American Journal of Computer Science and Technology
2022; 5(4): 222-228
http://www.sciencepublishinggroup.com/j/ajcst
doi: 10.11648/j.ajcst.20220504.15
ISSN: 2640-0111 (Print); ISSN: 2640-012X (Online)

Enhancing Exercise Performance Through Heart Rate Zone Monitoring in Exergaming

Khasnur Abd Malek[1], Mazapuspavina Md-Yasin[1], Ilham Ameera Ismail[1], Zahirah Tharek[1], Nik Munirah Nik Mohd Nasir[1], Hashbullah Ismail[2], Mohamad Nahar Azmi Mohamed[3], Mohamed Fareq Malek[4], Hock Chuan Lim[4]

[1]Primary Care Medicine Department, Universiti Teknologi MARA (UiTM), Shah Alam, Malaysia
[2]Faculty of Sports Science & Recreation, Universiti Teknologi MARA (UiTM), Shah Alam, Malaysia
[3]Malaysia Sports Medicine Department, University of Malaya, Kuala Lumpur, Malaysia
[4]Faculty of Engineering and Information Sciences, University of Wollongong in Dubai, Dubai, United Arab Emirates

Email address:

drkhasnur@uitm.edu.my (Khasnur Abd Malek), puspavina@uitm.edu.my (Mazapuspavina Md-Yasin),
ilham874@uitm.edu.my (Ilham Ameera Ismail), drzahirah@uitm.edu.my (Zahirah Tharek),
nikmunirah@uitm.edu.my (Nik Munirah Nik Mohd Nasir), hashbullah@uitm.edu.my (Hashbullah Ismail),
nahar@ummc.edu.my (Mohamad Nahar Azmi Mohamed), MohamedFareqMalek@uowdubai.ac.ae (Mohamed Fareq Malek),
hclim@uowdubai.ac.ae (Hock Chuan Lim)

To cite this article:

Khasnur Abd Malek, Mazapuspavina Md-Yasin, Ilham Ameera Ismail, Zahirah Tharek, Nik Munirah Nik Mohd Nasir, Hashbullah Ismail, Mohamad Nahar Azmi Mohamed, Mohamed Fareq Malek, Hock Chuan Lim. Enhancing Exercise Performance Through Heart Rate Zone Monitoring in Exergaming. *American Journal of Computer Science and Technology*. Vol. 5, No. 4, 2022, pp. 222-228.
doi: 10.11648/j.ajcst.20220504.15

Received: November 30, 2022; **Accepted**: December 19, 2022; **Published**: December 29, 2022

Abstract: Exercise performance helps to improve healthcare of the general public. It is important to create a fun environment to exercise as this will encourage people to maintain their effort to keep healthy and fit. The focus of this paper is to highlight a blueprint work which focuses on the initiative to improve exercise performance in current exergame innovation. This expert-driven work involved a collaborative initiative from four faculties of various disciplines as well as ICT experts from other universities. This is an important strategy as we intend to create effective and practical techniques to address the needs of the users' end who are the patients. The work evolved around the concept of measurement and monitoring of real-time heart rate zone to target exercise intensity during exergame sessions. The work also aims to provide people with the ease and simplicity to monitor their real-time exercise performance based on heart rate zone through mobile exergaming. Findings from this project suggest the importance of improving exercise via exergame for example, effective performance during exergaming sessions, in the long run, is critical for a positive impact on health. This work can form a basis for a community-wide approach to address the major public health problem of non-communicable disease from physical inactivity.

Keywords: Aerobic Exercise, Heart Rate Zone, Exergame, Resistance Exercise, Game

1. Introduction

The purpose of this study is to discuss on the inter-professional collaboration work in pulling knowledge and expertise from various disciplines in proposing a blueprint to use colour codes for heart rate zones (HR zones) as key to the monitoring of exercise intensity in an exergaming smartphone application.

Physical inactivity has been attributed to the rising in premature death related to non-communicable (NCD) worldwide. Despite this known fact, the rate of engagement in regular exercise remained at a constant low and has not significantly increased. A survey involving 1.9 million adults across the globe found that between 2001 and 2016, the level of physical inactivity has remained low and had only marginally improved [1]. The pace to enhance physical activity to enhance health is too slow. This is worrying as increased morbidity and mortality posed a great threat to reduced productivity and increases health care cost. These statistics indicated that there is a dire need for effective interventions to reduce the impact and burden of NCD through increasing physical activity.

