracking a child's lifestyle and how emerging IoT and AI technologies can improve such lifestyles and cause it to be easier to apply.

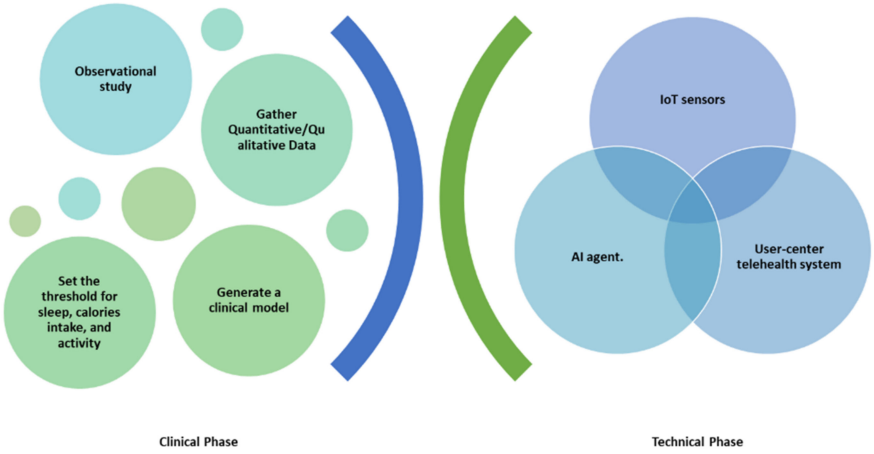

Figure 1. Phases of the proposed framework.

The second phase of the proposed framework is the technical phase, in which the IoT and AI are utilized to develop an AI agent (Figure 2) at the backend to customize the application behavior using ML methods and communicate with the child depending on the historical data collected during the clinical phase in addition to the streamed data monitored from the smart device. Figure 3 shows how the AI agent works and interacts with other components and the process of its characterization and recommendation. The agent will start by collecting the sensory data from the IoT devices (such as sleeping patterns, heart rate, and activities). The relevant child information (such as diet consumption, weight, height, age, gender, and BMI) will also be provided to the agent from the server. Then, the data will be preprocessed to be cleaned and normalized. The child's features will then be used as the input to the clustering ML method to characterize the child behavior and predict what group they belong to.

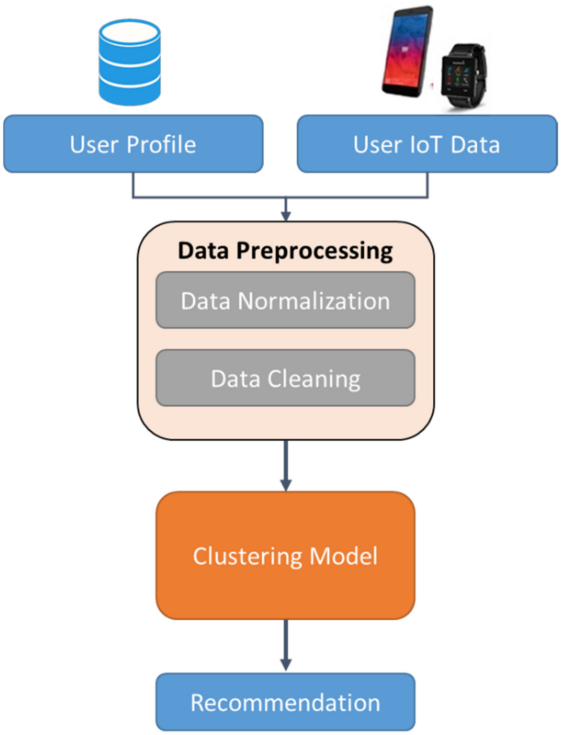

Figure 2. AI agent architecture.

