Mobile Based Solution to Weight Loss Planning for Children (with Obesity) in Sri Lanka

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***Abstract*—Obesity is a condition where there is excess fat in the body, and it is one of the world's most extreme and dangerous dietary diseases. Genetic factors, lack of physical activity, unhealthy eating patterns, or a combination of these factors are the most common causes of obesity. This is important because it influences every part of a child's life. More, in particular, this disorder leads to poor health and negative social standing with perceptions. Nowadays, children are paying keen interest in technology and related devices. Therefore, in this research, we are planning to give a mobile-based solution with a smart band that is used to monitor the child. In this solution, we are mainly focusing on Sri Lankan children with obesity who are aged between 5-10. In our solution, there are four main sections which are, monitoring child activities, recognizing the activities, and getting relevant data, then based on those data and previous activity completion levels, this solution will suggest activities for losing weight, provide specific diet plans for each child considering the health conditions and predict the probability of having main obesity-related diseases by using previously gathered data**.

Keywords—Activity recognition, activity suggestion, childhood obesity, deep learning, diet plans, disease prediction, machine learning

I. INTRODUCTION

Obesity in adults and children has been considered a global epidemic and prevalence among children is still too high. Over 340 million children are obese globally. Among them, almost half of the children are live in Asia [1]. Children from South Asian (SA) countries show abnormal metabolic profiles at young ages compared to white children. Furthermore, SA children are reported to be more likely to be overweight and obese [2]. Once obesity was considered a high-country problem, but now obesity is rising in low-and middle-income countries like Sri Lanka. Recent research [4] conducted with hundred and ten children showed that most participants were obese. Out of that around 70-80% were severely obese. 75% of deaths in Sri Lanka are due to non-communicable diseases (NCDs) [3]. Obese children are likely to stay obese into adulthood and more likely to have NCDs like diabetes, cardiovascular diseases, fatty liver, and breathing problems at a younger age.

The fundamental cause of obesity is an energy imbalance between calories consumed and expended. High intake of energy-dense foods that are high in fat and sugars and an increase of physical inactivity due to sedentary activities are the major reasons for obesity. The lack of parental attention and spending insufficient time can cause children to have certain health and behavioral problems such as negative encouragement on food consumption and physical activities. As a result, this makes it tough for parents to control their children's eating habits and activities. Parents should take an active role in their children's lives and encourage them to adopt healthy living habits. By giving necessary guidance, parents can assist to prevent and reduce childhood obesity.

In recent years, many solutions were proposed for obesity with the use of the Internet of Things (IoT) and modern computer technologies. Most of the existing obesity prevention developments are focused on adults, elders, and adolescents. Only a few developments have looked at how to reduce childhood obesity using the latest advancements in computer technologies. However, most of these applications are not suitable for preventing childhood obesity in Sri Lankan children, as they are not developed for the Sri Lankan context due to changes in social, cultural, and religious aspects in different countries and regions.

In this paper, we present a child health monitoring mobile application with the use of wearable wristband data which can help parents to prevent obesity, assess the risk of disease, and encourage them to learn more about healthy habits by motivating child and the parent.

II. LITERATURE REVIEW

Most of the existing research for the prevention of obesity has provided mobile apps which have focused on adults, adolescents, and the elderly. Very few studies focused on children's obesity prevention.

According to Saad et al. [8], they provide some video type of tutorials to improve the child's knowledge about taking a healthy breakfast. After that, there are some animated exercises where children were asked to select healthy foods from several food items. A score will be given. Then in the proposed game, there is an animated character who represents the player. The child plays the role of feeding and exercising the avatar. When an avatar is doing exercises, the child is also asked to follow the movements of the avatar. However, they didn't monitor the actual child activities or behaviors, and everything is based on a game avatar. They didn't predict diseases, suggest diet plans, or analyze the progress of weight loss.

In a research conducted by Kozlovszky et al. [9], it is a remote patient monitoring environment using client-side software and a gaming console to increase children's motivation to do exercises. This mainly focus on monitoring diabetes in obese children by getting sensor data like blood sugar level, blood pressure, pulse, and eating habits by a sensor placed on the refrigerator, etc. There is also a feature that enables to track data in certain periods like measuring patient's blood glucose level regularly. Furthermore, it provides some games to play that already exist in the software game market using a gaming console and calculate the burned calories. It is a combined obesity and diabetes monitoring solution. However, it didn't predict diseases, suggest diet plans, or suggest different physical activities to weight loss.