Exercise intensity is an important marker for effective exercise performance. Guidelines have recommended for an accumulation of at least 150 minutes of moderate-intensity exercise a week to reap the benefit for health. [2] There are several ways to measure exercise intensity and the most objective technique is through measurement of target HR zone. During an exercise, individuals should put effort to reach a target heart rate range that falls between the moderate or high exercise intensity zones. For this reason, intensity levels are usually measured using smart heart rate wearables. However, these conventional tools require users to read small numerical displays continuously and this indirectly interferes with their concentration to exercise. This method is not practical especially if the exercise requires fast and vigorous movement.

2. Possible Solution

A possible solution to this worldwide crisis is to integrate exercising gaming as an innovative way to promote and sustain physical activity while meeting the exercise intensity recommendation to impact health. Exergaming, defined as "Interactive video gaming that stimulates an active, whole-body gaming experience" [3] is now a growing niche worldwide. Combining tailored made exercises programs for various health-related needs and exergaming can attract users from a wide age range and medical conditions to exercise while having fun. The element of fun in exergaming can promote long term adherence. Additionally, a new approach to simplifying monitoring of exercise intensity level using simple HR zone colour codes can provide an effective way to enhance exercise performance. This application is convenient to be used at home or in the workplace. The exercise routine only requires a small exercise space and lightweight exercise equipment, as compared to heavy gym equipment.

This work is mainly focusing on creating a blueprint related to exercise structure, exercise intensity, android system, textile antenna and HR zone colour coding within the game environment in the effort to develop a concept of simplifying measure to monitor HR zones in gaming to enhance the effectiveness of exercise performance. This project concentrates on the interdisciplinary work needed to create an exergaming structure sufficient to raise an adult's heart rate to the moderate-intensity zone. Additionally, contribution includes the discussion on the use of the heart rate sensor and smart textile antenna to capture and transmit real-time heart rate into a microcontroller which is then transmitted to a smartphone. The heart rate is used to compute the exercise intensity which is displayed in colour codes within the in-game play to inform users of their HR zones. The collaborative work and the use of different technology modality are described in more detail in the sections below.

3. Proposed Solution

3.1. Functionality

The importance of multiple modes of exercise and flexibilities are core aspects of this blueprint. Design of these features and functionality draws from F. Cibrian et al [4] to improve interactivity. More recents works on exergames can be observed from A. Sanpablo et al [5] and D. Koulouris et al [6], and adds to the extended list of design considerations.

3.2. The Intended Usefulness

This design consideration list, in turn, helps to provide optimum performance at each exergaming session. Targeted HR zone performance allows users to meet their performance outcome. Moreover, the software is connected to a real-time database, allowing users to monitor their HR zones and track their progress and achievement over time. Exercising at green or amber HR zones can help develop users' cardiorespiratory fitness. Moreover, for those who want to burn fat during their exergaming sessions, they would most want to maintain their performance within the green HR zone while trying to avoid the amber and red HR zones. As such, this application help users to achieve their performance goals within a set timeframe and when performed regularly, in the long run, is able to impact health positively and effectively.

3.3. Other Functions

Additionally, the application is planned to screen new users for their safety to exercise and prompt the need to seek medical advice accordingly. The application will also be able to recommend users with the most appropriate exergaming program related to their current musculoskeletal medical conditions. These measures are important to keep exercise safe as well as reducing exercise-related injuries.

4. Solution Components

4.1. Android Application

The functionalities offered by the android's application are planned with the main aim to make the heart rate-based intensity measurement and monitoring practical and easy for users. Users only need to enter their information related to age in years into the system. Using a formula for maximum heart rate calculation, the system will use individual mode to calculate the heart rate range for each of the four HR zones; low intensity, moderate intensity, high intensity, and very high intensity. Users' heart rate will be colour coded according to their individualized intensity zones, which will be grey for low, green for moderate, amber for high and red for very high intensity. Users will be able to edit their information related to weight, height and age.

