# Immersive Virtual Reality Exergaming impact on Muscle Activity

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## Introduction

Technology is incorporated in many daily life activities. Physical exercise is one activity that impacts health and quality of life [29]. "Exergaming" is a term that describes the technological application that have combined the physical demands of exercise with video gameplay [4,52]. While exergaming was introduced as early as the 1980's [57], it has reemerged due to the recent development and application of immersive virtual reality (IVR) technology.

IVR technology employs body sensors and head mounted displays (HMD) to create three-dimensional engaging environments that go beyond traditional screen-based exergaming which yields higher outcomes [3,9,11,30,31,38,49,64]. Preliminary studies on IVR cable resistance training demonstrated substantial metabolic demand, energy expenditure, and equally important high ratings of enjoyability. This is attributed to IVR's ability to distract users from perceived exertion and pain [23,24,54]. This distraction challenges the feeling of excretion that has been reported to be one of the leading barriers for exercising across a wide range of populations [21,33,35,55], posing a promising solution to improve health and fitness. While IVR cable resistance training has been posited to sufficiently meet the 75-150 minutes of weekly vigorous exercise criteria, as defined by the Physical Activity Guidelines for Americans [24,44], little has been explored to clarify the musculoskeletal implications. Thus, further investigations would allow for a more comprehensive understanding of musculoskeletal responses associated with this novel form of resistance training.

## Purpose

This exploratory study aimed to measure and characterize muscle activation via surface electromyography (sEMG) during a signature 30-minute session of IVR cable resistance exergaming (Black Box VR®, Boise, ID, USA). sEMG allows one to quantify muscle activation during isometric and dynamic exercises[12,40,53] using highly-sensitive voltmeters that detect depolarizations and hyperpolarization's (increases and decreases in voltage, respectively) on the sarcolemma (muscle fiber membrane), which are necessary for muscle contraction[60].

**Figure 1.** Screenshot of IVR gameplay (as seen through the head mounted display)

## Methods

- Ten college-aged males (aged 20-26 years) were recruited from the University of California, Los Angeles (UCLA) campus through word of mouth.
- The testing and training were performed in a controlled laboratory environment (21-23◦C and 55-65% relative humidity) near the same time of the day (i.e., to avoid any influence of circadian variations on performance) by the same investigators.
- The data was collected using sEMG compression garments for a signature 30-minute session on an IVR-based adaptive cable resistance exergame system to quantify muscle activation.
- The sEMG compression garments were fit to each participant to ensure the electrodes embedded in the garments were directly on the surface of the skin of the following muscles: vastus medialis, vastus lateralis, biceps femoris, gluteus maximus, latissimus dorsi, pectoralis major, anterior and posterior deltoids, biceps brachii, and triceps brachii. The sEMG was paired to a mobile application to present results.
- The IVR exergaming system (Black Box VR®, Boise, ID, USA) employs a servo-based electromagnetic adaptive resistance mechanism. The system's HMD and wrist-worn sensors process movement data to ensure proper syncing between the user's actions and the IVR gameplay.
- The exergame was similar to traditional tower defense, a subgenre of strategy video game where the goal is to defend a player's territories or possessions by obstructing/eliminating the enemy attackers. Users protected their crystal by fending off enemy units while concurrently dealing damage to the opponent's crystal. The six cable resistance exercises (i.e., lat pulldown, chest press, row, overhead press, stiff-leg deadlift, squat) were linked to in-game attacks and used for defensive and offensive actions.

**Figure 2.** Participant equipped with the HMD and motion sensors during the IVR exergaming session while simultaneously being measured by an Athos compression suit embedded with an integrated sEMG measurement system.

