Exercycle Exergame: Integrating a Diverse Range of Fitness Equipment and Fitness Types

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ABSTRACT
Exergames have become quite popular in the commercial market and research field recently, as they promote fitness, rehabilitation and good health. Physical inactivity, obesity and health issues with elderly are critical concerns overshadowing our society in the present time. This is a greater concern in higher-income homes where despite all the luxuries, adults and children undermine the importance of fitness and healthy eating [1]. We discuss some context-based topics analyzing definitions, categories and evaluative measures related to physical fitness. This literature review will also examine fitness equipment and technologies that have been prevalently implemented within exergames. After analyzing current literature, we realize how there is a dearth of integrating various types of exercise equipment in exergames. More importantly, there seems to be a significant gap as current exergames neglect resistance training completely.

Author Keywords
Exergaming, physical fitness, virtual reality, exertion interfaces, fitness equipment

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): Multimedia Information Systems, User Interfaces

INTRODUCTION
Nowadays, technology has taken over the world and it has negatively impacted numerous lives in several ways. Physical inactivity and obesity are becoming increasingly troublesome issues. According to World Health Organization’s 2010 report, approximately 3.2 million people die each year due to physical inactivity [1]. Furthermore, at least 2.8 million people die each year as a result of being overweight or obese [1]. Physical inactivity and obesity can result in various health conditions such as high blood pressure, diabetes, depression, heart diseases, strokes and breast cancer. The two graphs Figure 1 and Figure 2 showcase the seriousness of this issue, highlighting statistics of insufficient physical activity and overweight adults, according to regions and income groups.

Exercise games better known as exergames have recently showed a lot of potential, in regards to motivating people and increasing fitness levels. They are able to use interactive technology to engage with the games while working out and practicing exertion. Exergames do not only provide a means to fight against inactivity and obesity in an entertaining way. They also foresee promising improvement in respect to rehabilitation for specific movement and neurological conditions within children, adults and elderly [3]. Some exergames that have existed over time include: Tectrix Vr Bike, VR Climber, Exertris Interactive Gaming Bike, PC Gamer Bike, Gamercize, Nexersys and Brainbike. There is a limited amount of exercise equipment that has been utilized in exergames,
mainly stationary bikes and treadmills. The problem that exists here is focusing on one exercise machine restricts players to only work out specific muscle groups. These types of locomotion interfaces have limited interactions and players are not able to achieve a full body workout [3]. Additionally, they are only able to indulge in cardiorespiratory training.

An example of an exergame is the Exercycle implemented using immersive technologies [9]. In this game, players cycle a stationary bike while avoiding obstacles, collecting rewards and improving their game score. Oculus Rift is used as a head mounted display to employ virtual reality into the game to motivate users with an immersive experience. The purpose of this literature review is to examine different types of physical fitness to see what the Exercycle exergame is currently missing, in terms of the different modalities. Current exergames and exertion interfaces have also been looked into, to survey the equipment and technology that has been used. This will help us in future to suggest different fitness equipment that can be integrated, to create a wide framework of exergames. The benefits of such integration would be the ability to accommodate to a wider audience and cater for different ages, genders, preferences and fitness goals.

The initial sections of the related work focus on defining, classifying and listing important concepts related to sports and exercise science. This will assist in establishing the context for the literature review. Subsequently, numerous applications of exergames will be discussed to evaluate how fitness equipment, technology and design components have been incorporated.

CONCEPTS

Physical Fitness

Physical fitness can have different interpretations for various people. Numerous terms surrounding fitness are used interchangeably. Caspersen et al. [2] define physical activity, exercise and physical fitness to build a standard framework across scientific studies. This is to provide clarification of important terms and avoid further confusion between experimental studies in the field of sport and exercise science. Physical activity refers to any movement carried out by the body that results in energy expenditure. This definition can be classified into three types of activity: leisure, at work and while sleeping. As a sub-category of physical activity, exercise is defined as structured and repetitive movement to accomplish physical fitness as the ultimate goal. In contrast to physical activity and exercise, physical fitness consists of qualities that people either have or want to achieve.

![Figure 3: Components of Physical Fitness](image)

Physical fitness divides several measurable components into two categories: health-related fitness and skill-related fitness as shown in Figure 3. Examining these measurable components, it is clear that physical fitness consists of a diverse range of elements. The authors further discuss how physical fitness varies amongst people from low to high. Population groups have different fitness goals based on their gender, age, stamina, health conditions and daily habits. Components relating to health are more important for the general public and skill-related components are more crucial for developing athletic ability.