An additional function includes screening for users' safety to exercise using the physical activity readiness questionnaire (Par-Q) from D. E. R. Warburton et al [7] when the users first register into the system. Par-Q is an internationally known preparticipation screening to safely clear individuals to exercise without the need for medical referral [8]. This is especially very important when users have been sedentary and have never had any form of exercise in the past. Users will be asked to click yes or no to seven questions: a) Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?; b) Do you feel pain in your chest when you perform physical activity?; c) In the past month, have you had chest pain when you were not performing any physical activity?; d) Do you lose your balance because of dizziness or do you ever lose consciousness?; e) Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?; f) Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?; and g) Do you know of any other reason why you should not do physical activity?. The application will prompt users to consult a doctor prior to starting the exergaming session if individuals clicked yes to one or more for the Par-Q questions.

Additionally, the application will provide users with multiple modes of exercises based on co-morbidities from N. M. Abdel-aal [9]. The application is proposed to provide users with personalized exergaming program recommendation, based on users' current medical conditions following from I. Mocanu et al [10]. Users will need to input the presence of specific joints or musculoskeletal problems such as osteoarthritis of the knees or spinal problem. Based on the medical information given, the application will be able to suggest the most appropriate exergaming program. Users can select their preferred exercise template which displays a character performing the whole workout movement. For both the screening and personalized exergaming function, the onus is on the users to be able to provide honest answers to all of the questions asked and seek medical advice if the application prompted. The application will not hinder users to proceed using the exergaming program. The application also would display a summary of overall targets and health indicators over time.

Conceptually, the Android system involves an application of a simple server-client set up to allow for three major data-related functionalities: a) data organization; b) data processing; and c) data interchange. The choice of server RAM size is based on a simple rule of thumb: 1 GB for each 4 GB between 4-16 GB of data and further 1 GB for each 8 GB above the limit of 16 GB. For this project, we placed an arbitrary upper limit of 32 GB of RAM. This design is intended for a small group. For a larger group, the server needs to be sized accordingly.

The data interchange functionality includes the data interface design for the sensor located in the wearable and the data exchange transfer protocol. This data interchange application is installed in both the server and client program space.

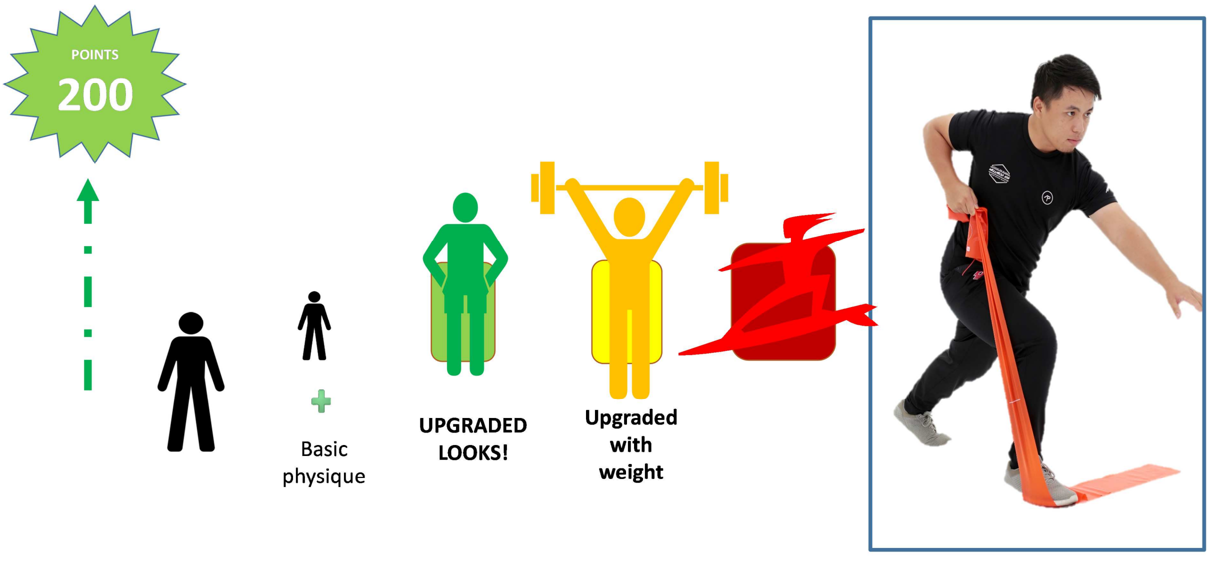

Figure 1. *The exergaming features the HR zone colour illustrated by the model's changing experience, scoring and model performing the exercise.*

