Original Article

The Effect of Virtual Reality on Isometric Muscle Strength

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Abstract. The aim of the study is to determine the acute effects of virtual reality on isometric muscle strength, pain intensity, perceived exertion, and heart rate. The study sample comprised 46 male sedentary individuals with a mean age of 28,56±5,25, who don't have a sports experience and any health problems. Participants were divided into two groups, A and B, and grouped randomly. The mean age of group A is 29,00±6,13 years, height 170,78±7,51 cm, body weight 70,58±9,57 kg. The mean age of group B is 27,69±3,94 years, height 172,69±6,32 cm, body weight 69,57±8,65 kg. During the Wall Squat Test, the participants verbally informed the perceived pain intensity and perceived exertion level every 30 seconds, and the heart rate was monitored using a smartwatch. After the first measurements were completed, a break was given for one week, and then a cross matching was made. According to the results of the study; It was determined that groups using virtual reality were more advantageous after first measurement and cross matching. Group virtual reality performed higher during the Wall Squat Test, and it was also determined that the pain intensity and perceived exertion levels were lower during the test. However, there was no significant difference in heart rate between the groups.

Key Words: wall squat, pain intensity, perceived exertion, heart rate.

Introduction

Today, with the development of technology, the use of technology in sports has also increased. Wearable technology products are becoming more and more common every year. Wearable technology includes devices that measure heart rate, smart watches integrated into mobile phones, speedometer devices, GPS systems and smart shoes, as well as technology products such as virtual reality glasses.

Virtual reality; It is a simulated environment that can simulate the physical existence of environments and spaces found in real or imaginary worlds. Virtual reality glasses allow users to experience a computer-simulated reality enhanced by auditory, tactile and olfactory interactions (1). The relationship between virtual reality and perceived pain intensity is one of the main concerns today.

Experiencing pain is a subjective situation. Even the same sensory signals lead to different levels of perceived pain intensity among individuals (2). Studies show that psychological factors based on visual information play an important role in experiencing pain intensity (3, 4, 5). In fact, all the pain we feel doesn't always cause great dangers for our body, it allows us to take precautions to protect our tissues. Although the pain caused by high intensity exercise doesn't cause us physical harm, people can avoid doing sports to prevent this painful experience (6). Virtual reality can direct our sensory receptors away from the pain signal and thus reduce the pain we feel (7, 8). In this respect, virtual reality can offer an alternative solution to humanity in terms of pain management (9, 10, 11, 12). Of course, the most important point here is, at what level the individual using virtual reality glasses can adapt to the virtual environment and integrate with that environment. Undoubtedly, the reduction in pain sensation depends on the quality of integration between the user and the virtual world. In order to increase the quality of the said integration, design revisions have been made in Virtual Reality (VR) products in recent years, and the headset has been added to better hear the application sounds and the image quality has been improved. The decrease in the cost of virtual reality glasses and being a technology that can be used by every individual in the society paved the way for scientific studies. Scientific publications based on virtual reality, including studies on pain and effort associated with exercise, contribute to field publication. The aim of this study is to determine the acute effects of virtual reality use on isometric muscle strength. It is also to detect the acute effects of virtual reality on pain intensity, perceived exertion level and heart rate while observing these effects. The first hypothesis of the study is that the use of virtual reality will increase the performance of the Wall Squat test in sedentary individuals. The second hypothesis of the study is that sedentary individuals who used virtual reality during the Wall Squat Test had lower pain intensity degrees. As the third hypothesis of the study, sedentary individuals who used virtual reality during the Wall Squat Test had lower perceived exertion levels. And finally, the fourth hypothesis of the study is that sedentary individuals who used virtual reality during the Wall Squat Test had lower heart rate.

Methods

Study Design

Individuals participating in the study were randomly grouped as groups A and B. In our study, there are 23 participants in Group A (VR) and 23 participants in Group B (NON-VR). Group A used virtual reality during the Wall Squat Test, while group B didn't. One week after the measurements were completed, a cross matching was made, this time group B used virtual reality during the Wall Squat Test, while group A didn't.

Subject Characteristics

Forty six male sedentary individuals between the ages of 21-47 without a sports background and without any health problems participated in our study. The study and all measurements were made in the fitness center of a technology company headquartered in city. Individuals who work in this technology company and don't have a sports background participated in our research. Our study, including cross matching studies, lasted a total of 20 days. The stages applied by a single participant are; providing information about the overall study and virtual reality, introducing the procedures to be performed during the test, giving information about the Informed Consent Form and the PARQ test and signing the forms, taking height and weight measurements, warming up by walking for 10 minutes with 6.0 km/h speed on the treadmill 0% inclination, performing the Wall Squat Test and finally, the people whose measurements were taken walked on the treadmill for 10 minutes with 5.0 km/h, 0% inclination and performed the cooling phase of the tests. All procedures took an average of 32 minutes per person. In our study, there are 23 participants in Group A (VR). Participants mean age 29,00±6,13 years, mean height 170,78±7,51 cm, mean body weight 70,58±9,57 kg, mean BMI 24,12±2,18 kg/m^2, lower extremity mean muscle weight is 20,61±5,29 kg. In our study, there are 23 participants in group B (NON-VR). Participants mean age 27,69±3,94 years, mean height 172,69±6,32 cm, mean body weight 69,57±8,65 kg, mean BMI 23,13±1,85 kg/m^2, lower extremity mean muscle weight is 21,10±4,91 kg.

