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Exergames to improve Rehabilitation after Anterior Cruciate Ligament Injury: Systematic review and GRADE evidence synthesis

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ABSTRACT

Introduction: Exergames are a fun, engaging, and interactive form of exercise that has been used in rehabilitation. This systematic review aimed to evaluate the effectiveness of exergames compared to usual rehabilitation after anterior cruciate ligament reconstruction.

Method: We performed a Systematic Review and GRADE evidence synthesis. The PRISMA guidelines for systematic reviews were followed. MEDLINE® (Medical Literature Analysis and Retrieval System Online), CINAHL® (Cumulative Index to Nursing and Allied Health Literature), SPORTDiscus, SCOPUS, SciELO (Scientific Electronic Library Online), Cochrane Central Register of Controlled Trials, and PEDro (Physiotherapy Evidence Database) were searched from their first record to May 2021. Randomised controlled trials using exergames as an intervention were included.

Results: Initial literature searches yielded 794 non-duplicated records. After exclusion based on title, abstract, and full text review, five articles were included for analysis. Compared with the control group, the participants in the exergames group showed differences in proprioception and flexion angle difference.

Conclusion: Although there is no conclusive evidence that favours exergames over traditional rehabilitation, they did not aggravate the effects of rehabilitation. Nonetheless, exergames can be safe and motivating.

1. Introduction

The knee is one of the joints that present a high incidence of injuries, with the most frequent injury affecting the anterior cruciate ligament (ACL) (Cordeiro et al., 2017; Kungwengwe et al., 2020). The ACL provides stabilisation support for knee movement (Kungwengwe et al., 2020; Ahmed et al., 2020; Atkinson et al, 2014), as well as passive restriction for anterior translation of the tibia into the femur and rotational stability in the frontal and transverse planes (Raines et al, 2017).

Many of these injuries result in reconstructive surgery, leading to a long period of rehabilitation (Kungwengwe et al., 2020). The ACL is one of the most common reconstructions of the knee ligaments (Cheecharern, 2018) and ACL reconstruction has become a standard surgical procedure attempting to prevent the development of musculoskeletal consequences of the injury (Atkinson et al, 2014).

After reconstruction there is a rehabilitation phase which aims to improve the capacity and function of the knee (Cheecharern, 2018). Postoperative rehabilitation can last from 6 months to 1 year, and it is essential that patients are aware of the need to adhere to the post-operative rehabilitation process to improve health outcomes (Atkinson et al, 2014). Rehabilitation and recovery after surgical intervention plays a crucial role in orthopaedics and take up a lot of time. During the early stage of rehabilitation the goal is to prevent atrophy and increase muscle strength (Cheecharern, 2018; Gunaydin et al., 2018). A complete rehabilitation program is needed pre- and pos-toperatively to produce positive patient outcomes; exercise modalities are initiated as soon as possible after an ACL tear and before surgical reconstruction of the ACL (Atkinson et al, 2014).

Rehabilitation can be a repetitive and tedious task (Ficklscherer et al., 2016), leading many patients to face problems such as lack of motivation and reluctance to maintain treatment (Gunaydin et al., 2018), so finding strategies to motivate participation is important.

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Regular care and patient continuity are essential, and increasing patient participation in treatment improves treatment success rates (Gunaydin et al., 2018; Ficklscherer et al., 2016). To return to their life activities, many patients are motivated and willing to practice by themselves, even beyond the standard rehabilitation possibilities (Ficklscherer et al., 2016).

The market for digital healthcare interventions for rehabilitation has grown exponentially in recent years (Kungwengwe et al., 2020). They allow patients to practice their own exercises, provide direct feedback during their performance, and motivate them to train more (Ficklscherer et al., 2016). As digital technologies and connectivity improve rehabilitation service providers are incorporating gamified elements (Kungwengwe et al., 2020), providing more engaging and personalised experiences for wider audiences. These games help professionals assess the intervention's quality and efficiency and encourage patients to use it (Cordeiro et al., 2017). In addition, during rehabilitation, the game provides motivation, making the process more fun, enjoyable, and interactive (Kungwengwe et al., 2020).

