

# Thighrim and Calf-Life: A Study of the Conversion of Off-the-Shelf Video Games into Exergames

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## ABSTRACT

Exergames are a fun and engaging way to participate in physical activity. Exergame players consistently require new content to maintain interest in the activity. One way to provide users with high quality content with minimal development work is to convert existing off-the-shelf digital games into exergames by using the game's "modding" interface. To explore the potential of converted exergames for inspiring high exertion levels, we performed a conversion on two popular games: Half-Life 2 and The Elder Scrolls V: Skyrim. The conversions were performed in two stages. The first stage mimics existing black box conversion techniques and a second stage uses Heart Rate Power-Ups to incent players to exert themselves. A study of 18 participants found that the resulting games support anti-sedentary levels of exertion while falling slightly below national recommendations for cardiovascular exercise. Adding exercise to the games did not affect players' enjoyment.

## Author Keywords

Exergame; video game design; active video game

## ACM Classification Keywords

K.8 [Personal Computing]: Games

## INTRODUCTION

Exergames – games that require physical activity to play – are a promising tool to help people become more physically active. As with all games, however, exergames can become boring over time [20]. This can make it difficult to create enough game content to keep people motivated. Converting off-the-shelf games into exergames has the potential to solve this problem, by leveraging the thousands of existing high-quality games. Tools are available to assist in the conversion of off-the-shelf games into exergames: for example, the PCGamerBike Mini pedaling device emits simulated key presses when players pedal, controlling forward movement of an avatar in an existing game [3]. As

we will show, however, this style of black box conversion fails to motivate high exertion levels in players. This is largely because off-the-shelf games were not designed with exercise in mind – the game's activities can make it difficult to focus on exertion, and the game's pacing may not be conducive to fast pedaling. We propose that richer conversions of off-the-shelf games can be performed using the modification ("modding") tools that many games provide. Modding tools allow the public to create extensions of existing games. We show how mods can be used to add Heart Rate (HR) Power-ups [16] to existing games, providing incentive for players to exert themselves. We have used this technique to modify the popular games The Elder Scrolls V: Skyrim [4] and Half-Life 2 [36]. As shown in Figure 1, players of our converted games pedal a recumbent bicycle and hold a gamepad controller while viewing the game on a display placed in front of the bike.

Our research provides insight into three questions. First, does mapping avatar movement to pedaling (black box conversion) solicit adequate activity from the player? Second, how well does the addition of Heart Rate (HR) Power-ups to these games help us attain the goal of increasing players' exertion? And third, how well do the mechanics and play styles of such off-the-shelf games lend themselves to conversion into exergames?

Both Skyrim and Half-Life 2 are high-action games, but surprisingly, we found that this in-game action did not lead to high levels of exertion in the simple black-box conversion. The games include activities that make it difficult for some players to maintain a consistently high cadence.

In both games we implemented HR Power-ups [16], a generic technique that has been shown to increase players' exertion in exergames by rewarding players for maintaining a target heart rate. Using the modding interface requires more work than the simple black box conversion but dramatically less than building a complete game from scratch. The Heart Rate Power-up conversion of the off-the-shelf games inspired higher exertion in players. These fell slightly below national guidelines for exercise while meeting guidelines for anti-sedentary activity.

This paper makes three main contributions. First, it is one of few papers to measure how successfully conversions of existing games into exergames drive exertion. Second, it characterizes how pace and other elements of existing

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**Figure 1. The game play setup with a stationary bike and gamepad.**

games can affect players' ability to reach desired levels of exercise. Last, it shows how the generic HR Power-up technique can be successfully applied to off-the-shelf games.

The paper is structured as follows. First we discuss background research, reviewing adherence problems with exergames, and describing existing techniques used to modify off-the-shelf games into exergames. We then describe the HR Power-up conversions we created for *Skyrim* and *Half-Life 2*. Finally, we report on the results of our study and discuss implications for design.

## BACKGROUND

Exergames are digital games whose play involves physical activity. Examples of exergames include *Dance Dance Revolution*, in which players match a rhythm by stepping on buttons on a floor mat [18], *GrabApple*, in which players try to catch apples with a virtual hand that is controlled through body movement [12], and *Liberi*, in which players move an avatar by pedaling a stationary bicycle [17].

### Usage over time

People often adhere better to exercise regimens when the activity is enjoyable [40], and so combining exercise with the entertainment of video games offers the potential to motivate increased and continuing physical activity. For example, Mark and Rhodes found in a six-week home trial that children used a GameBike-based racing game significantly more than a traditional stationary bike [20].

Long-term adherence to exergame play has proven elusive, however. A systematic review of nine exergame studies was performed by Bernett et al., determining that for most people, frequency of play declines over a short period of time [2]. Reduced engagement with video games over time is not unique to exergaming, however; for example, *Red Dead Redemption* was named Game of The Year in 2010 by several publications including GameSpot [11], and *Game Spy* [35], and yet the game was only completed by 10% of its players [30]. *Liberi*, an exergame for children with cerebral palsy, employed a strategy to maintain

player's interest by releasing new content over time [17]. A six-week in home trial began with three mini games available to be played. Subsequently, a new game was released every two weeks until a total of six were available. This strategy helped to combat decline in play time over the six weeks. It is likely that as with traditional digital games, players of exergames continually require new content to hold their interest.

### Converting off-the-self games into exergames

One strategy for providing exergame users with new content is to convert existing off-the-shelf games into exergames. Adding an exercise component to existing games allows developers access to the deep storylines and high quality assets that are typical of top-tier "AAA" games [38].

