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FACULTEIT GENEESKUNDE EN LEVENSWETENSCHAPPEN
master in de revalidatiewetenschappen en de kinesitherapie

Masterproef

The effects of serious gaming on pain and fear of movement in patients with chronic low back pain

Promotor :
Prof. dr. Annick TIMMERMANS

Copromotor :
De heer Thomas MATHEVE

Janna Van Hove , Patricius Wolters
Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie

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Promotor	Prof. Dr. Timmermans, Annick
Co-promotor	Drs. Matheve, Thomas

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Mol, 7th of june 2016

Guttecoven, 7th of june 2016

J.V.H.

P.W.

Research context

This master thesis is a randomized controlled trial (RCT) situated in the musculoskeletal rehabilitation, more specifically in the rehabilitation of chronic non-specific low back pain. The study has been conducted in the Jessa Hospital (Hasselt) by two students in physiotherapy and rehabilitation sciences at the University of Hasselt. It's part of a PhD by Thomas Matheve and follows a literature study carried out last year.

The lifetime prevalence of low back pain (LBP) is reported to be as high as 84%, while the prevalence of chronic low back pain (CLBP) is estimated to be 23%[1]. CLBP has an influence on the patients' daily functioning and quality of life. A large number of rehabilitation modalities have been reported, but CLBP remains a very common cause of long-term disability. Therefore, further research and studies should be carried out regarding other possible treatment methods.

The primary aim of this study is to investigate whether the application of a serious game leads to a reduced pain experience during the performance of exercises in patients with CLBP. Secondly, it will be investigated whether serious gaming influences the time spent thinking about the pain during the exercises and whether it affects the patient's thoughts about the harmfulness of the exercises. Finally, the influence of the level immersion on the aforementioned parameters will be explored. The intervention was applied in a game-like environment (Valedo®Motion, Hocoma) through three motion-sensitive sensors, attached on the lower back and sternum. The patients assigned to the control group exercised without the use of the serious game.

The study protocol was developed by Thomas Matheve in cooperation with the students. Under supervision of the co-promotor the students recruited patients with regard to the selection criteria. Then they decided whether a patient could be included or not. The single-session treatment was explained and carried out under supervision of the students. The input of data was done independently, dependening on which student was present at the hospital the moment of testing. The students analyzed and interpreted the data independently of each other. Afterwards they compared all the information and combined it to one work. The writing process was the responsibility of the students supervised by the co-promotor.

The effects of serious gaming on pain and fear of movement in patients with chronic low back pain

A randomized controlled trial

Hasselt, 2016

Content

1 Abstract

Background An analgesic effect of virtual reality environments and serious games is reported in several patient populations. As for now, this effect has never been shown in patients with chronic low back pain (CLBP). Nor is it clear what effect serious games have on fear avoidance with CLBP.

Objectives The purpose of the study is to examine whether the use of serious games during exercise therapy could influence pain perception and fear avoidance in patients with CLBP.

Design A single-session, randomized controlled trial.

Methods Thirty-three patients with chronic nonspecific low back pain and a pain score of ≥3/10 on the numeric pain rating scale were randomized into an intervention and control group. The intervention group performed one session of pelvic tilting exercises with the use of the Valedo®Motion, while the control group performed pelvic tilts without the application of a serious game. Both groups were evaluated at baseline using the numeric pain rating scale (NPRS), Roland Morris Disability Questionnaire, Tampa Scale for Kinesiophobia and Pain Catastrophizing Scale . After the intervention, the pain experienced during exercise (NPRS), time spent thinking on pain (NRS), fear to injure the back during exercise (NRS) and the level of presence in the serious game (Immersion Questionnaire) were assessed.

Results Three patients from the control group were excluded after baseline measurements, because they did not meet the inclusion criterion of a minimum NPRS-score of 3/10 at the time of testing. The subjects in the intervention group experienced less pain during exercise ($p<0.01$) and spent less time thinking on pain ($p<0.01$) compared to the control group. The intervention group experienced a decrease of 53% in pain while exercising compared to baseline ($p<0.01$) which corresponded with a decrease of 2.5 points at the NPRS and a minimal clinical important difference (MCID).

Conclusions Participants experienced less pain and spent less time thinking about their low back pain during the exercises performed with serious gaming, compared to the participants who performed the exercises without serious gaming.