4.2. Game Engine

Computer Sciene experts lead the discussion on the most appropriate game engine to cater for this work, with considerations from K. H. Sharif and S. Y. Ameen [11]. The game is intended to focus on the creation of an environment for single-player mode. The main idea to the development of the gaming mode is to have an animated model to perform the exercises displayed on the screen, which will be followed by the users. The user interfaces compromise of the main scene in a well-lit exercise gym, with the model in the middle. While the model is exercising, music with the right tempo will be used as a motivation for users to continue their exergaming. The pieces of music from authorized sources will be vetted and agreed by the team. Users will be able to choose different types of exercise programme recommended by the application following core suggestions from P. Polero et al [12]. The main objective for the users is to raise their HR zone to meet at least a moderate intensity level, which is coded as green. The four HR zones will be displayed in four colour codes. During the exergaming session, users only have to monitor the colour code displayed on the screen, for which green being the optimum colour. If the colour turns red, it means users have exceeded the recommended optimum intensity while grey colour means their exercise performance is suboptimal and users need to increase their exercise effort to increase their exercise intensity. The game will use two forms of rewards to mark users' performance. First, users will learn that the speed of their score acquisition acceleration depends on their colour-coded intensity. When exergaming intensity turns green, the rate for score acquisition accelerates while exercise intensity in grey colour code will slow down their score acquisition. A second award system is through the model's experience. These features are illustrated in Figure 1. For every two minutes that users have spent within a combination of green, amber and red colour codes, the model will level up into an upgraded look. The exergame provides a summary on a game scoreboard, to quantify the duration of time users spend in the respective colour codes. As this is a blueprint, the initial test for proof of concept will be focused on the calibration and fine-tuning of the calculation of the HR zone. Data received from the heart rate sensor will be compared against that of Polar H10®. The Polar H10® heart rate sensor is selected for its high reliability to accurately measure real-time heart rate [13].

4.3. Exercise Protocol

Structured exercise training is important as it addresses different fitness components, capable to correct muscle imbalances, improve core muscle strength, improve flexibility, improve cardiovascular fitness, increase energy and decrease stress level. According to the American College of Sports Medicine (ACSM), exercise prescription should be based on the four core principles to include adequate: a) frequency; b) intensity; c) time; and d) types [14]. Everyone should strive towards accomplishing 30 minutes of moderate-intensity exercise, five times a week, adapting from American College of Sports Medicine- Website [14]. In this work, experts from primary care medicine, sports science and sports medicine department collaborated to develop and record a video of a structured, 35 minutes exercise program with the main aim to address all fitness components. Reference to the patients' medical condition and problems in the clinical setting provides valuable input in this matter. The exercise is choreographed with reference to the interest expressed by overweight patients attending the primary care clinic and to meet the functional needs of our clients who work in a busy university hospital setting, known to be exposed to job-related musculoskeletal complaints [15]. This first exercise video is meant for individuals without medical restriction to exercise. Using functional exercises, we developed a 35 minutes exercise program consisted of three components: dynamic warm-up; conditioning stimulus; and dynamic cool-down. These components are important to improve fitness and reduce exercise-related complications. The conditioning stimulus had 3 sets of 2 minutes of aerobic movement. Additional 6 sets of 1-minute resistance training using 'theraband' resistance band or resistance tube band were added to develop the upper-lower body muscle strength. Combination of aerobic and resistance training has been shown to increase cardiorespiratory fitness [16] and improve adherence to exercise [17]. In summary, the 35 minutes exercise video consists of 5.5 minutes dynamic warm-up, 12 minutes of conditioning stimulus consisting of three movement sets of upper-lower body (each set has 2 minutes of cardio and 2 minutes of strengthening exercises), 2 minutes of core muscles exercises and 10 minutes cool-down stretching exercises. The exercises also include 6 minutes of rest intervals. The initial exercise protocol went through several changes for fine-tuning of movements for injury prevention. The final exercise protocol was performed and recorded by exercise trainers in their 20s. The exercise movements are illustrated in Figure 2. These sets of movements will be the reference for the animated model to mirror. The team will continue to work on several exercise structured tailored for individuals with osteoarthritis of the knees and spinal problems.