We identify three core approaches for converting off-the-shelf games into exergames: *black box conversion*, *source-code modification* and *modding*. A black box conversion uses a software tool to convert inputs from an exercise device to game inputs, without requiring modification to the game itself. For example, the FitXF software provided with the commercial PCGamerBike Mini pedaling device can be configured to inject the keystroke of choice (usually "W") into a game whenever the player pedals, leading the game to move the player's avatar forward [3]. This allows players to move their avatar by pedaling while using a standard game controller for other forms of input.

Chatta et al. performed a black box conversion of Sega's *Sonic All Stars Transformed* to an exergame [8]. Players were told to perform leg lifts while playing the game and received feedback regarding their performance of the exercise through a visual overlay on the game screen. This conversion was similar to the overlay technique of Mandryk et al. used to convert off-the-shelf games into biofeedback games [19]. Black box conversion was also used by Sportal, an exergame adaptation of the popular *Portal 2* [38,39]. Walther-Franks et al. used the Kinect SDK [23] and the virtual gamepad controller vJoy [10] to map players' walking movements to avatar movements, where the player walking forward moves the character forward. The authors assert that the off-the-shelf game does not encourage high exertion and so built custom levels using the Valve Hammer Editor. The custom levels were designed to encourage more exercise than the original game levels would have done.

Interestingly, a black box modification was performed by Monedero et al. to enhance the energy expenditure in an existing exergame [24]. The *Wii Sports* games were augmented so that players were required to take large steps in addition to the upper body movements already required to, for example, swing a tennis racquet.

A second technique for converting off-the-shelf games into exergames is to modify the source code of the game. Two

toolkits have been developed to support such conversions: FFAST [34] and GAIM [7].

FFAST interprets body positions using a Kinect, which are used as inputs to a game. FFAST has been used to perform a source-code conversion of a driving video game [13], where body movements are mapped to the acceleration of the car. Participants performed the exercise with greater frequency when playing the game, but their maximum heart rates were significantly higher when performing the exercise without the game.

The GAIM toolkit supports pedaling, running, gesture and balance-based input [7]. It has been used to convert the XNA Racing Game so that cycling or jogging on the spot powers the player's car, and to convert the Spacewar game so that players lean to control the direction of their spaceship and perform a "hammering" gesture to fire its weapons.

These two approaches have significant disadvantages – a pure black box approach allows no modification of the existing game beyond the use of exercise as a form of input. Source-code modification can work well, particularly when supported by a toolkit, but is limited to games whose code is available.

In this paper, we explore a third approach for converting games into exergames: the use of the modification (or "modding") programming interface provided by many games. This approach provides the benefit of being able to modify gameplay to suit an exergame while not requiring access to the game's source code. In 2014 alone, 30 games with modding interfaces were released on the Steam digital store [33], supplementing an existing robust catalogue. Game modding has become a popular activity with significant impact. The popular mod sharing site Moddb.com has seven and half million monthly visitors and over one petabyte in downloads per month [15]. A substantial and growing base of games is therefore available for conversion into exergames, potentially helping with the problem of player satiation with games over time.

This third approach of game modding is illustrated through Gemini, a modified version of Bioware's Neverwinter Nights 2, developed using the Aurora toolset [31,32]. The player's daily activity metrics affect the behaviour of an in-game animal companion. Stanley et al. explain how modifying a mature game can help to eliminate the balancing problems that can plague online games, as these problems have already been addressed by the developers.

### Energy Expenditure

If we hope to evaluate the potential of off-the-shelf conversions as a substitute for traditional exercise, we must consider the energy expenditure and exertion levels of players. We evaluate exertion based on guidelines for exercise provided by the American College of Sports Medicine (ACSM), which recommends that most adults exercise at a moderate (40-60% heart rate reserve) to

vigorous intensity (60-90% heart rate reserve) [1]. Heart rate reserve is the difference between people's resting heart rate and their maximum heart rate. It is often used to measure exertion levels because it reflects relative intensity more accurately than a raw heart rate value. The ACSM provides additional recommendation for those leading a sedentary lifestyle, that is those who are not participating in at least 30 minutes of moderate intensity activity three days a week for at least 3 months [1]. Sedentary individuals are encouraged to reducing their time spent sitting still and will gain health benefits for doing so.

Exertion levels seen in off-the-shelf conversions have met the requirements for anti-sedentary activity, but fall well below the ACSM recommendations for cardiovascular exercise. The *peak* average heart rate values inspired by Chatta et al.'s conversion of Sonic All Stars Transformed fell below the warm up and cool down range (50-60% of maximum heart rate) for people age 20-30 when calculated as a percent of maximum heart rate ( $220 - \text{age}$ ) [8,29]. *Average* heart rates for this game are presumably lower yet. Guo and Quarles found that participants peak heart rates reached the "weight loss zone" (60-75% max HR) for people aged 20-30, falling on the low end of ACSM recommendations, but again do not report *average* heart rate [13]. In contrast, the augmented Wii Sports created by Mondero et al. led to moderate exercise intensity. Interestingly, this positive result was seen by augmenting a game that was designed with movement in mind [24].

Over all, neither of these examples of conversions of traditional digital games to exergames has inspired even moderate exertion levels in players. These very modest results contrast with custom exergames such as the Liberi minigames which encouraged players to reach the high end of moderate exertion exercise recommendations [15].