Key words Low back pain, chronic pain, pain management, exercise therapy, virtual reality exposure therapy, video games, serious games

2 Introduction

Chronic low back pain (CLBP) is a frequent health problem leading to limitations in daily functioning and a reduced quality of life[2, 3]. The lifetime prevalence of low back pain (LBP) is reported to be as high as 84%, while the prevalence of CLPB is estimated to be 23%[1]. Furthermore, the socio-economical cost of CLBP is high, because it leads to long-term (para)medical care and work absenteeism[4].

Exercise therapy is an important part in the rehabilitation of patients with CLBP[1, 5]. However, the problem is that patients with CLBP often experience pain during exercises [6]. This can lead to reduced program adherence or a less optimal exercise performance, and thereby limit the effectiveness of the intervention. Finding methods to reduce the pain that is experienced during exercises is therefore needed.

Virtual reality (VR) and serious gaming (SG) have been shown to reduce the pain experience in different populations suffering from painful conditions. This has been well-investigated in patients with burn wounds[7, 8]. Patients who were asked to play a serious game during a painful wound procedure, i.e. replacing a bandage, experienced lower levels of pain compared to the patients who did not play this game. Similar results have been shown in other pathologies such as phantom limb pain and complex regional pain syndrome[9, 10]. These effects are attributed to the distraction of pain, according to Melzack and Wall's gate control theory[11].

Up till now, it has not been investigated whether patients with CLBP experience less pain during exercises when they are immersed in a VR environment. Although an analgesic effect of VR has been shown in various acute and chronic pain populations[7-10], it can be questionend whether these effects will be found in patients with CLBP during the performance of active exercises. For example, patients with burn wounds undergo their wound cleaning passively. Their attention is focused on the virtual environment and not on the painful intervention. This may not be the case when patients with CLBP play a serious game. The patients are asked to concentrate on the virtual environment, but the problem is that they interact with this environment through movements of their lower back. This could possibly result in less distraction from their lumbar spine and LBP, and consequently in a reduction of the analgesic effect of the VR. Futhermore, it has been shown that the level of presence of the patient, i.e. the illusion of being inside the computer-generated environment, seems to play an important role in the analgesic effects of a virtual reality environment. A greater presence results in greater pain reduction[12].

Besides having positive effects on pain, the immersion in a virtual reality environment can also reduce the time spent thinking on pain. This has been shown in healthy subjects during experimentally induced pain[13-15], but has not yet been investigated in patients with CLBP. Reducing the time that patients with CLBP spent thinking on their pain can be important. It is known that a substantially large subgroup of patients display fear avoidance behaviour and have catastrophizing thoughts about their lumbar spine[16, 17]. These patients typically spent a lot of time thinking (negatively) about their LBP[18]. However, the exact effects of VR on fear avoidance and catastrophizing thoughts are not clear, especially in the LBP population, and needs further investigation. If VR can reduce the time spent thinking about LBP, this could potentially have a positive effect on fear avoidance and pain catastrophizing.

The primary aim of this study is to investigate whether the application of a serious game leads to a reduced pain experience during the performance of exercises in patients with CLBP. Secondly, it will be investigated whether serious gaming influences the time spent thinking about the pain during the exercises and whether it affects the patient's thoughts about the harmfulness of the exercises. Finally, the influence of the level immersion on the aforementioned parameters will be explored.

3 Methods

3.1 Research design

This study is a single-session randomized controlled trial.

3.2 Participants

3.2.1 Patients and recruitment

A total of 33 participants at the department of physical and rehabilitation medicine of the Jessa hospital (Hasselt, Belgium) were recruited between January and April 2016. All patients provided written informed consent before being included in the study. The patients were randomly assigned to either the serious gaming group (SG) or control group (C) , resulting in sixteen subjects in the SG group and seventeen in the C group. After the baseline measurements, three participants from the C group were removed from the study because they did not meet the inclusion criterion of a minimum NRPS-score of 3/10 at the time of testing (Fig. 1).