## Summary of Results

**Table 1.** Basic demographic and anthropometric data

| | Male participants (n=10) |
|---|---|
| **Age** | |
| Mean (SD) | 22.5 (2.2) |
| Range | 20 – 26 |
| **Height (cm)** | |
| Mean (SD) | 179.1 (6.3) |
| Range | 170.2 – 188 |
| **Weight (kg)** | |
| Mean (SD) | 75.9 (8.4) |
| Range | 63 – 95 |
| **Bodyfat (%)** | |
| Mean (SD) | 11.0 (4) |
| Range | 4.4 – 17.5 |

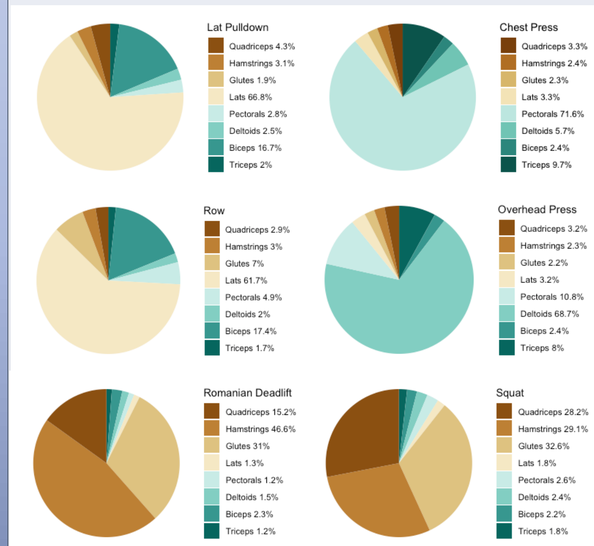


**Figure 3.** Muscle contribution to each exercise (normalized to 100%) as measured by sEMG.

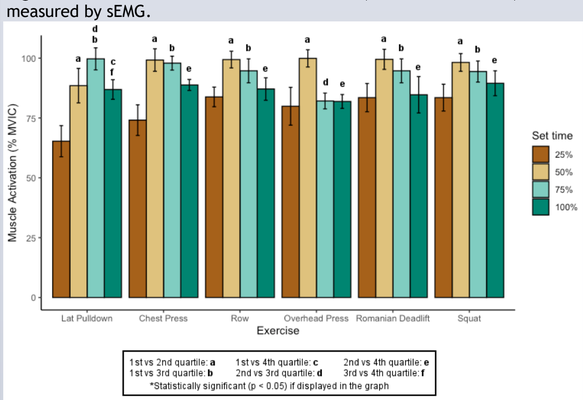


**Figure 4.** Muscle activation of the most activated muscle during each exercise over time: Lat.dorsi for lat pulldown and row exercises, Pec maj for chest press, deltoid for overhead press, hamstrings for Romanian deadlift, and gluteus maximus for squat. Bars and lines represent means and standard deviations, respectively.

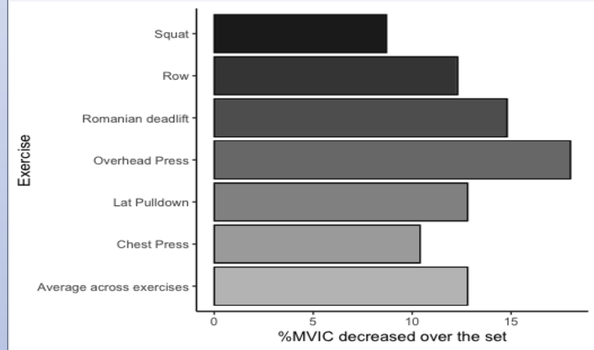


**Figure 5.** %MVIC drop from the highest activated quartile to the last quartile in the most activated muscle involved on each exercise.

**Table 2.** Training volume of the workout by exercise. Means (SD)

| | Volume (kg) | Sets | Average vol/set |
|---|---|---|---|
| Lat Pulldown | 5082 (928) | 4 (1) | 1438 (272) |
| Chest Press | 2983 (1209) | 4 (1) | 719 (186) |
| Row | 4305 (1010) | 4 (1) | 1287 (434) |
| Overhead Press | 1487 (479) | 4 (1) | 381 (85) |
| Romanian Deadlift | 3234 (1464) | 3 (1) | 1128 (227) |
| Squat | 6283 (2711) | 3 (1) | 2094 (440) |

## Conclusion

IVR exergaming is an emerging technology that has a promising role to attract a wide range of users to improve physical health and adhere to exercise. This study suggests similar muscle activation responses compared to traditional resistance exercises and reinforce the ability of an IVR exergaming system to make practitioners exercise at a high intensity while distracting them from the high demands of the exertion. Further investigations are needed to explore addition benefits of IVR exergaming in comparison to traditional exercising.

## References

References are available upon request.

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