### THIGHRIM AND CALF-LIFE: CONVERTING OFF-THE-SHELF GAMES INTO EXERGAMES

To assess the potential of converted off-the-shelf games as exergames, we converted two popular games, Valve Corporation's Half-Life 2 and Bethesda Game Studio's Elder Scrolls V: Skyrim, into games where the avatar is powered by pedaling a stationary bicycle. Skyrim is an action role-playing game set in an open world in which players have the freedom to participate in crafting, combat, looting, bartering, and questing. As players perform in-game actions, they are able to level up skills and improve their armor and weapons. Skyrim has been well-received by the gaming public, with an 8.4 user score on metacritic.com [22]. Half-Life 2 is a fast-paced first-person shooter interlaced with environmental puzzles. Players must save the world from attacking aliens. Players are required to use tactics and props from the environment to outmaneuver enemies and advance the plot. Half-Life 2 was also well-received, with a user score of 9.2 on metacritic.com [21].

We performed the conversion of Skyrim and Half-Life 2 to exergames in two stages. The first stage was a black-box conversion in which we add pedaling to enable avatar movement, similar to the conversions enabled by the PCGamerBike Mini and FitXF.

We hypothesized that black-box conversion would fail to incent high exertion, since the off-the-shelf games incorporate no incentives for exertion and do not attempt to match gameplay activities with the pace of physical exercise. The second stage uses the games' modding interfaces to augment pedal-based control with HR Power-ups. These power-ups give the player a benefit in the game for reaching and maintaining target heart rate levels, adding an explicit incentive for exertion not present in the black box conversion. Our conversions demonstrate how the modding approach to off-the-shelf exergame conversions offers the designer the ability to adapt game elements for exertion - an important advantage over the black box approach.

#### Identifying which off-the-shelf games to convert

To help identify which off-the-shelf games would make good candidates to convert to exergames, we appealed to selection guidelines provided by Walther-Franks et al. [38]. These guidelines suggest using character-based action games because movement input can be directly mapped to avatar movement. First-person games are also recommended because they increase a player's sense of presence. Both Skyrim and Half-Life 2 are first-person games involving significant action. In addition to these guidelines, we selected games with rich modding interfaces to allow the addition of the HR Power-ups. Finally, we selected games from different genres to gain insight into how elements of a game might affect players' exertion.

These considerations led us to choose Elder Scrolls V: Skyrim and Half-Life 2 for conversion to exergames: both are action-oriented first-person games, representing the two genres of first-person shooter and role playing games respectively, and both provide rich modding languages. We name the converted games *Thighrim* and *Calf-Life*.



Figure 2. The right image shows player feedback when the HR power-up is active. Note the heart indicator and whirlwind effect over the weapon.

#### Customizations of games via Heart Rate Power-up

We performed the conversion of Skyrim and Half-Life 2 using each game's modding interface. A custom tool used in both conversions records a player's heart rate and pedaling cadence in real time, and injects keystrokes into the game to communicate these values. The tool calculates a player's target heart rate as a percentage of their heart rate reserve. The tool also provides an overlay displaying a heart icon that provides feedback to the player on their heart rate levels. The games can be seen in Figure 2 and Figure 3.

For each game, we created a custom mod that responds to the injected keystrokes associated with target heart rate and cadence values. In both games, the mod moves the player's avatar in its current direction whenever the pedaling cadence is above a threshold of 20 revolutions/minute (RPM). Power-ups are enabled when the keystroke is injected to indicate that the player has reached their target heart rate. Players receive an in-game advantage when their power-up is active, e.g., doing more damage on attacks or healing more quickly.

Our approach of rewarding players when they achieve a target heart rate has been used in several earlier custom-designed exergames. Boyd et al. use heart rate monitors to motivate players of 'ere be dragons, in which players walk around the real world while a virtual world is displayed on a mobile device [6]. Players are rewarded with lush and pleasant environments if their heart rate is high, and are shown dull and impoverished areas when their heart rate is low. Wylie and Coulton's Health Defender rewards players with in-game bonuses for attaining heart rate thresholds [41]. In Webz of War [26], as players' heart rates increase, their avatars become more powerful. In earlier work, we applied HR Power-ups to custom exergames, increasing players' average percentage of heart rate reserve by as much as 11% [16]. Our approach therefore adopts techniques that have been explored in custom exergames but have yet to be applied to converted off-the-shelf games.

#### Base Conversion: Pedaling to move avatar

In both Thighrim and Calf-Life, players' pedaling is used to enable avatar movement. The original games both use the first person convention for dual analog controllers in which one joystick moves the players' camera and another moves their avatar. This allows players to look forward while moving sideways or backwards, or to look behind them as they run forward. In custom cycling-based exergames [14], pedaling simply moves the avatar in its current direction. In our converted games, the player must both pedal and use a joystick to specify the direction of movement.

In custom cycling-based exergames, players' movement speed is based on the speed of pedaling. Off-the-shelf shooter and role-playing games typically support only one or two movement speeds (e.g., walking, sprinting), and therefore in Thighrim and Calf-Life, a pedaling cadence threshold is used to enable movement. If the player exceeds the threshold, the avatar moves at a constant speed.





**Figure 3.** The bottom image shows the visual feedback when the player has the power-up. Note the heart rate indicator, the blue border and the text at the bottom of the screen

As we shall see, both of these decisions impact the effectiveness of the games as exergames. More involved conversions, as would be possible with source code-level conversions, could allow the exergames to adopt control schemes closer to those used in custom exergames.

#### Enhanced Conversion: HR Power-ups

We hypothesized that the black box approach of simply adding pedaling to enable avatar movement would encourage low exertion levels, and as we shall see, our study confirmed this expectation. To incent higher levels of exertion, we used the games' modding languages to implement HR Power-ups, which provide an in-game benefit for reaching a target heart rate level. We have argued that HR Power-ups are a generic technique that can be widely applied, but to-date the method has been used only in custom exergames [16]. We hypothesized that HR Power-ups would indeed be applicable in these off-the-shelf games, and would incent higher exertion levels. As we shall see, our study's results were consistent with this hypothesis.