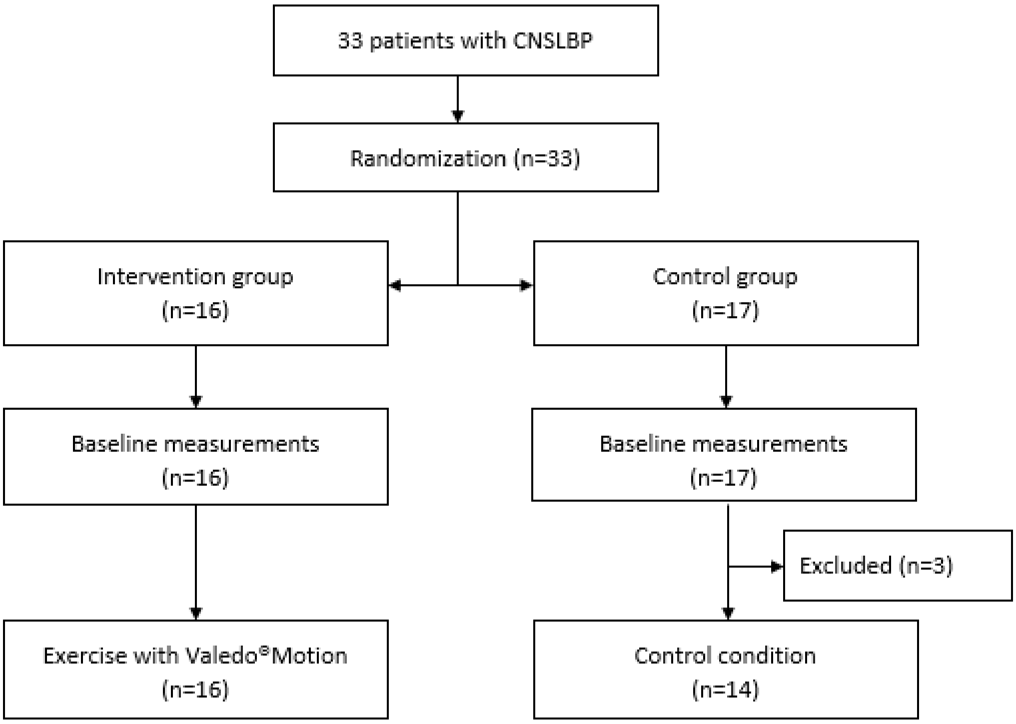

Figure 1. Participant flow diagram

3.2.2 *Inclusion criteria*

- Diagnosis of chronic non-specific low back pain (pain >3 months, localised below the costal margin and above the superior gluteal folds, with or without leg pain[1]);
- A pain intensitiy level of at least 3 on a scale of 10 at the moment of testing;
- Aged between 18 and 65 years;
- Sufficient knowledge of the Dutch language to provide adequate communication;
- Being familiar with pelvic tilt exercises.

3.2.3 *Exclusion criteria*

- Surgery of the spine in the past;
- Signs or symptoms of nerve root compression;
- Other underlying pathologies such as tumors or serious neurologic and rheumatic disease;
- Pregnancy;
- Known allergy for tape.

3.3 Procedure

After collecting the baseline-information, the patients were randomized using sequentially numbered sealed opaque enveloppes. The trial was a single-session intervention which consisted of four minutes (two times two minutes) of exercise. The post-measurements were conducted immediately after the intervention.

3.3.1 *Serious-gaming intervention*

The patients assigned to the serious gaming group performed the exercises with the Valedo®Motion system, version 2.0 (Hocoma, Volketswil, Zwitserland). This system uses three wireless motion sensors that are attached to the lumbar spine (L1), the sacrum (S1) and the center of the sternum, using double-sided tape. The sensors capture the movements of the spine, and this information is sent to a laptop. This way, the patient can interact with a game-like environment by moving the spine and thereby controlling the game. Two different games (glider (Fig. 2) and cavediver (Fig. 3)) were played for two minutes each, in which pelvic tilts in the sagittal plane were used to control the game. Between these two games, a rest period of one minuted was provided.

Figure 2. Glider: patients control the caterpillar which must fly through the hoops and catch objects on their way.

Figure 3. Cavediver: patients control the caterpillar which must swim through the cave without hitting the edges and avoid catching objects on their way.

The laptop was connected to a TV screen (47 inch). As shown in Figure 4, the patients stood directly in front of the TV screen at a distance of approximately two meters and could hear the sounds produced by the virtual environment clearly. In this study, the sensor on the sternum was of less importance since we were only performing pelvic tilts, and the sternal sensor does not provide information about this movement.