A study conducted by Almonani et al. [10] is mainly focused on preventing childhood obesity by teaching children to eat healthy food and suggesting physical activities. It has two components, namely persuasive mobile courseware, and persuasive mobile games. Simple educational-based mobile games are used to improve child knowledge in healthy eating. In the second section, children are asked to play the games in a specific place (fixed location) or by moving based on the required physical activity. Then the user is requested to update the information at the end of each activity to assess the effectiveness of the learning courseware and the games. However, it didn't monitor the child's activities or behaviors, didn't predict diseases, suggest diet plans, or analyze the progress of weight loss.

As shown by Tacyildiz et al. [11] is a semantic and rule-based health care expert system. The system provides live and distant HE consultations for their child/adolescent obesity patients via mobile devices. It uses SWRL knowledge base and Inference Engine for obesity tracking but also examines the gathered and deduced data to provide the next proper treatment suggestions, daily activities, and required nutritional habits. However, this system didn't monitor users' activities or behaviors using any wearable device, didn't predict diseases.

A Research conducted by Yom-Tov et al. [12] mainly focus on helping type 2 diabetes patients to increase the level of their physical activity. They provide type 2 diabetes patients with a smartphone-based pedometer and a personal physical activity schedule. Patients were sent brief messages to promote physical exercise between once a day and once a week. Messages have been customized using a Reinforcement Learning algorithm to enhance each participant's compliance with the activity regime. In this study, they monitor and get their physical activity data and provide a messaging service to encourage the user to do activities. However, this study does not suggest activities based on the previous completion level of activities. In addition, this study didn't use obese children.

A team of researchers came up with recognizing 5 activities walking, standing, standing up, sitting, and sitting down using a waist-mounted smartphone, and they are also concerned about people aged between 19-48 [13]. Research [14], shows that they are able to recognize three activities walking, running, and staying still. Research [14] uses only the accelerometer data, but Research [13] uses both accelerometer and gyroscope sensor data. Both Research [13] [14] didn't use children for their studies.

In this research [15], a machine learning-based methodology was proposed to improve the accuracy of an activity identification system. Research [15] uses only the accelerometer data. They recognized five activities walking, standing up, sitting down. The recognition accuracy is 99.8% However, they didn't use children for this research.

The team of researchers came up with solution-recognized activities using smartphones sensors. They recognized walking, running, sitting, and standing. They used an accelerometer, gyroscope, and gravity sensor for recognized activities. The research identified physical activities from elderly people, not from children [16].

'CalFit' [17] is a developed application on the iOS platform, which automatically sets personalized, adaptive daily step goals. It designs a reinforcement learning algorithm that generates only personalized step goals for users. In addition, it is designed for college students, not for children.

When considering the research conducted by Oyeleke et al. [18], have considered the changing human emotional, behavioral, and environmental contexts to offer support to people diagnosed with mild cognitive impairment (MCI) or Alzheimer's in their everyday life activities [9]. That suggested system is based on the 'Situ-framework' that represents an activity as a sequence of situations. It uses the modified model learning algorithm as a decision-making method to suggest acceptable acts or sequences of tasks to the inhabitant in situations of ambiguity induced by episodes of misunderstanding or memory loss. The main objective of this research is to propose situ-centric reinforcement learning for the recommendation of tasks in activities of daily living. And this study recommends only the next step for the sequence of daily living activities for the adult that are suffering from cognitive impairment and suppose to prevent the risk. (e.g.: recommending 'turning off the stove after use, to prevent the risk). They didn't analyze their previous activity completion level or didn't use it for children. Furthermore, it didn't consider diet planning or disease detection.

III. METHODOLOGY

Our proposed system's main users will be the parent with the mobile application and the child with the wristband. Figure 1 presents the high-level architecture of the overall system.