When a player is at or above their target heart rate, the power-up becomes active. The player is provided with visual and audio cues to show when they are near to or at their target heart rate. Figure 2 and Figure 3 demonstrate the visual feedback in each game.

#### Thighrim

When the power-up is active in Thighrim, players' attacks are 50% more effective and their health regenerates faster. Additionally, the power-up allows players to activate

sprinting (by pressing a button on the controller) without draining their stamina resource. The attack and health related benefits are intended to incent players to pedal harder during combat by increasing their power versus enemies. The stamina resource is normally spent when sprinting or used to increase attack strength. Allowing sprinting without depleting stamina can reduce the tedium of travelling long distances between cities. To ensure that players understand when the power-up is active, we added visual feedback: on activation, there is a bright flash followed by a tornado effect surrounding the players' weapons. When the power-up is deactivated, the swirling effect disappears. Additionally, the heart rate overlay signals how close players are to their target heart rate. Figure 2 shows the player's display with and without the power-up.

#### Calf-Life

When the power-up is active in Calf-Life, players may sprint without using auxiliary suit power, players' health regenerates over time, and players' ammunition is unlimited. Similarly to Thighrim, these benefits increase players' effectiveness in combat, and reduce the cost of travelling. A visual swirl of blue particles around the player indicates the activation of the power-up. As long as the power-up is active, a border overlay is visible, and text mimicking the game's head-up display shows "Power-Up Active". Again, the heart rate overlay from the power-up manager signals how close players are to their target heart rate. Figure 3 shows Calf-Life when the power-up is (bottom) and is not (top) active.

It was important for each game's power-up to be sufficiently rewarding for players to strive for them, but not so powerful that they trivialized game play. In order to attain this balance, several rounds of playtesting and adjustment were necessary.

#### EVALUATION

We performed a study to help answer three questions. First, does mapping avatar movement to pedaling solicit sufficient activity from the player? Second, how well does the inclusion of HR Power-ups help to encourage players to reach the goal of raising their exertion? Third, how well do the mechanics and play styles of typical off-the-shelf games lend themselves to conversion of exergames? We recruited participants to play Skyrim, Half-Life 2, and their exergame conversions. We measured participants' energy expenditure and player experience, and followed up with a semi-structured interview. As we shall see, our core results were that black-box conversions of both games required low levels of exertion to play, and that the heart-rate power-up versions required higher exertion levels. Neither version was a suitable substitute for traditional physical exercise, but the HR power-up version met requirements for anti-sedentary activity. Both games had design elements that made it difficult for players to attain high levels of exertion,

indicating that for true exercise, custom-designed exergames may be necessary.

### Participants

Participants were solicited through advertisements on Kijiji and a University-affiliated Facebook group. The target users of converted off-the-shelf games are people who enjoy videogames but do not perform recommended levels of exercise. As such, we recruited 18 participants between the ages of 18 and 35 who had played first-person games for at least 100 hours using an analog controller. In addition, we required that participants perform less than one hour of vigorous intensity exercise per week, while feeling confident that they could cycle at a moderate pace for 25 minutes. We administered the Physical Activity Readiness Questionnaire (PAR-Q) [9] to ensure that it was safe for them to perform exercise. In a demographic questionnaire, 16 of 18 said they currently play video games, at an average of two hours weekly. Eight of the 18 participants had played Half-Life 2 before, and 11 of the 18 had played Skyrim. Of the 18 participants, five were female and 13 were male.

### Setup and Apparatus

As shown in Figure 1, players used a Vision R10 recumbent bicycle as input to the games. A Garmin Speed and Cadence sensor was used to transmit cadence information to the game in real time. Participants wore a Garmin Premium heart rate monitor to provide real time heart rate information to the game. Additionally, players used a Logitech gamepad to control the game. The games were displayed on a 55" display positioned in front of the bike.

### Conditions

We tested three conditions of each game. The *control* condition was the unmodified game played while sitting on a couch. The *pedaling* condition was the black-box conversion, played on the recumbent bicycle. Participants pedaled to enable avatar movement and used a gamepad to perform all other game input. The *power-up* condition was the extended pedaling condition including the HR Power-ups described above.

In all three conditions, a screen overlay provided a visual representation of players' heart rate. As seen in Figure 2 and Figure 3, players' heart rate is represented by the size of a heart image. The image size is a percentage of an outlined heart that represents their target heart rate. As players' heart rates increase, the image grows until the player reaches their target heart rate and the outline is full. As players' heart rate decreases, the image size decreases proportionally.

In order to avoid players becoming uninterested in the games by playing the same section three times (once in each condition), we identified three different sections of the game. Pilot testing with four participants ensured that each game segment was of similar length and difficulty. The order in which participants played the conditions was

balanced using a Latin square. Half of the participants played Half-Life 2 in the first session and Skyrim in the second session, and the other half played in the other order. Each segment was played with each condition an equal number of times.

### Measures

During each second of gameplay, the player's heart rate and cadence and the state of the power-up were logged to a file on the testing computer. A custom log analysis tool was used to calculate players' average percent of heart rate reserve. After the first combat section in each gameplay scenario, we showed players the Borg rate of perceived exertion scale [5] and asked them to rate their exertion from 6–20. After playing each game segment, players completed the intrinsic motivation inventory (IMI) questionnaire to gauge their game experience [28]. Following play of each condition, we performed a semi-structured interview regarding their experience with the game conversions.