Measurements and Calculations

During the Wall Squat Test, the test times of the participants in both groups were measured with the Sportive stopwatch, and their heart rate was checked in 30 second periods using the Kalenji Onrhythm 110 Pulse Meter. At the same time, the participants were asked to verbally state the perceived pain intensity and perceived exertion level every 30 seconds. The 0-10 Cook Scale was used to calculate the perceived pain intensity. Previous studies show that the Cook Scale has a high reliability and validity in measuring perceived pain intensity (13). 6-20 Borg Scale was used to measure the perceived exertion level. Previous studies show that the Borg Scale has a high reliability and validity in measuring perceived exertion level (14). During the virtual reality tests, the Samsung Gear VR SM-R323 Virtual Reality Glasses and the Samsung S6 Edge smart phone integrated with this device were used. The group using VR completed the test with an interactive application named "The Zion Narrows Experiences" during the Wall Squat Test. The reason for choosing this application, which allows for a virtual tour in Zion National Park (Utah, United States), is to keep the participants away from their physical activity and their environment. In addition, extraneous sounds are minimized in order to ensure full integration with the virtual world. Total body weight and lower extremity muscle weight were measured with the BIA method, while Tanita MC-780 model device was used. The height was measured using a meter fixed to the wall.

Wall Squat Test

Squat exercises equally develop both upper body and lower body muscles and can be done anywhere and anytime (15). In addition to being preferred in many sports to increase physical performance, this type of exercise is also used effectively in postoperative rehabilitation programs (16). Also, squat damages the waist and puts pressure on the knees if performed in an unbalanced stance (17). However, Wall Squat, which is a type of squat, has a minimal possibility of damaging the lumbar vertebrae or knees, it is safe. Because body weight is used, which makes it easier for beginners to do this exercise (18). The Wall Squat test is used to measure the lower extremity isometric muscle strength and endurance of the participants, it isn't complex and can be applied anywhere (19, 20). Participants take a squat position with their backs touching the wall, and the test taker must stay in this position for the maximum time. During the test, the contraction rate is an important variable for motor control (21). In addition, the fact that isometric contraction is a static contraction type, its neuromuscular effect may affect the muscles differently from other contractions (eccentric, concentric, etc.) (22).

Pain Intensity Rating

Participants verbally reported their perceived pain levels using the 0-10 Cook Scale ranging from 0 (no pain) to 10 (worst possible pain), by stating a number to the question asked every 30 seconds. The Cook Scale is a highly reliable scale for measuring perceived pain intensity (13).

Rating of Perceive Exertion

Participants verbally reported their perceived exertion levels using the 6-20 Borg Scale ranging from 6 (no exertion at all) to 20 (maximal exertion), by stating a number to the question asked every 30 seconds. The Borg Scale is a highly reliable scale for measuring perceived exertion level (14).

Statistical Analysis

The data were analyzed with SPSS program and Independent Sample T test was used. The compliance of the variables to the normal distribution was evaluated using the Shapiro-Wilk test. As a result of the normality test, it was determined that the data provided the normal distribution conditions and analysis was made using the Independent Sample T test, one of the parametric tests. A value of $p<0.05$ was accepted as statistically significant. Data are expressed as mean ± standard deviation.

Results

In Table 2, a statistically significant difference was determined in the first and second measurements of the Wall Squat Test ($p<0.05$). It was determined that the group using virtual reality continued testing for a longer time.