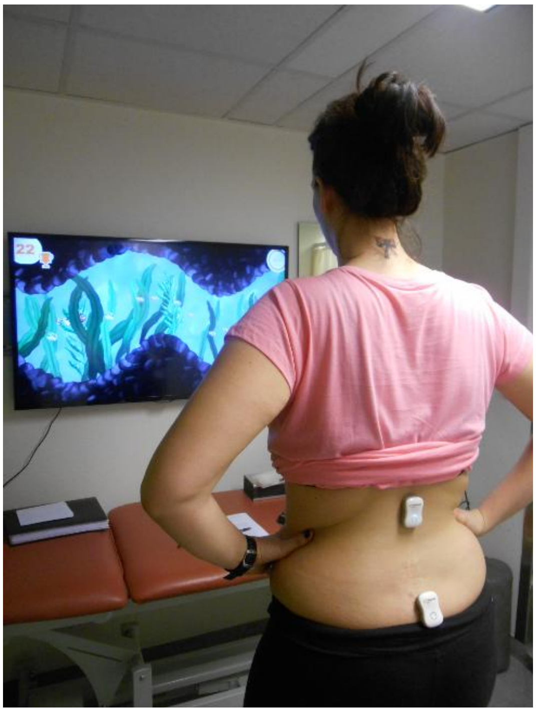

Figure 4. Participant of the serious gaming group playing 'cavediver'

3.3.2 Control intervention

Patients in the control group also performed pelvic tilts in the sagittal plane for two times two minutes, with one minute of rest in between. The number and speed of pelvic tilts that the patients in the C group had to perform were well-defined and as similar as possible to the SG group. These parameters were based on a previous pilot study conducted with six patients, who met the inclusion and exclusion criteria of the present study. The number of pelvic tilts asked to perform in the control condition was the average of the number of pelvic tilts patients performed in this pilot study. The tilts followed each other in various speeds, which was also the case in the SG condition. An auditory signal was used to indicate when patients had to tilt the pelvis in the other direction, either anteriorly or posteriorly.

3.3.3 Outcome measures

The baseline-measurements included:

- Sociodemographic information
  - Age, gender, length, weight;
  - Time since onset of low back pain;
  - Experience of playing videogames;
- Intensity level of low back pain (Numeric Pain Rating Scale (NPRS, 0-10)) at the moment of testing and of the previous 7 days;
- Disability due to low back pain (Roland Morris Disability Questionnaire (RMDQ));
- Kinesiophobia (Tampa Scale for Kinesiophobia (TSK));
- Catastrophizing thoughts (Pain Catastrophizing Scale (PCS)).

The post-intervention measurements, which were immediately obtained after the intervention, included:

- Primary outcomes:
  - Pain intensity felt during exercising (NPRS);
  - Time spent thinking about pain during exercising (Numeric rating scale (NRS), 0-10, 0 = never, 10 = all the time);
- Secundary outcomes:
  - Fear to injure the lower back during exercising (NRS);
  - The level of presence in the serious game (Immersion Questionnaire[19]);
  - Number of pelvic tilts performed.

3.3.4 Questionnaires

Numeric Pain Rating Scale (NPRS)

The numeric pain rating scale (NRS) is a measure of pain intensity in adults[20, 21]. The most frequently used version is the single 11 point numeric scale. The scale is presented on a horizontal bar with numbers ranging from 0 to 10, with 0 as 'no pain' and 10 as 'worst imaginable pain'. Chronic pain patients prefer the NRS over other measures of pain intensity. High test-retest reliability is observed and the NRS correlates highly to the Visual Analog Scale (VAS)[22].

Harmfulness (NRS)

An 11-point NRS was used to assess the fear to injure the lower back during exercising. The scores ranged from 0 (the exercise is not harmful at all) to 10 (the exercise is extremely harmful).

Time spent thinking about pain

An 11-point NRS was used to score the time spent thinking about pain. The scores ranged from 0 (never) to 10 (all the time).

Roland Morris Disability Questionnaire (RMDQ)

The RMDQ[23] consists out of 24 statements and assesses the level of low back pain-associated physical disability. The patient is asked to put a check mark next to each appropriate statement. The total score is calculated by adding up the number of marked statements, and ranges from 0 (no disability) to 24 (maximal disability). RMDQ scores correlate well with other measures of physical function[23].