By having a clear understanding of what physical fitness means and the elements it encompasses, we can cater meaningful exergames to a wider population. This will also allow us to effectively measure fitness against users’ goals using assorted factors.

Table 1 below illustrates similarities and differences amongst different literature articles, fitness related concepts and exergame application elements. The details have been discussed in the respective, separate sections. Exergame related concepts have been elaborated upon in the Applications section and fitness concepts have their own individual sections.

<table>
<thead>
<tr>
<th>Paper</th>
<th>Game</th>
<th>Design Considerations</th>
<th>Target Audience</th>
<th>Equipment used</th>
<th>Fitness Measures</th>
<th>Fitness Types</th>
<th>Virtual Reality</th>
<th>Social Relationships</th>
<th>Co-located Environments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caspersen et al., (1985)</td>
<td>Asterojumper</td>
<td>✓</td>
<td>✓</td>
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<td>X</td>
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<td>Finkelstein et al., (2011)</td>
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Practicing resistance training first can be beneficial for athletes who need to focus on strength, endurance and power. In addition to that, it is said to be more effective in augmenting aerobic gain in women and elderly. This is because their VO2max is mostly restricted by aging-related loss of muscle mass and strength. Resistance first sequence also favours fat utilization as metabolism is positively affected during the subsequent cardiorespiratory session. As a solution to residual fatigue from both the sequences, trainers recommend more recovery time and training of different muscle groups.

Based around an assumption that men and women have different fitness goals, Patton et al., [8] examine gender differences in fitness equipment use. They presume that men exercise to gain strength, muscle mass and leanness. Whereas, women generally exercise to lose weight and burn fat. Their aim was to study if the difference in fitness goals motivates participants’ usage of exercise equipment. The equipment was split into two categories: cardiovascular and strength (for resistance training). Cardiovascular equipment included stationary bikes, elliptical trainers, stepmills and treadmills. Conversely, strength equipment consisted of bench press stations, free weights and assisted plate loading machines. For a period of three consecutive weeks, students were observed using the campus recreation centre at the University of North Texas. The results were absolutely opposite for both the genders and the differences were statistically significant. Majority of males used strength equipment (at 80%) compared to a small group using cardiovascular equipment (only 20%). In contrast to this, 80% females used cardiovascular equipment and only 20% used strength equipment. Ellipticals were the most used cardiovascular equipment among both the genders. This study shows how males and females have different equipment usage.

<table>
<thead>
<tr>
<th>Kang et al., (2014)</th>
<th>Table Tennis for Three, Jogging Over a Distance, Remote Impact, Hanging Off a Bar</th>
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<tr>
<td>Park et al., (2012)</td>
<td>Swan Boat</td>
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Table 1: A summary of current literature

Types of Fitness
In this section, we move away from the specific measurable components of physical fitness towards two main exercise styles: resistance and cardiorespiratory. These are also sometimes referred to as strength training and aerobic exercises. Kang et al. [4] discuss these two exercise modalities and their benefits. However, the main argument is based on the importance of the order of exercises in a fitness program. Cardiorespiratory exercise encourages higher energy expenditure and effective fat utilization. On the other hand, resistance exercise facilitates an increase in muscle strength, endurance, size and power. The real challenge here is to balance concurrent training in a way that maximizes performance benefits from both the exercise groups. Athletes use concurrent training to prepare themselves for sports. However, such training is carried out with caution and prioritization of goals so that it does not cause fatigue and overtraining. Similarly, combination of both the exercises has been recommended for the elderly. This is encouraged as an effective strategy to endorse health, boost fitness and preserve functional abilities.

In concurrent training, there is a high possibility of residual fatigue from the first exercise sequence, affecting the second set and diminishing overall performance. This is why it is crucial to consider if cardiorespiratory exercises should be carried out first or resistance exercises. There is no overall consensus regarding this, hence trainers recommend switching the two modalities between workouts. If cardiorespiratory training is done first, it can improve the maximal oxygen uptake (VO2max) to a greater extent and enhance running performance. This order allows elimination of the delayed-onset muscle pain as an additional benefit. The general drawbacks exist in this situation where strength and power would be reduced for the subsequent set of resistance exercises. Furthermore, the same group of muscles may be used for both the exercise types, leaving the user with lasting fatigue.
preferences in terms of fitness equipment (and fitness types).