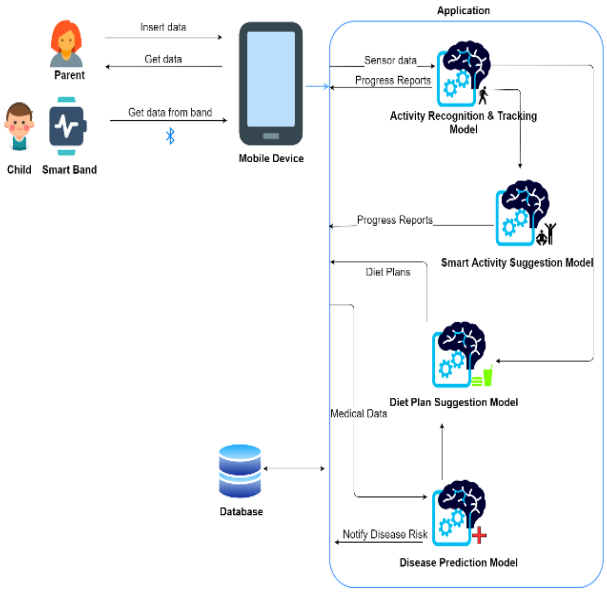

Fig 1: System Overall Diagram.

There are four primary aspects of the proposed system. The first is to recognize and track a child's daily activities with the use of wearable device sensor data. The second part includes the smart activity suggestion technique based on the child's physical activity history since physical activeness is one of the key aspects for preventing childhood obesity. The third part includes diet planning and suggestion techniques for a healthy diet which is the next key aspect of preventing obesity. Finally, the fourth part includes an early obesity-related disease detection technique.

A. Activity Recognition and Tracking

According to the WHO guidelines on physical activity and sedentary behavior [6], children should do at least an average of 60 minutes per day of moderate- to vigorous-intensity, mostly aerobic, physical activity across the week. As physical activities are more important in obesity prevention, we implemented a Deep Learning (DL) model to recognize, track a child's daily activities with the use of wearable device sensor data. The wearable device is implemented using Arduino Pro min board as shown in Figure 2.

The dataset used for training the model contains data of 11 participants which one activity performs at least 3 minutes at a frequency of 50 sensor data records per second. Among them, 80% of data is used as training and the other 20% as a testing set. The CNN-LSTM model consists of the input layer, convolutional layers, LSTM layers, fully connected layers, and SoftMax layer. Raw data are input via the input layer and convolutional layers do the feature extraction process of input data. After the LSTM layer is applied, the fully connected layer followed by a SoftMax layer returns the correct activity identification. As shown in Figure 3.

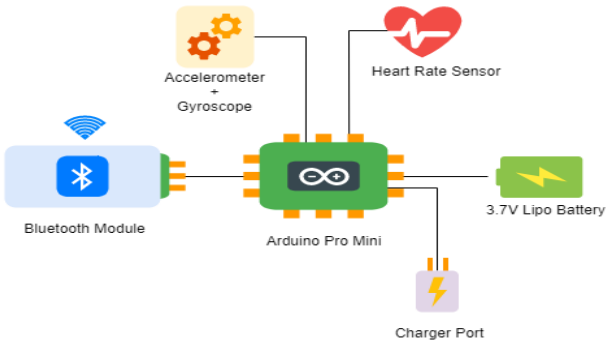

Fig 2: Overview of Wearable Device.

The built CNN-LSTM model can accurately recognize 8 physical activities, running, walking, standing, sitting, cycling, going downstairs, upstairs, and forward and backward fall detection. With recognized activities, the application can calculate the number of burned calories. All the recognized and calculated data are then uploaded to the system database and parents can view the data in tabular and graphical ways using the mobile app to track a child's physical activity status and history.

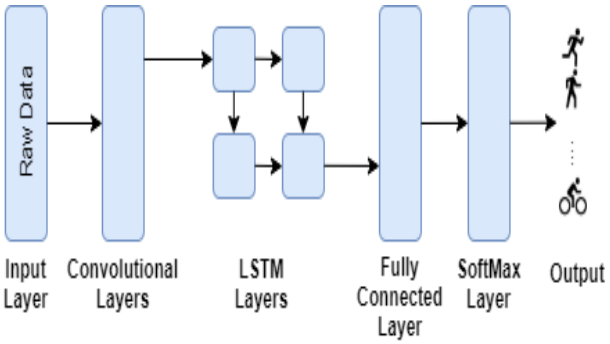

Fig 3: LSTM Model Architecture

B. Smart Activity Suggestion

In childhood obesity, parents have the most responsibility for their children's health issues. According to our previously conducted survey, Figure 4 shows that most Sri Lankan parents did not recognize that their child is obese. Even if parents recognize their children as obese, they have very weak behavior towards it because of the lack of time and the really busy lifestyles. Nowadays, both parents are working and don't have much time to spend and are concerned about their children and families. Even though they want to keep track of them, they are unable to do this because they are busy. A good dietary awareness of parents and support for physical activities are correlated with a healthy lifestyle in children.