Tampa Scale for Kinesiophobia (TSK)

The TSK[24] is a 17-item self-reported questionnaire measuring fear of movement or (re)injury. Each item is scored on a 4-point Likert scale, ranging from 'stronlgy disagree' (score= 1) to ‘strongly agree’ (score = 4). The scores can range from 17 to 68. A high score indicates a high degree of kinesiophobia. The TSK is a reliable and valid instrument on patients with chronic low back pain[25]. The translated version into Dutch (Vlaeyen et al., 1995) is used in this trial.

Pain Catastrophizing Scale (PCS)

The PCS[26] is a 13-item self-reported questionnaire where the patient has to reflect on past painful experiences. The patient has to indicate the degree to which they experienced thoughts or feelings when experiencing pain, scoring from ‘not at all’ (score = 0) to ‘all the time’ (score = 4). The total score (range 0-52) is calculated by summing responses to all itmes, and a high score indicates a high level of catastrophizing. The PCS is shown to be a valid instrument[27]. In this trial the Dutch version is used[28].

Immersion Questionnaire

The immersion questionnaire[19] is a self-reported tool to measure the level of immersion in a virtual reality environment. The questionnaire consists of 31 statements that patients have score on a 8-points Likert scale how far they agree (1 = totally unagreed, 7 = totally agreed). There is also a extra measure of immersion consisting of one single question: to what extent did you feel merged into the game? This question is scored on a 10-point Likert scale[29].

3.4 Statistical analysis

Data were analyzed using JMP® Pro, version 12.1 (©SAS Institute Inc. Cary, North Carolina, USA). The normality and homoscedasticity of the distributions for all continuous data was examined via the Shapiro-Wilk test and Bartlett’s test, respectively. Because none of the data met both criteria, the statistical analysis was carried out using nonparametric testings. A Wilcoxon rank-sum and Chi-Square test were used to compare baseline characteristics. Between group and within-group differences for outcomes with continuous data were also analyzed using the a Wilcoxon rank-sum test. A Spearman’s rank correlation test was used to examine correlations between parameters. Because of the small sample size, correlations were not examined for the control and intervention group separately, but for the whole sample together. The α-level was set at 0.05.

4 Results

4.1 Baseline characteristics

The baseline characteristics of the participants are presented in Table 1. No significant differences were found between the two groups for any variables.

Table 1. Group characteristics at baseline. Values are median [IQR] unless otherwise stated.

Variable	SG (N=14)	C (N=16)	p-value
Gender (females, %)	9 (64%)	10 (63%)	1.00
Age (yr)	45.0 [35.5; 55.0]	43.5 [33.5; 54.8]	0.95
BMI (kg/m²)	26.3 [23.5; 29.3]	26.5 [23.0; 31.8]	0.93
Years since first LBP episode	3.5 [1.4; 10.0]	1.5 [0.9; 5.0]	0.26
Pain past 7 days (0-10)	6.00 [5.00; 7.00]	5.00 [4.00; 6.75]	0.19
Pain at moment of testing (0-10)	5.00 [4.00; 6.25]	4.00 [3.00; 5.75]	0.16
RMDQ (0-24)	10.50 [5.75; 14.25]	12.50 [7.25; 14.00]	0.51
TSK (17-68)	36.00 [28.00; 42.25]	37.00 [32.25; 44.50]	0.53
PCS (0-50)	25.00 [13.50; 32.00]	24.50 [19.25; 32.5]	0.80
Days since first rehabilitation session	60 [60; 90]	120 [60; 150]	0.34

IQR: interquartile range; SG: intervention group; C: control group; BMI: Body Mass Index; LBP: low back pain; RMDQ: Roland Morris Disability Questionnaire; TSK: Tampa Scale of Kinesiophobia:, PCS: Päin Catastrophizing Scale.

4.2 Primary outcomes

The results of the primary outcomes are presented in Table 2.

Table 2. Summary of the primary outcomes, values are median [IQR].

	SG	C	p-value
$Pain_{before}$	4.00 [3.00; 5.75]	5.00 [4.00; 6.25]	0.16
$Pain_{during}$	1.50 [0.00; 5.00] [b]	5.00 [4.00; 7.00]	<0.01 [a] 0.03 [b]
Change in pain ($pain_{before}$ - $pain_{during}$)	2.50 [0.25; 4.00] [b]	0.00 [-2.25; 2.00]	<0.01 [a] 0.03 [b]
Change in pain ($pain_{before}$ - $pain_{during}$) (%)	53 [100; 4] [b]	0 [30; -54]	<0.01 [a] <0.01 [b]
Time spent thinking about pain	1.50 [0.00; 5.00]	5.00 [3.75; 7.25]	<0.01 [a]