### Procedure

Participants attended an hour-long session on two different days. Half of the participants played Thighrim on the first day and Calf-Life on the second, and the other half played the games in the other order. Before beginning the first day's session, participants filled out a consent form, demographic questionnaires regarding their physical activity levels and video game usage, and the PAR-Q. Participants then put on a heart rate monitor and laid on a couch for five minutes so we could measure their resting heart rate. Using the participants' age and resting heart rates, the Karvonen formula [1] was used to calculate the participant's target heart rate. We chose a target heart rate based on ACSM guidelines [1]. We piloted the games with a target heart rate reserve of 60%, but players found that intensity difficult to maintain while concentrating on playing the game. With this feedback, we chose the target range to be moderate intensity at 40–59% of heart rate reserve. At the beginning of the first day's session, participants performed three-minutes of light cycling that served as a warm up and allowed participants to find a comfortable cycling resistance. At the beginning of the second session, participants cycled for three minutes at the resistance chosen during the previous session as a warm up. Before participants began each day's session, we allowed them to play the game while cycling until they felt comfortable with the controls.

In each hour-long session, participants played three segments of the game each under a different condition. The control, pedaling and power-up conditions were played for seven minutes each with a five-minute rest between conditions to remove crossover of heart rate levels from the preceding condition. The first two minutes of data from each game was considered to be acclimatization time, and was not included in the analysis. This left five minutes of data for analysis. Following each condition, participants completed the IMI questionnaire.

	Control	Pedaling	Power-up
Half-Life 2	M = 6.8 SD = 1.4	M = 11.5 SD = 2.1	M = 13.8 SD = 2.6
Skyrim	M = 7.0 SD = 1.4	M = 11.6 SD = 1.8	M = 13.9 SD = 2.0

**Table 1** Participants' mean rates of perceived exertion (M) and the standard deviation (SD) of the responses.

## RESULTS

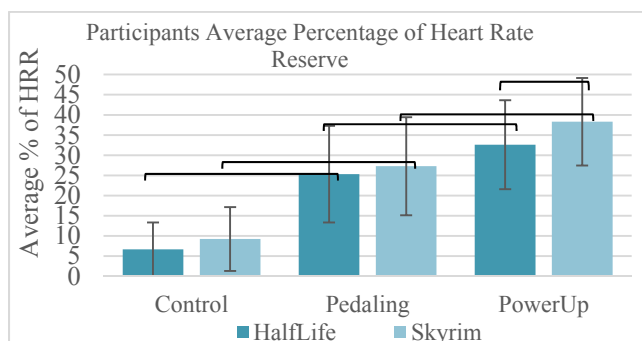
We first report participants' exertion levels and perceived exertion for each condition and then present participant responses to each section of the Intrinsic Motivation Inventory (IMI). In the following section, we interpret these results with respect to our three research questions.

### Exertion

In both Skyrim and Half-Life 2, players' average percentage of heart rate reserve was significantly different between each condition. Figure 4 shows participants' average percentage of heart rate reserve for the three conditions. A 3x2 repeated measures ANOVA revealed a significant effect of condition (Control, Pedaling, and Power-up) on average percentage of heart rate reserve,  $F(2,34)=87.0$ ,  $p<.001$ .

Post-hoc tests using Bonferroni correction revealed that players' average percentage of heart rate reserve was higher in the pedaling condition ( $M=26.3$ ,  $SD=2.7$ ),  $p<.001$  and power-up condition ( $M=35.5$ ,  $SD=2.5$ ),  $p<.001$ , versus the control ( $M=8.0$ ,  $SD=1.4$ ), and the power-up condition was higher than the pedaling condition ( $p<.001$ ). The RM-ANOVA also showed an effect of game (Half-Life 2 and Skyrim) on average heart rate reserve,  $F(1,17)=7.7$ ,  $p=.013$ . Players had a higher average percentage of heart rate reserve in Skyrim ( $M=24.9$ ,  $SD=2.1$ ) than in Half-Life 2 ( $M=21.5$ ,  $SD=2.1$ ),  $p=.013$ .

The interaction between game and condition for players' average percentage of heart rate reserve was significant  $F(2,34)=3.3$ ,  $p=.048$ . In order to investigate this interaction, we performed three paired t-tests on participants' average percentage of heart rate reserve between the two games for each condition. There was no significant difference between the average percentage of heart rate reserve in the Half-Life 2 control condition ( $M=6.7$ ,  $SD=5.2$ ) and the Skyrim control



**Figure 4.** Error bars show standard deviation. Horizontal lines indicate statistical significance ( $\alpha=.05$ ).

	Control vs. Pedaling	Control vs. Power-up	Pedaling vs. Power-up
Half-Life 2	$p < .001$ $d = 2.6$	$p < .001$ $d = 3.4$	$p < .001$ $d = 1.0$
Skyrim	$p < .001$ $d = 2.9$	$p < .001$ $d = 4.0$	$p = .002$ $d = 1.2$

**Table 2.** Results of the post-hoc tests on RPE responses.

condition ( $M=9.2$ ,  $SD=7.9$ ),  $t(17)=1.8$ ,  $p=.09$ . There was no significant difference between participants' average percentage of heart rate reserve in the pedaling condition of Half-Life 2 ( $M=25.3$ ,  $SD=11.9$ ) and the pedaling condition of Skyrim ( $M=27.3$ ,  $SD=12.2$ )  $t(17)=1.3$ ,  $p=.23$ . There was a significant difference in participants' average percentage of heart rate reserve between the power-up condition of Half-Life 2 ( $M=32.6$ ,  $SD=11.0$ ) and the power-up condition of Skyrim ( $M=38.3$ ,  $SD=10.8$ ),  $t(17)=3.6$ ,  $p=.002$ . Cohen's  $d=0.52$  indicates a medium effect.