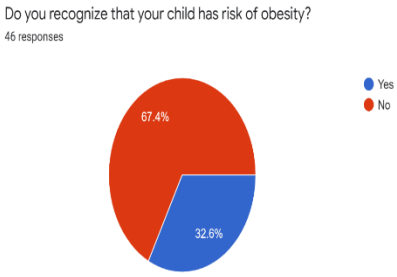

Fig 4: Summary of responses about parent's recognition of child obesity

When it refers to the child activity level, nowadays, most of the children do not meet their required amount of physical activities [7]. Then the main concerns are,

- How to identify a child's activity level?
- How to increase the physical activity level of children?
- How to suggest personalized activities to each child?

To identify a child's activity level, we implement a machine learning model (ML) using the child's previous activity completion data. It will use previously collected sensor data by the wearable device such as, allocated time, completed time, burned amount of calories as well as the BMI of the child as well. By comparing the allocated time and completed time, we identify the child's activity level as lazy or active. Next, using the ML model we suggest the next activity time for each child. The overview of the activity suggestion component is shown in Figure 5.

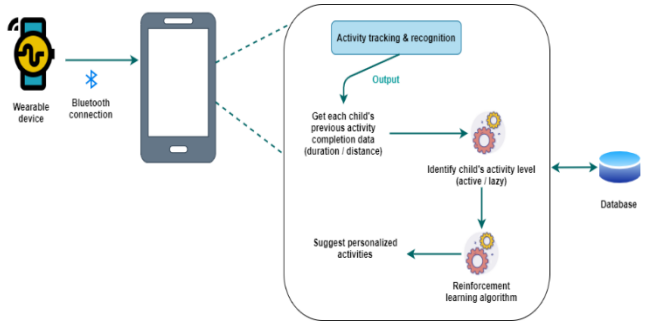

Fig 5: Overview of Activity Suggestion

C. Diet Planning

According to WHO guidelines, the proper healthy dietary plan is very important in every child's meal [6]. To prevent obesity and obesity-related problems, a proper diet plan is very important. We have implemented a Machine Learning (ML) model to predict the correct number of calories that a child needs in their meal for a day.

In order to predict the calories, we get the data from the user when they register to the application. To implement this process, the age, gender, and BMI of the child is required. Then all the data will be directed to the ML algorithm which is created using Linear Regression Model in Supervised Learning Algorithm. Using the above factors, the ML algorithm will predict the suggested calorie expenditure of the child and display it on the system.

The healthy meal plans are stored in the database and will be shown to the user divided into the 3 main meal courses. The parents can choose what healthy meal they want to pick. Each meal contains the number of calories it has.

The predicted calories will be shown when choosing the meals and it will inform the user when the daily calorie expenditure is reached. Healthy and unhealthy eating habits and food will also be included so that parents can avoid or limit the unhealthy food and habits.

D. Risk of Related Diseases Detection

Obese children are likely to stay obese into adulthood and more likely to have non-communicable diseases like:

- Diabetic Disease
- Cardiovascular Diseases
- Fatty liver
- Breathing problems

at a younger age. Obesity has risen in prevalence in recent years, bringing it to the forefront of public health in Sri Lanka, especially among children [19]. In this study [20], they pointed out that in urban Sri Lanka, the prevalence of obesity among children aged 5-18 years is 10.3% and overweight is 11.3%.

In this section, our goal is to identify if a child is at risk for obesity-related diseases. We implemented a Machine learning model to the identified risk level of each disease respectively. Figure 6 shows a system diagram of predicting obesity-related diseases risk levels.