SG: intervention group; C: control group
$Pain_{before}$: NPRS before exercise
$Pain_{during}$: NPRS during exercise
[a] Denotes between-group difference
[b] Denotes within-group difference compared to baseline

4.2.1 Pain before vs pain during exercise

The $pain_{during}$ for the intervention group was significantly lower compared to the $pain_{before}$ (*p <0.01*). In the control group there was no significant difference between $pain_{before}$ and $pain_{during}$. The median decrease in pain for the intervention group was 2.5 points on the NPRS compared to a median change of 0 in the control group, which was a statistically significant between-group difference (*p<0.01*). Percentagewise, the intervention group had a median decrease of 53% compared to their pain before exercising (*p<0.01*). In the control group, the patients experienced 0% change in their pain scores.

4.2.2 The time spent thinking about pain

Subjects in the intervention group spent significantly less time thinking about their pain compared to the control group (*p<0.01*).

4.3 Secondary outcomes

The results of the secondary outcomes are presented in Table 3.

Table 3. Summary of the secondary outcomes, values are median [IQR].

	SG	C	p-value
Number of pelvic tilts performed	90 [80; 105]	100 [100; 100]	0.12
Fear to injure the back	0.00 [0.00; 1.75]	0.00 [0.00; 2.00]	0.80
Immersion score	7.50 [4.50; 8.00]	8.50 [7.75; 10.00]	0.05

SG: intervention group; C: control group

The number of pelvic tilts performed over the two exercises in the intervention group ranged between 69 and 146. In the control group every subject performed 100 tilts. The difference in number of tilts was not statistically significant (*p=0.12*).

Concerning the ratings of fear to injure the back, there was no statistical difference between the two groups (*p=0.80*). The scores in the intervention and control group ranged from 0 to 3 with the exception of one outlier with the score of 8 in the control group.

4.4 Correlations between primary outcomes and immersion score

The time subjects spent thinking about their pain was negatively correlated to the changes of their pain ratings ($pain_{before}$ - $pain_{during}$) (*p<0.01*) and positively correlated to the fear to injure the back (*p<0.05*). The more patients thought about their pain, the more likely it was to experience more pain during exercise compared to baseline and the more they thought the exercises could harm their back. The changes in pain ratings correlated negatively with the fear to injure the back (*p<0.01)*. The immersion score was not related to any of the other variables. (Table 4)

Table 4. Correlation matrix (N=30)

Variables	*Time spent thinking about pain (ρ)*	*Change in pain (ρ)*	*Harmfulness (ρ)*	*Immersion score (ρ)*
1 Time spent thinking about pain		0.74***	0.46*	0.24
2 Change in pain ($pain_{before}$-$pain_{during}$)			0.55**	0.21
3 Harmfulness				-0.26
4 Immersion score				

ρ: Spearmans's rank correlation coefficient

*p<0.05; **p<0.01; ***p<0.001.

5 Discussion

The purpose of the study was to examine whether the use of serious games during exercise therapy could influence the pain perception in patients with CLBP. The results of this RCT show that patients who used serious games during exercise therapy experienced less pain compared to the pain felt before exercising, while this was not the case for the patients in the control group. In addition, patients in the SG thought less about their pain during the exercises than the control subjects. The time spent thinking on pain was related to the pain ratings during exercise and the idea of how harmful the exercises were. Another relation was found between the thoughts about harmfulness of the exercises and pain ratings during exercise.

The analgesic effects of VR-immersion might be explained by Melzack and Wall's gate control theory[30]. Pain can be controlled, modified and inhibited by distraction. In the central nervous system it is determined which afferent stimuli from nociceptors (and other possible receptors) can be blocked on their way to the brain by inhibitory mechanisms, since these stimuli are not useful. When playing a game, attention shifts to other stimuli than the patient's LBP. This may also reduce fear avoidance behaviour, since this behaviour is founded in negative, catastrophizing thoughts about the patient's pain[16].