Our analysis of players' rates of perceived exertion revealed that in both games, participants were aware of their changes in exertion between each condition. Players mean rates of perceived exertion can be seen in Table 1. A one-way repeated measures ANOVA was conducted on the rate of perceived exertion responses collected during the three conditions of both Skyrim and Half-Life 2. The ANOVA performed on the Skyrim data indicates significant difference between players perceived exertion over the three conditions,  $F(2,16)=111.6$ , ( $p<.001$ ). The ANOVA performed on participants' rate of perceived exertion in Half-Life 2 also indicated a significant difference over the three conditions  $F(2,16)=70.9$ ,  $p < .001$ . The results of post-hoc tests using Bonferroni correction revealed significant differences of players' perceived exertion between all conditions, seen in Table 2.

### Player Experience

During the interviews, we asked players to rank the conditions from their favorite to least favorite for both games. For Skyrim, 12 of 18 participants ranked the pedaling condition as their least favorite, while 14 of 18 ranked the power-up condition as their favorite. The results are similar for Half-Life 2, with 11 of 18 ranking the pedaling condition as their least favorite and 14 of 18 ranking the power-up condition as their favorite.

A one-way repeated measures ANOVA was completed on each section of the Intrinsic Motivation Inventory (IMI) used to evaluate the effect of condition and game on player's experience. Participants average scores on each subscale can be seen in Table 3.

### Competence

No significance was found for the competence subscale scores of the IMI for Half-Life 2  $F(2,16)=.14$ ,  $p=.87$  or for Skyrim,  $F(2,16)=.4$ ,  $p=.70$ .

### Importance

A significant effect was found for the importance subscale scores for Half-Life 2,  $F(2,16)=7.61$ ,  $p=.005$ . Post-hoc tests using Bonferroni correction indicate an increase in players' importance score between the control ( $M=4.2$ ,  $SD=1.0$ ) and pedaling conditions ( $M=5.0$ ,  $SD=1.1$ ),  $p=.013$ , with a large effect size ( $d=0.9$ ). There is also a statistically significant increase in players score from the control condition ( $M=4.2$ ,  $SD=1.0$ ) to the power-up condition ( $M=5.3$ ,  $SD=1.0$ ),  $p=.003$  with a large effect size ( $d=1.1$ ). There is no statistically significant difference between the pedaling and power-up condition,  $p=.67$ .

A one way repeated measures ANOVA for the importance subscale scores of the IMI during Skyrim indicates a significant effect,  $F(2,16)=16.8$ ,  $p<.001$ . Post-hoc tests using the Bonferroni correction indicate a statistically significant increase in players importance subscale score between the control condition ( $M=3.7$ ,  $SD=1.1$ ) and the pedaling condition ( $M=4.7$ ,  $SD=1.0$ ) in Skyrim,  $p=.003$ , with a large effect ( $d=0.9$ ). There was also a statistically significant increase in players' importance subscale scores from the control condition to the power-up condition ( $M=5.1$ ,  $SD=1.0$ ),  $t(17)=5.9$ ,  $p<.001$ , with a large effect ( $d=1.3$ ). There was no statistically significant difference of the importance subscale scores between the pedaling and power-up conditions for Skyrim,  $p=.11$ .

### Interest

A one-way repeated measures ANOVA over the interest

subscale scores for the Half-Life 2 session showed no statistically significant effect,  $F(2,16)=.95$ ,  $p=.41$ .

Similarly, a one way repeated measures ANOVA for the interest subscale scores for the Skyrim session showed no statistically significant effect,  $F(2,16)=2.2$ ,  $p=.14$ .

### Tension

A one way repeated measures ANOVA scores for the pressure/tension subscale during the Half-Life 2 session indicate a statistically significant effect,  $F(2,16)=8.8$ ,  $p=.003$ . Post-hoc tests using the Bonferroni correction indicate there is a statistically significant increase in players pressure and tension scores from the control condition ( $M=2.3$ ,  $SD=.8$ ) to the power-up condition ( $M=3.2$ ,  $SD=1.2$ ),  $p=.004$ , with a large effect ( $d=0.9$ ). There was no statistically significant increase in pressure and tension subscale scores from control condition ( $M=2.3$ ,  $SD=.8$ ) to pedaling condition ( $M=2.7$ ,  $SD=1.1$ )  $p=.223$ , nor from the pedaling condition ( $M=2.7$ ,  $SD=1.1$ ) to power-up condition ( $M=3.2$ ,  $SD=1.2$ ),  $p=.28$ .

A one way repeated measures ANOVA for pressure/tension subscale scores during the Skyrim session showed no statistically significant effect,  $F(2,16)=1.59$ ,  $p=.24$ .

## ANALYSIS AND DISCUSSION

Our results show that the conversion of off-the-shelf games into exergames holds promise, particularly as an anti-sedentary activity. One concern regarding converting off-the-shelf games into exergames is that the exertion required may negatively affect player enjoyment. Both the RPE scores (Table 1), and the IMI effort and importance subscale scores (Table 3) show that participants were aware of their increased exertion in pedal and power-up conditions. This did not translate, however, into a reduction of enjoyment: there was no significant difference in the IMI interest and enjoyment subscale scores (Table 3). Participant feedback during the interviews was positive, with the majority of participants rating the power-up version of the games as their favourite. Participant 18 stated, for example, "I think it's really cool to be honest, if they did have these exercise games available, I think it'd be pretty popular." We now discuss our results in terms of our three questions.