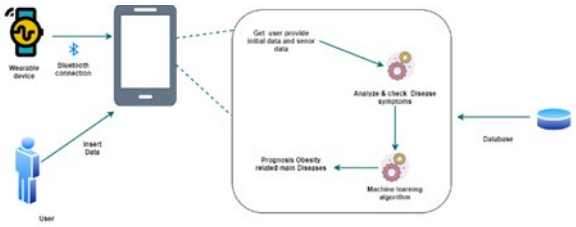

Fig 6: Overview of Disease Risk Level Prediction

As shown in Figure 6, we collected user provide initial data and disease symptoms. Next, we analyzed and checked diseases risk levels through a machine learning algorithm and predicted the risk level of each main obesity-related disease. We categorized risk level into 2 levels, namely high-risk levels, and low-risk levels.

The machine learning algorithms have been built by using random forest algorithms and support vector algorithms using Jupyter notebook.

IV. Results and Discussion

The goal of this research is to evaluate the effectiveness and convenience of childhood obesity prevention using smartphones and wearable devices with the use of machine learning and deep learning techniques. This section presents the proposed solution's results of each major component with a full analysis and evaluation.

A. Child Activity Recognition

The result revealed that child activity recognition using sensor data and deep learning can be accomplished satisfactorily. The accuracy of some activities reaches as high as 97%. But some activities are more difficult to recognize because of the similarities between them. However, the proposed method accurately recognized these activities, although there is a small error rate. As mentioned earlier, the proposed method was tested with 20% data which contained more than 100,000 samples. The accuracies of recognizing child activities for the test data are shown in Table I.

TABLE I. RESULT OF CHILD ACTIVITY RECOGNITION

Activity	Accuracy
Walking	94.1%
Running	95.4%
Sitting	97.2%
Standing	97.8%
Cycling	95.3%
Downstairs	85.0%
Upstairs	87.3%
Forward Fall	89.1%
Backward Fall	90.2%

However, the result of the proposed child activity recognition method with the test dataset was satisfactory.

B. Identify Active Level and Suggest Next Activity

Identifying active levels using a machine learning model can be accomplished successfully. The accuracy of identifying each child's activity level such as active or lazy based on previous activity completion level is 84%.

Suggesting the next activity time by considering the active level and the previous activity completion level was done using another machine learning model. As result, it will output the suggested time for the next activity.

C. Diet Planning

According to each child's age, gender and BMI, the daily calorie expenditure can be predicted successfully by using the Machine learning model. The accuracy of the predicted values is around 94%.

Then the meals selection can be done by the parents according to the calorie levels of the child. The meals are divided into 3 main meals, and each has its own calorie limits.

D. Predict Probability of Diseases

The system automatically identifies whether the child is in "High Risk" or "Low Risk" of obesity-related diseases. The system gives more precise results once the input parameters of a child are clearly specified.

With the test data, the accuracy of diabetic disease risk level detection through the ML model is 94%. Then we used another machine learning model to predict the heart disease risk level and it gets accuracy of 75% with test data.

Since each component shows a satisfying result with test data, all the components are integrated into the mobile application. After the completion of 90% of the system, the result of the system was discussed with a pediatrician who is an expert in child health in Sirimavo Bandaranayake Specialized Children Hospital Peradeniya. As a result of the discussion, the pediatrician validated the proposed system as a novel solution for child obesity prevention.

V. Conclusion and Future Work

This research paper proposed a mobile-based solution for child obesity prevention and obesity-related disease prediction among children aged between 5 – 10 in Sri Lanka. The proposed mobile application helps parents to track their child's health and encourages the prevention of obesity by tracking the child's physical activities, nutrients, and early disease prediction. A wrist-worn device with an accurate Deep Learning model is implemented to track a child's daily physical activities. For suggesting new activity goals based on previous activities, a machine learning model is implemented. For healthy diet plan suggestions and disease prediction, various Machine Learning models are implemented in the mobile application. With all of these, we provided a convenient and accurate way for Sri Lankan parents to prevent their children's obesity.

As future work, the proposed system is planned to be tested in the child obesity care units at several hospitals in Sri Lanka. As we discussed in the Results and Discussion section, in the future we will plan to connect the wearable device through a network instead of a Bluetooth connection to overcome the short range between parent and child.

References

[1] W. H. Organization, "Obesity and Overweight," April 2020

[2] E. L. Eyre, M. J. Duncan and A. Nevil, "South Asian Children Have Increased Body Fat in Comparison to White Children at Same BMI," November 2017

[3] V. P. Wickramasinghe, "Childhood Obesity," Sri Lanka Journal of Child Health, 2018

[4] Gunawardana, S., Gunasinghe, C.B., Harshani, M.S. et al. Physical and psychosocial quality of life in children with overweight and obesity from Sri Lanka. BMC Public Health 21, 86 (2021).