In Table 3, a statistically significant difference was determined in the Perceived Pain Intensity in the first

Table 1. Group A and Group B standard values

	Group A	Group B
Age (Mean±Std.)	29,00±6,13	27,69±3,94
Body Height (cm) (Mean±Std.)	170,78±7,51	172,69±6,32
Body Weight (kg) (Mean±Std.)	70,58±9,57	69,57±8,65
Lower Extremity Muscle Weight (kg) (Mean±Std.)	20,61±5,29	21,10±4,91

Table 2. Group A and Group B Wall Squat test period

First Test			
	n	Wall Squat test period (sec) (Mean±Std.)	p
Group A (VR)	23	77,12±20,77	**0,034**
Group B (Non-VR)	23	65,60±14,40	
Second Test			
	n	Wall Squat test period (sec) (Mean±Std.)	p
Group A (Non-VR)	23	69,78±18,23	**0,025**
Group B (VR)	23	80,68±13,12	

Table 3. Group A and Group B Perceived Pain Intensity

First Test			
	n	Perceived Pain Intensity (Mean±Std.)	p
Group A (VR)	23	5,23±1,24	**0,032**
Group B (Non-VR)	23	5,92±0,84	
Second Test			
	n	Perceived Pain Intensity (Mean±Std.)	p
Group A (Non-VR)	23	5,94±0,72	**0,035**
Group B (VR)	23	5,27±1,25	

Table 4. Group A and Group B Perceived Exertion Level

First Test			
	n	Perceived Exertion Level (Mean±Std.)	p
Group A (VR)	23	12,58±1,55	**0,008**
Group B (Non-VR)	23	13,79±1,37	
Second Test			
	n	Perceived Exertion Level (Mean±Std.)	p
Group A (Non-VR)	23	13,58±1,54	**0,045**
Group B (VR)	23	12,60±1,72	

Table 5. Group A and Group B Heart Rate values

First Test			
	n	Heart Rate (Mean±Std.)	p
Group A (VR)	23	78,58±4,64	0,982
Group B (Non-VR)	23	78,61±4,23	
Second Test			
	n	Heart Rate (Mean±Std.)	p
Group A (Non-VR)	23	78,75±4,63	0,606
Group B (VR)	23	79,39±3,65	

and second measurements ($p<0.05$). It was determined that the group using virtual reality felt less pain.

In Table 4, a statistically significant difference was determined in the first and second measurements of Perceived Exertion Level ($p<0.05$). It was determined that the group using virtual reality felt less exertion.

In Table 5, no statistically significant difference was determined in Heart Rate values in the first and second measurements ($p>0.05$). Heart rate values of both groups were found to be close to each other.

Discussion

In our study, the performance of the group using virtual reality glasses during the Wall Squat test was higher than the other group. In the first comparison, the group using VR (Group A) performed 77,12±20,77 sec. On the other hand, Non-VR group (Group B) performed less than VR group (Group A) with 65,60±14,40 sec. After cross matching, the groups were changed and the performance of the group who used virtual reality was longer than the Non-VR group. This time, the group using VR (Group B) performed 80,68±13,12 sec, but the Non-VR group (Group A) fall behind the group B with 69,78±18,23 sec.

These results support our first hypothesis. These findings are consistent with those of Matsangidou (2). Matsangidou measured the muscular endurance of the participants with the elbow joint positioned at 90 degrees. As weight, 20% of the maximum weight that the participant can lift was used. In the results, it was observed that the group using virtual reality stayed longer in the 90 degree position.

In addition, in our study, the perceived pain intensity of participants using virtual reality was lower. In the first comparison, the group using VR (Group A) reported that they felt 5,23±1,24 degrees of pain according to the Cook Scale, while the Non-VR group (Group B) reported that they felt more pain with 5,92±0,84 degrees. After cross matching, the group using VR (Group B) felt 5,27±1,25 degrees of pain, while it was observed that the non-VR group (Group A) had a higher level of perceived pain intensity with 5,94±0,72 degrees. Based on this, it is seen that the present findings support the second hypothesis in our study. These findings are consistent with those of Wender (23). Wender observed that participants using virtual reality in high-intensity cycling activities felt less pain in the quadriceps femoris muscle.

This technology is used in a variety of areas and has recently been applied as a distraction method for pain management during medical procedures. For example, many studies on burn care mention the positive contribution of VR applications carried out with physical therapy to pain management (24, 25, 26, 27, 28). Virtual reality is also used in the treatment of chronic pain. Positive results are also seen in the treatment of patients with chronic neck and chronic phantom limb pain (29, 30).

If we take a look at the difference in perceived exertion levels between the two groups in our study, we again come up with important results. Participants using virtual reality have a lower level of perceived exertion. In the first comparison, the group using VR (Group A) felt 12,58±1,55 degrees of strain according to the Borg Scale, while the Non-VR group (Group B) reported that they felt more strain with 13,79±1,37 degrees. After cross matching, the group using VR (Group B) felt the exertion at 12,60±1,72 degrees according to the Borg Scale, while the non-VR group (Group A) had a higher level of perceived exertion with 13,58±1,54 was observed. These findings support the third hypothesis in our study.