Figure 2. *The exercise protocol encompassing four phases: dynamic warm-up; conditioning stimulus; and dynamic cool-down.*

5. Heart Rate Zones Evaluation

5.1. Arduino System

The approach for this work is for users to monitor their current HR zone during their exergaming session. To do this, we plan to utilise an Arduino compatible pulse rate sensor. The pulse rate sensor will be embedded is a textile antenna which has the conducibility, tensile strength and the ability to be attached to another fabric. The development of the textile antenna will be lead by telecommunication experts. The heart rate sensor can be placed to any part of the human skin such as the tips of the finger or earlobe. However, we proposed that the textile antenna with embedded heart rate sensor to be strapped around the chest, near the epigastrium region as it is the closest to the mitral valve, through which the blood first flows out from the heart before travelling out to the rest of the body. This allows for greater accuracy in heart rate monitoring. The designed textile antenna will be used to radiate the signals from the transmitter to the receiver. The collected data from the pulse sensor is sent to the Arduino microcontroller and the heart rate value is transmitted to a mobile phone using a Bluetooth module. Specific coding will be used to categorize collected heart rate data from the sensor into four HR zones. When a user's heart rate falls into the specific zone, it will cause the command of the heart rate display to light up according to the corresponding colour zone. This kind of user-friendly application helps users to monitor their heart rate zone immediately and continuously. The schematic flow is illustrated in Figure 3.

Additional relevant sensors will be conducted on the flexible Arduino IDE using the VirtualWire Library. This enables wireless communication between the Arduino board and another Arduino or LCD screen. The Arduino IDE (integrated) is an open-source software platform and microcontroller which use programming languages of C and C++. The IDE includes an in-built software library for easy access of data manipulation. Using coding, the screen will show four colours based on current HR zone: a) grey for zone 1; b) green for zone 2; c) amber for zone 3; and d) for zone 4.

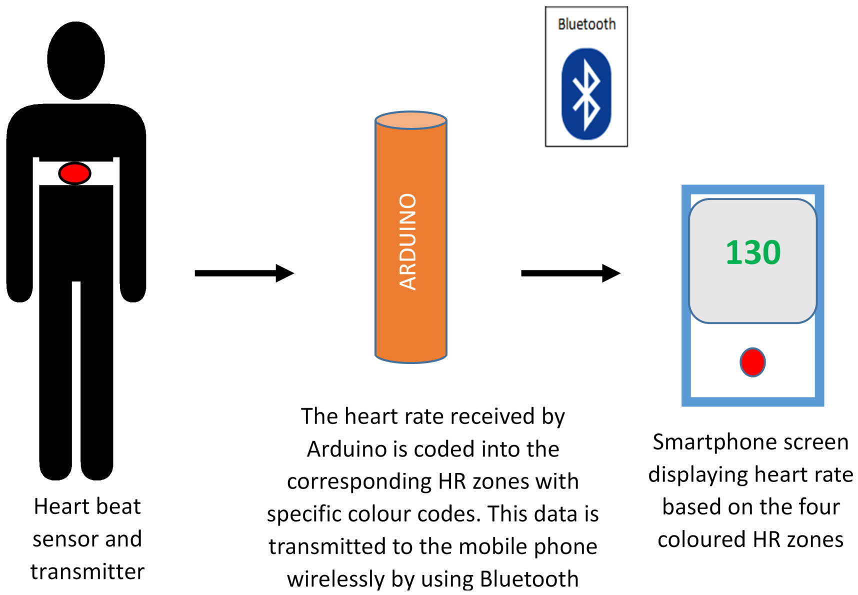

Figure 3. *A heart rate sensor captures the real-time heart rate. Embedded telemetry conveys the heart rate to Arduino. Arduino acts as a microcontroller. Using specific coding, the heart rate are categorized into four colour-coded HR zones. The colour-coded HR is then transmitted to a smartphone a Bluetooth module. The smartphone screen displays the coloured heart rate based on the users' HR zone.*

5.2. Heart Rate Zones Calculation

The processing and calculation of the heart rate are very important in this project to allow users to receive their HR zone classifications with accurately. Direct measurement of heart rate is recommended in any prescription of exercise for accurate estimation of the exercise intensity. For this purpose, based on the ACSM recommendation, we adopt the formula of percentage heart rate calculation.