In 2006, Nintendo released the Wii gaming system. This new system allowed interactive physical movement in addition to simple hand play, making exergames a research topic (Kooiman and Sheehan, 2015). Physically active videogames or so-called "exergames" have gained popularit, particularly for rehabilitation (Stanmore et al., 2017). An exergame is played on a video game system, but it requires the player to move his body to interact with an avatar involved in a movement activity (Kooiman and Sheehan, 2015). Exergames include several essential elements: motivational features, psychological outcomes, and outcomes resulting from their use in rehabilitation, physical activity, and health (Matallaoui et al., 2017). Exergames can be used as a stand-alone intervention or in conjunction with other rehabilitation interventions (Reis et al., 2019).

To date, exergames have been implemented to address rehabilitation needs in specific contexts, such as ACL reconstruction recovery (Kungwengwe et al., 2020). Although rehabilitation exergames can be important tools after ACL, it is not clear if they are significantly more effective than standard rehabilitation without exergames (Baltaci et al., 2013). To the best of our knowledge, no previous systematic literature review or meta-analysis has analysed the efficacy of exergames to improve rehabilitation for ACL injury. Moreover, no previous systematic review has based their findings on randomized controlled trials (RCT). We also did not find records in PROSPERO, Cochrane, or JBI regarding any protocol or systematic review on the subject.

Therefore, this systematic review aims to assess the effectiveness of exergames compared to standard rehabilitation care after reconstruction of the anterior cruciate ligament.

2. Method

2.1. Review design

A systematic review study was conducted based on the PRISMA model (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) for information organisation. We also used the original version of the Rating, Development, and Evaluation of the Rating of Recommendations (GRADE) process to rate the quality of evidence and the strength of the recommendations (Pollock et al., 2016). The review sought to answer the following question: How effective is the use of games in comparison with the usual functional rehabilitation care in people undergoing anterior cruciate ligament reconstruction?

2.2. Search strategy

First, the descriptors suitable for each of the databases were identified: MEDLINE® (Medical Literature Analysis and Retrieval System Online), CINAHL® (Cumulative Index to Nursing and Allied Health Literature), SPORTDiscus, SCOPUS, SciELO (Scientific Electronic Library Online), Cochrane Central Register of Controlled Trials and PEDro (Physiotherapy Evidence Database) (Appendix 1). Regarding population, all publications in which the diagnosis was ACL rupture and in which injuries were surgically reconstructed, were included. Regarding intervention, all publications that described and evaluated an exergame to support patients at any stage of the rehabilitation process were included. The following outcomes were included in the analysis: rehabilitation outcomes, pain, strength, balance, coordination, and knee proprioception. Only publications reporting RCTs were considered.

Screening was performed by two independent reviewers. First, the titles and abstracts were selected for eligibility, and then eligible articles were read. Additional studies were searched for in the reference lists of all publications included through "Backward citation searching." Disagreements were resolved by consensus. The Rayyan QCRI® platform (the Systematic Reviews web app) was used for the first data selection stages. Screening took place in June 2021.

2.3. Study selection

The following inclusion criteria were employed: Randomised clinical trials (RCTs) with a diagnosis of ACL rupture, surgically reconstructed, and an intervention with exergames carried out, using of two groups, comparing exergame with usual functional rehabilitation care. All studies up to May 30, 2021, were included. Articles that included patients with other various pathologies of the knee were excluded.

2.4. Evidence synthesis

The Review Manager software RevMan, version 5.4.1 (Nordic Cochrane Center—Cochrane Collaboration) was used for analysis. Each primary study's results were expressed as the standardized mean difference (SMD) between groups. The mean, standard deviation (SD) and respective confidence interval (CI) were considered for calculations. The statistically defined difference was presented as a value of $p < 0.05$.