### Q1 Do black box conversions solicit adequate activity from the player?

Although players' average percentage of heart rate reserve increased with the addition of pedaling, the average exertion levels recorded for the pedaling condition of both Calf-Life and Thighrim failed to meet the lowest ACSM recommendations for cardio-respiratory exercise. The average exertion for the pedaling condition of Calf-Life and Thighrim were 25% and 27% of heart rate reserve respectively, both substantially lower than the minimum recommendation of 40% of heart rate reserve.

Our results are in line with the exertion levels seen in other black box conversions of off-the-shelf games, such as Chatta et al.'s conversion of Sonic All Stars Transformed whose maximum heart rates reached only warm-up levels of

		Control Condition	Pedaling Condition	Power up Condition
Interest/ Enjoyment	Half-Life 2	5.38	5.55	5.63
	Skyrim	5.17	5.33	5.52
Perceived Competence	Half-Life 2	4.14	4.21	4.19
	Skyrim	4.62	4.68	4.80
Effort/ Importance	Half-Life 2	4.21*†	5.04*	5.29†
	Skyrim	3.66*†	4.64*	5.07†
Pressure/ Tension	Half-Life 2	2.30*	2.68	3.24*
	Skyrim	2.03	2.50	2.51

**Table 3.** Average IMI subscale scores. Values in a row sharing a \* or † symbol are significantly different ( $\alpha=.05$ ).



exertion for university aged people [8]. The low exertion levels we observed arise both with our cycling-based exercise and with Chatta et al.'s knee-raise exercise. We conjecture that the low exertion is inherent to properties of off-the-shelf games, which we discuss under our third question

**Q2: How well does the addition of Heart Rate (HR) Power-ups work to increase players' exertion?**

Players' exertion levels increased substantially in the HR Power-up condition over the pedaling condition. Exertion levels in the power-up condition still fell below ACSM recommendations for cardiovascular exercise, with an average percentage of heart rate reserve of 32.6% for Calf-Life 2 and 38.3% for Thighrim. These results are nonetheless promising, particularly in the case of Thighrim, which is close to the recommended level of 40% of heart rate reserve. These results shown an increase of 7 percentage points of heart rate reserve in Calf-Life with the presence of HR Power-ups, and an 11 percentage point increase in Thighrim. This increase is in line with the 6 - 11 percentage point increases found when applying HR Power-ups to custom exergames [16]. However, the base exertion level for the converted games with pedaling was much lower than the custom exergames. If off-the-shelf games are to be converted to exergames that can be used as a substitute for traditional cardiorespiratory exercise, more work is required to incent and permit higher levels of exertion. Adding HR Power-ups is one way to improve player exertion in converted off-the-shelf exergames. We argue that more work is needed to find other techniques that can further increase player exertion and push converted exergames to be suitable as a replacement for traditional exercise.

The exertion levels seen in this study show that the exergame conversions with HR Power-ups can be suitable as an anti-sedentary activity. Video games are considered to be a sedentary activity by the Canadian Society for Exercise Physiology [27]. Converting off-the-shelf games to exergames allows people who enjoy playing video games the opportunity to fight a sedentary lifestyle while participating in a passtime they enjoy. Some of the benefits of spending less time being sedentary for children aged five to 17 are listed by the Canadian Society for Exercise Physiology as maintaining a healthy body weight, improved performance in school, and improved self-confidence [27].

During the interview, players indicated that the pedaling condition was the least favorite over all, with the power-up condition being the most favored. When questioned about why they ranked the games in this order, participant 3 stated "Because I found the pedaling distracting, but when I got a power-up from it, it was worth it." Participant 13 explained the pedaling condition was their least favorite by stating "I felt like I was pedaling for like no reason". The same participant claimed they liked the power-up condition because "I felt like I actually put some effort in". These participants valued the pedaling aspect when it led to a gameplay reward, but otherwise found it to be a chore. The

addition of HR Power-ups was valuable not only as a tool for increasing exertion but also as a tool for improving players' perception of adding exercise to off-the-shelf games.

**Q3: How well do the mechanics and play styles of off-the-shelf games lend themselves to conversion of exergames?**

As we have seen, our converted exergames failed to motivate levels of exertion meeting the ACSM guidelines for cardiorespiratory exercise. These results contrast with earlier research using similar techniques in custom-designed exergames – for example, Ketcheson et al. have shown that exergames using HR Power-ups can achieve an average heart rate reserve as high as 60% [16].

This difference in results hints that some design aspects of off-the-shelf games may conflict with the requirements of exergames. Existing guidelines for the design of exergames will not have been followed during the design of off-the-shelf games such as Skyrim and Half-Life 2. For example, Mueller et al. recommend consideration of movement's cognitive load [25], a guideline which would not have been relevant to the design of a game intended for play that uses a keyboard or gamepad as input. The results presented before together with interview comments provide hints of where the design of off-the-shelf may conflict with exercise.

**Control Scheme**

Thighrim and Calf-Life both use a movement control scheme based on pedaling and the use of dual analogue joysticks. The player moves only when pedaling, in the direction specified by the left analogue stick. Since the games support only the two movement speeds – normal walking and sprinting (the latter a special mode triggered by a gamepad button) – pedaling faster does not cause the avatar to move faster. For some players, this created a disconnection between pedaling and avatar movement. Some players continued to pedal even when their avatars were not moving. Participant 6 described their approach to playing: "pedaling to me was the least important thing so I just, you keep pedaling at a constant rate regardless of what you were doing and then you play the game." Perhaps if the pedaling were tied to avatar movement speed this would be a big enough benefit to pedaling that players would place more value on the exercise component. Other players forgot to pedal when they wanted to move their avatar after they had stopped. Participant 15 admitted that in Calf-Life, "I was more engaged [causing me to] forget sometimes to pedal." Thus, the fact that role-playing and first-person shooter games such as Skyrim and Half-Life 2 support only one speed of movement and require a joystick to specify direction of movement weakens the natural mapping of pedaling to avatar movement found in pedaling-based exergames[14].