**Fitness Measures**

There are various measures that people use to evaluate fitness performance. Energy expenditure and VO\textsubscript{2max} are a few of the popular measures [4]. VO\textsubscript{2max} is the maximum rate of oxygen consumption measured during fitness. Energy expenditure is typically a sum of the amount of internal heat produced with external work and is measured in kilojoules (kJ) [2]. Zeni et al. [10] measure the rate of energy expenditure at three fixed RPE (rating of perceived exertion) values. They compare performance on six different exercise machines using three measures: oxygen consumption to calculate energy expenditure rate, heart rate and blood lactate levels. The exercise test consisted of 3 stages where participants exercised for 5 minutes at self-selected work rates corresponding to 3 different RPE values. Participants also took part in an initial habituation program for 4 weeks to become familiar with the setup. Order of testing was randomized to avoid bias. The exercise equipment comprised of an Airdyne, cross-country skiing simulator, cycle ergometer, rowing ergometer, stair stepper and a treadmill.

The results of this study showed significant statistical differences between rates of energy expenditure for different exercise machines. It was the treadmill that stimulated highest rates of energy expenditure for the 3 fixed RPE values. Heart rates of participants varied radically as well, with the highest values existing for the stair stepper and the treadmill. The lactate concentration differed notably too, where stair stepper and rower illustrated the highest amounts. Overall, the treadmill was considered to be the optimal exercise machine for increasing energy expenditure. However, the authors claim longer periods of exercise can obtain similar levels of energy expenditure from any exercise machine. There are two key limitations to this study. The sample size isn’t large enough to hold a solid credibility. Moreover, the results may not be generalizable to a population with low fitness abilities, as the participants were young and fit. Heart rate is used as an evaluate measure in Astrojumper [3] and Athene prototypes [6].

**APPLICATIONS**

**Design Framework**

Mueller et al., [5] create a framework for designing exertion games based on four views of the human body and three views of gaming elements. They discuss how previous systems motivated the need for this framework and apply the framework in the creation of a new system. Exertion games consist of a digital game where physical effort is invested as input. A crucial problem is the limited understanding of how to effectively design interactive exertion interfaces. This motivates the need to understand how our bodies can be a part of exertion experiences and how game design and growing technology can enhance them in a positive direction. Authors examine three exertion interfaces where users can communicate over distributed settings. These include ‘Table Tennis for Three’, ‘Jogging over a Distance’ and ‘Remote Impact’- depicting combat sports.

![Figure 4: Exertion Framework](image)

The exertion framework (as shown in Figure 4) consists of four lenses constructed around various perspectives of the human body: responding body, moving body, sensing body and relating body. Additionally, there are also three key game schemas that sit centrally in the framework: rules, play and context. These elements of the framework have been followed to construct a novel exertion interface called ‘Hanging off a Bar’, where players have to hang on to the bar for as long as possible. This is the only example of a resistance-based activity within an exertion interface that tests muscle strength and endurance.

![Figure 5: Exertion Game - Hanging Off a Bar](image)

Various sub-systems can be formed in line with the Exercycle system by taking inspiration from the named exertion interfaces above. A widespread framework can be
created with a collection of exergames. Physical fitness components such as sports and various types of equipment can be incorporated to provide a diverse range of experiences for users. This will motivate users and allow them to engage with exergames at a greater level compared to interacting with just one type of activity. Moreover, by following such a defined framework, developers may be able to create efficient, interactive interfaces that support exertion as input, while focusing on effective gaming components.

**Social Interactivity**

Friendships and social bonds are quite important in sports and fitness, as they can foster motivation. Around this key concept, Park et al., [7] explore the possibility of using assorted exercise devices as game controllers for a multiplayer social exergame. Their system ExerLink is able to transfer exercise power towards game inputs and balances power and latency issues to provide a fair experience for players. The authors aim to ensure that such an exergame can cater for users with different exercising abilities and preferences, allowing them to play and exercise together. This would facilitate social bonds and friendships while using various, easy to access and use exercise devices. It would also allow users to play social exergames anywhere and anytime, regardless of their location.