Because the studies showed differences in the intervention time, the type of participants, and the type of games, the random-effects model was used a priori in the meta-analysis, assuming the presence of heterogeneity. When a researcher collecting data from different studies carried out by researchers operating independently, it would be unlikely that all studies included are functionally equivalent (Spineli and Pandis, 2020). A I2-point estimate must also be interpreted with caution when a meta-analysis has few studies (Von Hippel, 2015). Forest plots were used to illustrate the mean difference and CI (confidence interval) between the experimental group and the control group for each of the included studies. Finally, the results were assessed by multiple meta-analyses (pain, proprioception, strength), using only groups identified from effects originating from the same instrument to assess the results.

The overall level of evidence was determined using the Grading of Recommendations, Assessment, Development, and Evaluation Tool (GRADE) (Pollock et al., 2016), considering its five domains. Only the main results are included in Table 2; other data can be consulted in Appendix 2. The Cochrane tool was also used to assess the risk of bias of the included studies.

3. Results

The research resulted in 794 articles after removing duplicates, of which 775 were rejected by reading the title and abstract, leaving 19 articles for full reading, of which 14 were excluded. Five articles were identified for final analysis (Fig. 1).

3.1. Study characteristics

Five articles published between 2013 and 2020 were selected for review. Table 1 summarises the characteristics of the 5 studies included in the review, summarising authors, year, type of study, study

Table 1
Characteristics of included studies (n = 5).

Authors, Year; country	Study Design	Study aim	Participants	Game type	Intervention	Control Group	Outcomes
Ahmed et al. (2020) Saudi Arabia	Randomised control trial	Investigate the influence of 8 weeks Wii Fit exercise rehabilitation program on knee proprioception in young male adults after ACL reconstruction.	30 males ACL injury patients after performing ACL surgery Mean age 25.47 ± 3.5 years The inclusion criteria included patients who were in the early postoperative phase (week 2 after surgery)	Nintendo Wii Fit	Wii Fit for 8 weeks, 3 sessions per week, each session was 40 minutos	A program of regular exercises with the same frequency and regularity	Proprioception deviation Difference errors between joint angles (30,60,90°)
Baltaci et al. (2013) Turkey	Randomised control trial	Compare the outcomes of Nintendo Wii Fit with those of conventional rehabilitation on the subjects with ACL reconstruction.	30 males ACL injury patients after performing ACL surgery Mean age 28.95 ± 5.8 years In the immediate postoperative period	Nintendo Wii Fit bowling and skiing games in Wii Sports, Boxing, Football and Balance Board	Wii Fit for 12 weeks, 3 sessions per week, each session was 1 h	A program of regular exercises with the same frequency and regularity	knee strength, balance, coordination and proprioception
Clausen et al. (2020) Germany	Randomised control trial	Evaluate whether an app-game-based active muscle training program (GenuSport Knee Trainer) can improve rehabilitation immediately after primary ACL reconstruction surgery	26 patients after ACL surgery (14 women, 12 men) Mean age 25.19 ± 8.2 year In the immediate postoperative period	GenuSport Knee Trainer training mode includes different games	app-game-based active muscle training with game Available during 6 weeks Game used for 5 min and performed autonomously by patient	A program of regular exercises with the same frequency and regularity	Strength International Knee Documentation Committee Subjective Knee (IKDC) Lysholm activity scale score Pain(visual analogue scale)
Gokeler et al. (2014) Países Baixos	Randomised control trial	Evaluate the influence of immersion in a virtual reality environment on knee biomechanics in patients after ACL reconstruction	20 athletes following ACL reconstruction and 20 healthy controls (20 women, 20 men) (divided in 4 groups) Mean age 23.5 ± 4.3 years <1 year between injury and ACL surgery	Virtual reality environment that depicts a game of traffic scene with a crosswalk and a pedestrian traffic light	Immersive virtual reality with game of traffic scene. No reference to duration or whether accompanied	2 grupos de control (10 pacientes ACLR and 10 healthy volunteers) A program of regular exercises with the same frequency and regularity	Strength Knee flexion excursion
Karakoç et al. (2019) Turquia	Randomised control trial	Determine the effectiveness of virtual rehabilitation on balance and functionality in patients with anterior cruciate ligament (ACL) reconstruction.	22 males ACL injury patients after performing ACL surgery Mean age 31 ± 8.41 years Started 2–3 weeks post-op	Nintendo Wii© balance games	Both of the groups received 6 week rehabilitation in our department, and the games were added to Nintendo group after 3 weeks for 40 min a day, three times a week.	9 Weeks A program of regular exercises with the same frequency and regularity	Pain (visual analogue scale), Functionality (Lower Extremity Functional Scale), Centre of gravity (COG) and balance