The control schemes of the two games differ during combat. In Skyrim/Thighrim, players were provided with a melee weapon and a spell. In Half-Life 2/Calf-Life, they were able to choose between different guns and a crowbar. To aim in Skyrim, players need to turn the character's body roughly in

the direction of the target, while in Half-Life 2, precise aiming with a targeting reticle is required. This may have contributed to the significant difference we saw for the pressure and tension subscale scores of the Half-Life 2 game between the Power-up and Control condition (Table 3). Participant 2 noted a difference in their ability to raise their heart rate in Calf-Life saying, “I think in Thighrim, because it wasn’t as hard as Calf-Life, I ... reached that heart rate and just kind of coasted along but in Calf-Life I was like struggling”. Participant 6 described how the addition of pedaling affected their ability to aim: “It was harder to move into certain positions so I could aim. A lot of times when I aim it’s not just with the aiming reticle it’s also the movement along with the aiming reticle.” Participant 16 described how the addition of pedaling affected their gameplay: “it was harder for me to play Half Life 2 because of like the aiming whereas in Skyrim you like don’t have to aim.” It is unclear whether participants’ difficulty with aiming and pedaling simultaneously stems from the physical challenge of trying to make fine movements with the analogue stick while pedaling or from trying to split their focus between pedaling and aiming, although we hypothesize that both contribute to players’ difficulties. One possible tactic for future conversions of off-the-shelf games that require aiming would be to use a mod to implement aiming assistance to reduce the difficulty of aiming while pedaling, for example using algorithms suggested by Vicencio-Moreira et al. [37]. Future work is needed to determine the cause, possible solutions as well as to determine if conflict persists in the long term or if it is a learned skill that players can improve at over time.

#### *Pacing and in game activities*

We intentionally chose fast-paced games because we hoped the fast pace in the game would encourage rapid pedaling. Interestingly, for some participants, the pace of the game may have had the opposite effect. Participant 18 indicated that the faster pace distracted from pedaling stating that in “...Half Life 2 because it’s more fast-paced so you don’t get to think of the pedaling as much.” One reason the slower-paced Skyrim game may allow for higher exertion levels is that the cognitive load for players might be lower. Half-Life 2 has environmental puzzles, which are not present in Skyrim. For example, one section of game play leads players to a closed gate. Players are required to assess the environment and realize that a flammable barrel is located below a beam that if knocked over will cause the gate to open. Players must shoot the barrel to trigger the events that will open the gate. Participant 6 noted that splitting their concentration between tasks in Half-Life 2 was a problem: “it’s hard to concentrate on pedaling and moving and... the game.”

Both games include slow-paced activities such as looting, moving between areas and cut scenes. These activities are more prevalent in Skyrim and one participant indicated that this allowed them the chance to focus on their pedaling. “Skyrim made me pedal faster because it had more walking

in the game, like I had to go through the map and the area and search for stuff within this game.” The difference in pace and cognitive load may have contributed to the higher percentage of heart rate reserve seen in the power-up condition of Skyrim, since players were not distracted from their goal of reaching their target heart rate. By using the modding interface of a game, a developer could lower the required cognitive load either by providing more tasks that require less cognitive load, such as looting, or by adding assistance for cognitively demanding tasks. For example, a mod could add signifiers to indicate what a player should do next rather than requiring them to assess each situation; for example, in the Half-Life 2 scenario described above in which players are required to realize they must shoot the barrel to open the gate, the designer could make the barrel flash as a hint to players about where to focus. Interesting future work will be to assess whether the presence of such assistance affects players’ exertion levels.

We offer three reflections for designers interested in converting off-the-shelf games in a way that is conducive to exercise: (1) Without mapping pedaling speed to avatar speed, players did not see an inherent benefit in game to pedaling. It would be interesting future work to evaluate whether performing this mapping can further improved players’ perception and exertion in converted games. (2) Game actions that require the player to respond with precise inputs (e.g., aiming) distract from pedaling. Interesting future work would consider whether this distraction remained in the long term, the cause and possible tactics to reduce the effect. For example, aim assistance may reduce the precision required by the player without negatively impacting their experience. (3) Cognitively demanding tasks and a fast pace can distract the player from the exercise component. One possible tactic to combat this is to reduce the cognitive demand by adding assistance for those cognitively demanding tasks.

#### **CONCLUSION**

In this paper we have investigated the conversion of off-the-shelf games into exergames. We performed a two-step conversion on The Elder Scrolls V: Skyrim and Half-Life 2. We evaluated players’ exertion levels while they played an exergame conversion in which pedaling moves their avatar similar to existing techniques and during a power-up conversion in which players received in game rewards for reaching target heart rate levels. We found that adding pedaling to enable avatar movement does increase exertion above rest, and that the addition of HR Power-ups increases exertion higher still. The average exertion levels of players did not meet ASM guidelines for cardiovascular exercise (although the Skyrim conversion was close). The exertion levels are appropriate for anti-sedentary activity. We have identified aspects of off-the-shelf games that may have inhibited players’ ability to reach high exertion during play. We conclude that conversions of off-the-shelf games are appropriate for anti-sedentary activity but more work is required to find techniques that will motivate players of

converted games to reach an exertion level that can be recommended for exercise.

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