Multiple studies have showed that the level of immersion in the virtual environment can be an important condition for distraction, and consequently have an impact on pain perception[7, 8, 10, 31-34]. Virtual reality might have a dose-response relationship. This means that virtual reality worlds and systems which are more immersive reduce pain in a larger amount than virtual environments of lower quality[8, 12]. When properly immersed in the virtual environment, the patient will (unconsciously) shift his attention more from his LBP to other stimuli. In the current study, the immersion scores were rather high when compared to other studies using virtual reality environments[31, 35-37]. Therefore, the use of a TV-screen in the present study did not lead to less distraction compared to 3D-goggles, which were used in several other studies investigating the analgesic effects on VR[7, 8, 31, 32, 35-37].

The results of this study show that the pain reduction was clinically significant regarding pain experience. A reduction of 2.5 points (or 53%) at the NPRS was observed in the intervention group. The minimal clinical important difference (MCID) for CLBP is reported to be a 2-point or 30% change at the NPRS[31].

Compared to other studies studies investigating the analgesic effects of VR, the results from the present study are promising. Hoffman et al.[36] found that patients with burn wounds who were distracted by a virtual reality environment during a wound cleaning procedure, reported 19% lower pain ratings than in the control condition without distraction. The same findings were reported by Carrougher et al.[31], who reported a reduction of 27 percent in worst pain scores for the virtual reality condition when compared to no virtual reality in patients with burn wounds. In all these conditions, the patients' painful body part was passively involved in the procedure. Considering that the effect of VR on pain reduction in the present study was at least as large as in the aforementioned studies, the level of immersion must have been high enough to distract the patient from their LBP, despite the fact that the lower back was actively involved in the procedure.

The concept of pain reduction by VR has already been investigated in other populations such as patients with burn wounds[8, 32, 38], amputees suffering from phantom limb pain[9, 39, 40], patients with complex regional pain syndrome[10] and patients with incomplete spinal cord injuries[33]. The use of serious games in the rehabilitation of LBP has been reported in two studies[41, 42], in which a Nintendo Wii exercise program was added to a standard physical therapy program. However, these papers did not assess the analgesic effects of VR on pain during exercises, but investigated whether pain and disability improved after a rehabilitation program supported by serious gaming.

Pelvic tilts are often a part of a exercise therapy program for CLBP. The results of this study show that the patients who exercised with the use of VR experienced less pain than patients who performed pelvic tilts without the support a VR environment. Therefore, these VR-supported exercises could potentially replace the conventional exercises. When patients with CLBP experience pain during exercise, reduced program adherence can occur and exercises could be performed less optimal, which can result in lower effectiveness of the intervention[6]. Therefore, depending on the type of patients, the application of VR during exercise therapy could possibly have a positive influence on the program adherence in this population[43], which may result in better rehabilitation and reduction of symptoms[44].

Strengths and limitations

The current study has some limitations. First, blinding therapists was difficult in this trial. It might influence the result of the trial but its impact might be limited, because the outcomes were self-reported by a questionnaire and the therapists were not involved in filling these out. More important to consider is that the patients were not blinded. It was fairly easy to deduct what procedure they received. This may have influenced their perception about the trial and in which way they answered the questionnaires. Secondly, all patients were at different stages of the rehabilitation. It is possible that the experience and quality of pelvic tilting had an influence on the pain ratings and immersion score. Patients who are in the initial phase in the rehabilitation process may need to spend more time and attention on performing the pelvic tilts correctly, and so the time spent thinking about their lower back pain could be affected. Previously mentioned, more immersion leads to more pain distraction. The current visual quality of Valedo Motion's games and its gameplay are not always very high and sometimes the screen lagged, but the patients in this RCT reported a high immersion nonetheless. Therefore we can conclude this had no serious impact on our outcomes.

A strength of the current study is that despite the relatively small sample size of 30 subjects, the power is reported at 75%. Moreover, since all patients were enthusiastic after the performance of the exercises with the application of serious games, this intervention seems to be generally well tolerated. This again can be benefical for rehabilition program adherence.

Future recommendations

Our findings suggest that the performance of pelvic tilt exercises is less painful with the application of VR in patients with NSCLBP. Although the present study provides encouraging initial support for the use of VR as a technique for easing low back pain while exercising in a CLBP population, larger controlled studies are needed. Since the influence of the addition of serious games to a standardized exercise program on long-term outcome were not investigated in the current study, additional studies are particulary needed to investigate VR and long-term effects on CLBP.

6 Conclusion

This study showed that participants experienced less pain and spent less time thinking about their low back pain during the exercises performed with virtual reality, compared to the participants who exercised in the classic way. Further research with larger sample size is necessary to generalize the findings of the current study.

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