Lower limit at 64% = [64/100] x 220 – [age (in years)] = 115 beats per minute.

Upper limit at 76% = [76/100] x 220- [age (in years)] = 127 beats per minute.

Maximum limit at 95% = [95/100] x 220 – [age (in years)] = 171 beats per minute.

The HR zones for a 40-year old person is calculated using this equation [2]. In our work, zone 1 refers to low-intensity HR zone, zone 2 refers to moderate intensity, zone 3 refers to high intensity and zone 4 refers to very high intensity. Therefore, for a 40-year old individual, an estimation of HR zones are as follows:

Zone 1: <115 beats per minute.
Zone 2: 115 and 127 beats per minute
Zone 3: 128 – 171 beats per minute
Zone 4: > 171 beats per minute.

5.3. Progress and Future Development

This collaboration in producing the current blueprint involves four faculties who are expert in their field. A very important link to this work is clear communication in an organised manner to achieve targeted, meaningful outcomes.

This work has currently implemented a comprehensive 35-minute structured exercise protocol and is available online for use by the public. The game engine is in the final stage of implementation and looks forward to reporting the results once it is completed. The next level forward is to test out the proof of concepts by developing a prototype. The prototyped product work will be tested for several functionalities to include its effectiveness to capture the physiological components of exercise that allow integration with software, integrating datasets from physiological components of exercise from a wearable device into an exergaming software. Following this, there is a need to assess the validity and reliability of the physiological components of exercise dataset captured in the exergaming software with the current gold standard methodology. As this work is currently is at the blueprint level, findings from future work may inform the technical process within this blueprint. Therefore, The blueprint may be updated based on the current and research results.

Additional design features in exergame is a future consideration within this project. The first feature is to extend the exergame function to allow for useful applications that include computation of body mass index and how much calories in kcal have been burned during each of the exergaming sessions. For this, users will add in their weight and height. The second function is to allow for multiple concurrent gameplay modes and/or services. Along with the additional concurrent gameplay modes, more sets of exercise will be added, for example, a set of exercises targeting specific cardio or muscle systems like belly areas or thigh regions. This feature allows for greater community participation and further in-depth study of social and peer-to-peer motivation. The third function is the interface to other similar wearables. For example, customized wearables involving programmable Arduino devices can be allowed to be integrated into this work's architecture via open source libraries and APIs. This feature addresses the expendability of the Project to a wider scope. This is essential to cater for the inclusion of Social Internet of Things (SIoT) and other monitoring initiatives in future smart living [18].

6. Concluding Remarks and Future Works

This project provided for important insights into exergame design, applications and the use of gaming technologies for health benefits. The project allows for initial explorations into an important health / exergame domain and future works will include more in-depth studies for seniors and for gender investigations.

Acknowledgements

We would like to acknowledge Mr Alif Shukran Omar who performed the 35 minutes upper body exercise video, the exercise video production team and UOWD research grant support.

References

[1] R. Guthold, G. A. Stevens, L. M. Riley and F. C. Bull, "Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1·9 million participants," The Lancet Global Health, Vol. 11 (10), 2018, pp. e1077-e1086.

[2] C. E. Garber, B. Blissmer, M. R. Deschenes, B. A. Franklin, M. J. Lamonte, I. M. Lee, D. C. Nieman and D. P. Swain, American College of Sports Medicine, "American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise," Medicine and Science in Sports and Exercise. Vol 43 (7), 2011, pp. 1334-159.

[3] V. Benzing, M. Schmidt, "Exergaming for children and adolescent: strengths, opportunities and threats", Journal of Clinical Medicine, Vol 7 (422), 2018.