[5] L. S. Warnakulasuriya, M. A. M. Fernando, A. V. N. Adikaram, A. R. M. T. W. M. L. Anurasiri, R. Elisabet, K. D. R. R. Silva, D. L.

Samaranayake and V. P. Wickramasinghe, "Assessment of Nutritional Status in Sri Lankan Children:Validity of Current Anthropometry Cutoffs?," Asia Pacific Journal of Public Health, 2019

[6] WHO Guidlines on Physical Activity and Sendentary Behaviour," WHO, 2020

[7] Ha, A.S., Ng, J.Y.Y., Lonsdale, C. et al. Promoting physical activity in children through family-based intervention: protocol of the "Active 1 + FUN" randomized controlled trial. BMC Public Health 19, 218 (2019)

[8] S. Saad, M. O. Al-Sager, Al-Maadee and N. A.-M. Jihad M. AlJa'am, "Play, Learn and Eat Healthy Food: A Mobile Game for Children to Fight Obesity," in 2018 International Conferance on Computer and Applications (ICCA), Beirut, Lebanon , 2018

[9] M. Kozlovszky, K. Karoczkai, B. Jokai, B. Ruda, D. Kacsuk and Z. Meixner, "Children obesity treatment support with," in International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO) - Opatija, Croatia , 2014.

[10] E. Almonani, W. Husain, O. Y. San, A. Almomani and M. Al-Betar, "Mobile game approach to prevent childhood obesity using persuasive technology," in [IEEE 2014 International Conference on Computer and Information Sciences (ICCOINS) - , Kuala Lumpur, Malaysia , 2014.

[11] O. Tacyildiz, D. C. Ertugrul, Y. Bitirim, N. Akcan and A. Elci, " Ontology-Based Obesity Tracking System for Children and Adolescents.," in 2018 IEEE 42nd Annual Computer Software and Applications Conference (COMPSAC) , Tokyo, Japan , 2018.

[12] E. Yom-Tov, G. Feraru, M. Kozdoba, S. Mannor, M. Tennenholtz and I. Hochberg, "Encouraging Physical Activity in Patients With Diabetes: Intervention Using a Reinforcement Learning System," in Journal of Medical Internet Research, 2017

[13] Khimraj, P. K. Shukla, A. Vijayvargiya and R. Kumar, "Human Activity Recognition using Accelerometer and Gyroscope Data from Smartphones," in 2020 International Conference on Emerging Trends in Communication, Control and Computing (ICONC3), Lakshmangarh, 2020.

[14] S. M. Y. H. C. Song-Mi Lee, "Human activity recognition from accelerometer data using Convolutional Neural Network," in IEEE International Conference on Big Data and Smart Computing, 2017.

[15] M. Zubair, K. Song and C. Yoon, "Human activity recognition using wearable accelerometer sensors," in International Conference on Consumer Electronics-Asia (ICCE-Asia) , Seoul, South Korea , 2016.

[16] R.-A. Voicu, C. Dobre, L. Bajenaru and R.-I. Ciobanu, " Human Physical Activity Recognition Using Smartphone Sensors.," Sensors, vol. 19(3), p. 458–. , 2019.

[17] M. Zhou, Y. Mintz, Y. Fukuoka, K. Goldberg, E. Flowers, P. Kaminsky, A. Castillejo and A. Aswani, "Personalizing Mobile Fitness Apps using Reinforcement Learning," 2018

[18] R. O. Oyeleke, C.-Y. Yu and C. K. Chang, "Situ-centric Reinforcement Learning for Recommendation of Tasks in Activities of Daily Living In Smart Homes," in IEEE International Conference on Computer Software & Applications, 2018

[19] S. Mohamed, "Childhood Obesity: Epidemiology, Determinants, and Prevention," Journal of Nutritional Disorders & Therapy, vol. 5, no. 2, 2015.

[20] S. Gunawardana, C. Gunasinghe , H. MS and S. Seneviratne , "Physical and psychosocial quality of life in children with overweight and obesity from Sri Lanka," in BMC Public Health., 2021.