These findings are consistent with those of Liu et al. (31). Liu et al., in their study on 48 healthy university students, the participants were divided into two groups and used exercise bikes for 20 minutes. Verbal feedback was obtained while the cycling activity was continuing, and their morale during exercise with the Brunel Mood Scale and the perceived exertion levels using the Borg Scale were determined once every 4 minutes. As a result of the study, it was reported that the group using VR had higher morale during the test and felt 10,18±1,84 degrees of exertion on the Borg Scale, while the non-VR group felt more exertion with 12,86±2,13.

In addition, Chen et al., in their study on 30 patients with spinal cord injury, the participants were divided into two groups and used exercise bikes in a way that they can determine the end time themselves (32). Average cycling time of VR group is 584,47±180,94 sec, while it is 377±85,73 sec for non-VR group. However, there was no statistically significant difference between the two groups in terms of perceived exertion degrees.

Zeng et al., 12 university students were divided into two groups and they used a fitness bike for 20 minutes (33). Participants reported their perceived exertion degrees every 1 minute with the help of the Borg Scale while cycling. As a result of the study, it was observed that the perceived exertion degrees of the VR group were lower, and a statistically significant difference was found between the non-VR group.

Finally, Murray et al., in their study, 60 participants were divided into two groups and used a rowing ergometer for 9 minutes (34). When the participants finished the test period, they were asked to verbally report their perceived exertion levels using the Borg Scale. The results showed that the VR group felt less exertion than the other group, rowed more distance in 9 minutes and produced more power.

If we take a look at the heart rate between the groups in our study, there is no statistically significant difference between the two groups. In the first comparison, the group using VR (Group A) had an average number of 78,58±4,64 per minute, while the non-VR group (Group B) had an average of 78,61±4,23 per minute. After cross matching, the group using VR (Group B) had an average number of 79,39±3,65 per minute, while the non-VR group (Group A) was on average 78,75±4,63 per minute. The present findings don't support the fourth hypothesis in the study. In the hypothesis, it was assumed that sedentary participants who used virtual reality during the Wall Squat test had lower heart rate. However, no statistically significant difference was found between the experimental and control groups. These findings are consistent with those of Matsangidou et al. (2). Matsangidou et al. measured the muscular endurance of the participants with the elbow joint positioned at 90 degrees. Matsangidou et al. divided the participants into two groups as VR and Non-VR groups in their study with 80 participants and measured the muscular endurance of the participants while the elbow joint was at 90 degrees. As weight, 20% of the maximum weight that the participant can lift was used. Heart rate was checked throughout the test. At the end of the study, no significant difference was found between the VR and non-VR groups in terms of heart rate.

On the other hand, these findings aren't consistent with those of Plante et al. (35). Plante et al., in their study on 88 participants, divided the participants into two groups: those who use only bicycle ergo and those who use virtual reality technology while using ergo. At the end of the study, it was found that the group using virtual reality technology had a higher heart rate.

If we take a look at the effects of other studies on heart rate in different populations; Sullivan et al., 26 children aged 5-7 who received dental treatment were divided into experimental and control groups (36). The experimental group was shown the image with virtual reality during the treatment. It has been observed that the heart rate is significantly reduced in children using virtual reality. Busscher et al. in their study on 46 patients with anxiety disorder, the participants were divided into two groups (37). As a result of the verbal feedback without any activity, it was observed that the heart rate of the VR group decreased significantly after cross matching. Finally, Finkelstein et al. in the study involving 30 healthy participants aged 6-50 years, the participants played the game called Astrojumper for 15 minutes (38). A significant increase was observed in the heart rate of the participants who have been using virtual reality since the first minute.

If we look at scientific researches on heart rate in different populations, it cannot be said that there is consistency between the results of these studies and our research. Participants using virtual reality sometimes had a high heart rate, sometimes low, and sometimes average, as in our study. Undoubtedly, the reason for this is what kind of image the participant encounters in virtual reality is a very important factor. When the participants watched exciting images without physical exertion, their heart rate increased. However, when the participants watched images that relieved them, their heart rate decreased. In this respect, virtual reality technology is open to important consequences in the future.

Conclusions

According to the analysis made as a result of the study; It was determined that groups using virtual reality were more advantageous after both the first and cross matching. Groups using virtual reality performed higher during the Wall Squat Test. Also, the intensity of pain and the degrees of perceived exertion during the test were lower. Based on this, we can say that the acute effects of virtual reality use are positive. However, there is no difference between the experimental and control groups in terms of heart rate.

In the future, with the development of technology, the size of the devices will decrease and the comfort of use will increase accordingly. Increasing comfort will increase the integration between user and device and naturally individuals will feel more comfortable in the virtual world. These results give information that the use of virtual reality for sports purposes will become more common.

Athletes who have reached the elite level in terms of sports can overcome this limit with the help of new training systems. Virtual reality technology promises this innovation to athletes. In addition to all these, studies to be conducted in different populations and different age groups are very important. Virtual reality technology will make a name for itself in the future.

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