[4] F. Cibrian, M. Tentori, and A. I. Martínez-García. "Hunting relics: a persuasive exergame to promote collective exercise in young children." International Journal of Human-Computer Interaction Vol 32 (3), 2016, pp. 277-294.

[5] A. I. P, Sanpablo, J-A., Armenta-García, A. F., Muñiz, A. M., Peñaloza, A., Mendoza-Arguilés, and M. D., Rodríguez. "Integration of persuasive elements into exergames: Application in the development of a novel gait rehabilitation system for children with musculoskeletal conditions." Journal of Biomedical Informatics, Vol 132, 2022, 104130. pp. 1-14.

[6] D. Koulouris, A. Menychtas, and I. Maglogiannis. "An IoT-Enabled Platform for the Assessment of Physical and Mental Activities Utilizing Augmented Reality Exergaming." Sensors Vol 22 (9), 2022: 3181, pp. 1-19.

[7] D. E. R. Warburton, V. K. Jamnik, S. S. D. Bredin and N. Gledhill, "The ePARmed-X+ Physician Clearance Follow-up", Health & Fitness Journal of Canada. Vol 7 (2), 2014, pp. 35-38.

[8] D. E. R. Warburton, V. K. Jamnik, S. S. D. Bredin, J. Burr, S. Charlesworth, P. Chilibeck, N. Eves N, H. Foulds, J. Goodman, L. Jones, D. C. McKenzie, R. Rhodes, M. Riddell, R. J. Shephard, J. Stone, S. Thomas, P. Zehr, N. Gledhill, "Executive summary: the 2011 Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and the Electronic Physical Activity Readiness Medical Examination (ePARmed-X+)", Health & Fitness Journal of Canada. Vol 4 (2), 2011, pp. 24-25.

[9] N. M. Abdel-aal, M. M. Elsayyad and SA Zamzam. "Effect of Exergaming and Resistance Training on Obesity: A Review Article." The Medical Journal of Cairo University Vol 90 (9) 2022, pp. 1591-1596.

[10] I. Mocanu, R. Caciula, and L. Gherman. "Improving Physical Activity Through Exergames." eLearning & Software for Education 2, 2018.

[11] K. H. Sharif and S. Y. Ameen. "Game Engines Evaluation for Serious Game Development in Education." In 2021 International Conference on Software, Telecommunications and Computer Networks (SoftCOM), IEEE 2021, pp. 1-6.

[12] P. Polero, C. Rebollo-Seco, J. C. Adsuar, J. Pérez-Gómez, J. Rojo-Ramos, F. Manzano-Redondo, M. A. Garcia-Gordillo, and J. Carlos-Vivas. "Physical activity recommendations during COVID-19: narrative review." International journal of environmental research and public health Vol 18 (1), 2021, pp. 65.

[13] J. L. Goodie, K. T. Larkin and S. Schauss, “Validation of Polar heart rate monitor for assessing heart rate during physical and mental stress,” Journal of Psychophysiology. Vol 14 (3), 2000, pp. 159-164.

[14] American College of Sports Medicine- Website, principle of exercise prescription FITT, [Online]. Available: http://acsm.org/ (last date visited: January. 30, 2019).

[15] N. Koyuncu and Ö. Karcioglu. "Musculoskeletal complaints in healthcare personnel in hospital: an interdepartmental, cross-sectional comparison." Medicine Vol 97 (40), 2018.

[16] E. A. Castro, A. B. Peinado, P. J. Benito, M. Galindo, M. González-Gross, R. Cupeiro and PRONAF Study Group, “What is the most effective exercise protocol to improve cardiovascular fitness in overweight and obese subjects?,” Journal of Sport and Health Science. Vol 6 (4), 2017, pp. 454–461.

[17] S-Y. Hong, S. Hughes, and T. Prohaska. "Factors affecting exercise attendance and completion in sedentary older adults: a meta-analytic approach." Journal of physical activity and health Vol 5 (3), 2008, pp. 385-397.

[18] S. Shahab, P. Agarwal, T. Mufti, and A. J. Obaid. "SIoT (Social Internet of Things): A Review." ICT Analysis and Applications 2022, 289-297.