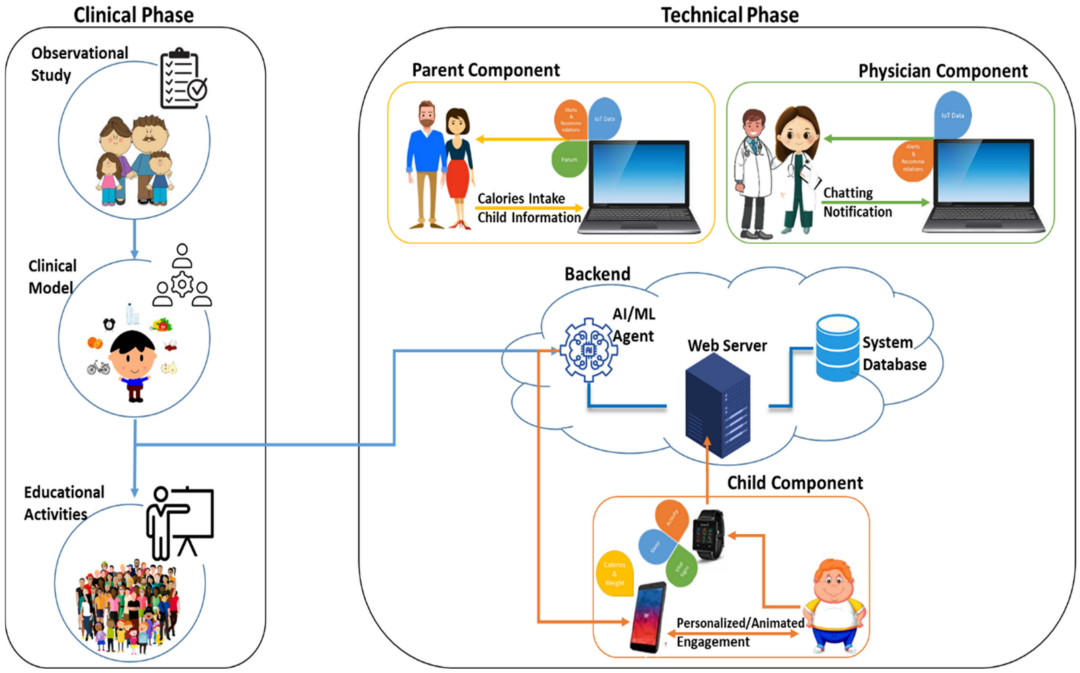

Figure 3. The proposed framework.

According to the ML result, the recommendation will be generated using rule-based methods and the users will be alerted with what should be performed. The child will be able to see an animated recommendation with the best action to do. For example, if the child was found in danger of obesity due to their bad sleeping habits, the recommendation will be related to sleeping habits. On the other hand, if the child shows better behavior in all factors, the recommendation will be an encouragement to keep doing what they are doing. Ultimately, the proposed framework will be divided into four main components: Child, Parent, Physician, and Backend.

- Child Component: The child is monitored and interactively advised by the system and provided with different recommendations to improve their lifestyle. The AI component of the application will allow it to encourage children to sleep better and eat healthy food. The recommendation is presented using a user-friendly interface that encourages the child to accept it.
- Parent Component: Equip the parents with a web-page platform that allows them to monitor the child's sleep and physical activities. The parents will be able to enter their child's calorie intake and the system will prompt them on how many calories are consumed from different dishes including Saudi food. Moreover, the system will send notices to both parents and physicians if abnormalities are detected within the child's sleep, diet, or physical activity. The platform also provides a social community forum where parents can share their thoughts with other parents.
- Physician Component: Equip the health care providers with a web-page platform that allows them to monitor the child's lifestyle and connect with them if needed. Through the system, physicians can evaluate the child's patterns, add notes, and send notifications to the child or their parents. They can also chat with the parent if they needed an answer to a quick inquiry.
- Backend Component: This part of the system contains the server that stores all the data and the AI agent that is developed to use ML methods and predict the best possible action to recommend the child with. Anomalies are also detected by this agent to alert the adults when things need to be taken more seriously.

4. Discussion

Currently, children spend long hours on electronic devices, which leads to problems of weight gain, low physical activity, and short sleep duration. In this study, we understood the clinical aspect of children with obesity and relevant factors that are of high impact and propose an interactive smart framework that combines clinical and emerging AI/telehealth technologies to manage child obesity. The proposed framework can be used to reduce children's obesity and improve their quality of life using ML. It utilizes IoT devices to integrate information from different sources and complement it with a mobile application and web-based platform to connect parents and physicians with their children.

The proposed framework addresses the shortages in the current research and systems. As we have seen in the previous literature review, there are almost no contributions relating to Arab children. The current researchers and systems are mostly focusing on the obesity of the general public; additionally, Arab children are not familiar with the English language, which creates a great burden on the parents to use and follow. Moreover, the proposed framework addresses cultural diets, which play an important role if we want the user to log their calorie intakes accurately. Another very important point that is ignored by the previous works and addressed by the proposed framework is the social aspect of obesity management. We address this aspect from two sides: Social and Intelligent interaction. When it comes to social interaction, this component allows the parent to socialize in an online community and motivate each other when reading other parents' stories and discussing similar concerns. On the other hand, intelligent interactivity is related more to the child, in which the system interactively provides their smart recommendations through the animated interface that engages the child and motivates them further.

5. Conclusions

Telehealth and emerging (IoT) technologies can be utilized to overcome the challenges related to obesity management and provide care from a distance to improve the health care services for obesity. This is of particular importance because the requirements for children are more difficult and challenging than for adults. However, IoT by itself is a limited resource and it is important to consider other AI components to analyze the data and interact with the child accordingly. Thus, this paper investigated the literature of obesity management and the association between sleep disturbances and childhood obesity alongside physical activity and diet. Then, based on the survey findings, a novel framework that combines clinical and emerging AI/telehealth technologies was proposed to manage obesity in Saudi children. The proposed framework can be used to reduce child obesity and improve their quality of life using ML. It utilizes IoT devices to integrate information from different sources and complement it with a mobile application and web-based platform to connect parents and physicians with their child. In the future, we are planning to implement the framework and develop health care systems with a smart telehealth solution that is compatible with the Gulf culture. The proposed system will be complemented with several functionalities, such as calorie calculation including Saudi food, notifications for both children/parents and physicians, personalized recommendations to improve children's habits, discussion forums for parents, and a specialized dashboard for the physicians to monitor and connect with the child while adding their own notes and recommendations. In addition, we are planning to investigate the effects of many other factors such as breastfeeding, infant food, the external environment, etc.

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