**Virtual Reality**

In the article [3], Finkelstein et al. present an immersive, stereoscopic virtual reality exergame ‘Astrojumper’ aimed at motivating players towards full-body exercise. Their focus is on assessing its effectiveness in promoting exercise and gathering feedback regarding design of immersive exergames. They claim that interactions with locomotion interfaces such as bicycles for exercise games are quite limited. Furthermore, they argue that motion sensing devices are unable to accurately measure users’ movement engaging the entire body. This motivates their use of 3D space with stereoscopy and immersion to support full-body activities using users’ feet and legs, as well as upper body. During the game play, a user flies through outer space environment avoiding speeding virtual planets coming towards him or her as shown in Figure 7. To allow diversity in exercise, users can shoot laser beams by throwing motion and grab bonus planets by stretching and reaching far. Electromagnetic trackers are attached to user’s forehead, wrists and waist, while stereoscopic projectors are used to display the game on immersive screens.
In their study, participants filled out pre-test and post-test questionnaires and were under observation as they played the game. Factors that were measured across participants included heart rate, workout intensity, motivation, feedback towards gameflow components and video game and exercise habits. Authors conclude that immersive exergames can motivate physical fitness in both adults and children. Furthermore, they claim that it is possible to design exergames that are enjoyable and productive for all users if proper attention is paid to their gameflow components. There is a significant gap in their study regarding the novelty factor of the system; since the study done was not longitudinal it’s hard to determine if the positive feedback was truly accurate.

This article highlights important issues with the design of immersive exergames that should be carefully noted. Astrojumper can facilitate various difficulty levels based on the player’s performance. Additionally, Astrojumper can be deployed on different hardware as required. These are properties that can be incorporated into the Exercycle system to cater for a diverse range of users and their ease of use. Exercycle can also benefit from the full-body movement Astrojumper incorporates, as users are able to get a complete workout.

An exergaming simulator (Athene) has been designed for gym training, exercise testing and rehabilitation that incorporates different exercise machines [6]. This is still under development and three prototypes have been implemented so far. The novel idea with this simulator is the integration of different fitness equipment, as well as the use of numerous virtual environments, games and sports applications. They use virtual reality and advanced motion controllers to provide an immersive gaming view. The variety of exercise modes includes jogging, biking, orienteering and adventure. This facilitates a range of activities the users can engage in as shown in Figure 8 and 9. We would like to allow a broader range of activities along the lines of these with the Exercycle system in the future. The Athen Communication Device is the key for integration between the different exercising devices. It enables communication between the exercise device, Athene software and different sensors.

The three prototypes include a Basic version with limited space requirements, Advanced version with 3 televisions to create an immersive experience. Moreover, there is a Premium version to provide the ultimate gaming experience with 3 video projectors and a CAVE structure to enhance the virtual environment. Each of the prototypes includes support for different add-ons such as a heart rate monitor, various sensors and Oculus Rift. Overall, the prototypes have received immensely positive feedback from the numerous evaluations that have been carried out with real users.

**SUMMARY**

In summary, exergames have been rapidly facilitating positive popularity and effective game design, resulting in systems that do social good for the society. They seem to be quite promising in motivating people to be fit and healthy. However, there exists a challenge of making exergames widely suitable for various audience groups. This can be done using a range of fitness equipment, facilitating for different types of fitness. While accommodating to a diverse range of users, exergames need to be entertaining and captivating as well. This is so that the game play can pose as an effective distraction mechanism, so it doesn’t start feeling like a routine exercise task to users.

**FUTURE WORK**

More research into user preferences and their interaction with various types of fitness equipment would be valuable. This will be able to establish the needs of a diverse range of users, facilitating their fitness goals and specific conditions within the exergame. Furthermore, a longitudinal study needs to be carried out to realistically evaluate the effectiveness of exergames in relation to fitness and health [3, 7, 9]. This has been mentioned as a key limitation of studies assessing exergames. Carrying out studies with a large sample size and a representational population is also something that can be worked towards in the future [9, 10].

There is a gap in literature in terms of an exergame for a diverse range of fitness equipment and audience groups. Establishing a common platform between fitness equipment may be a real challenge. However, the benefits of a wide...
exergame framework (somewhat along the lines of Mueller’s exertion interfaces [5]) will increase the effectiveness of the system. Giving careful consideration to design elements and gameflow components while designing an exergame will improve attractiveness of the game as well. Remote and co-located environments can also be developed in the future to facilitate social interactions between groups of people. Another significant gap exists in this field as no resistance/strength equipment has been employed within exergames. Earlier on in the literature review, we came across the importance of resistance training and strength equipment [4, 8], so it becomes very vital to integrate such equipment too.

REFERENCES