objectives, participants, type of game, intervention, and outcomes included. The studies were carried out in different locations. In total, 128 people participated in all the studies and were mostly men (n = 96) from younger age groups. The intervention programs used were primarily the Nintendo Wii (Ahmed et al., 2020; Baltaci et al., 2013; Karakoç et al., 2019)' with follow-up varying between 6 and 12 weeks, except for one of the studies in which the follow-up time is not mentioned (Gokeler et al., 2014).

3.2. Quality assessment

The results of the risk-of-bias assessment for the five studies are shown in Fig. 2. One of the difficulties relates to the blinding of patients and professionals as it is necessary to obtain informed consent from patients and the nature of the intervention makes blinding difficult. According to the GRADE scoring principles, the overall quality of the evidence of efficacy was assessed mostly as moderate (Table 2).

3.3. Outcome measures and results

Table 2 shows the heterogeneity of the instruments, both in terms of purpose and the time of application, making it difficult to group the results. The results of the intervention were evaluated using the following variables: pain, proprioception deviation, errors of difference between joint angles, strength, deficit of concentric and eccentric coordination deviation, anterior excursion, functional score (LEFS), centre of gravity (GOG), balance score, International Knee Documentation (IKDC), Lysholm activity scale score, and knee flexion excursion in degrees. Some of these instruments refer to issues of physical function, balance, proprioception, pain, strength, among others.

The "IKDC Standard Knee Assessment Form" was first published in 1993, and the modified version was published in 2006. The IKDC-SKF is a scale in which the score reflects the patient's reported outcome, which measures the patient's perception of symptoms, function, and sporting activity without symptoms (Grevnerts et al., 2015). The total score is calculated as the sum of the items, with the maximum possible score

Table 2
GRADE evidence Profile of included studies.

Certainty assessment							N° of patients		Effect	Certainty	Importance
N° of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Exergames	Usual rehabilitation Care	Absolute (95% CI)		
Pain (VAS) (assessed with: Visual Analogue Scale)											
2	Randomised trials	not serious	serious[a]	not serious	serious[b]	none	28	20	MD 0.24 higher (1.01 lower to 1.48 higher)	⊕⊕◯◯ LOW	Important
Proprioception deviation											
2	Randomised trials	serious[c]	not serious	not serious	serious[d]	none	30	30	SMD 1.73 lower (4.75 lower to 1.28 higher)	⊕⊕◯◯ LOW	Important
Difference errors between joint angles - 90°											
1	Randomised trials	serious[c]	not serious	not serious	not serious	none	15	15	SMD **3.31 lower** (4.46 lower to 2.16 lower)	⊕⊕⊕◯ MODERATE	Important
Strength											
2	Randomised trials	not serious	not serious	not serious	serious[b]	none	24	22	SMD **0.12 higher** (0.46 lower to 0.7 higher)	⊕⊕⊕◯ MODERATE	Important
Anterior excursion (Cm)											
1	Randomised trials	serious[c]	not serious	not serious	not serious	none	15	15	SMD **0.28 lower** (1 lower to 0.44 higher)	⊕⊕⊕◯ MODERATE	Important
Functional score (assessed with: Lower Extremity Functional Score; Scale from: 0 to 80)											
1	Randomised trials	serious[e]	not serious	not serious	not serious	none	14	8	SMD **0.43 higher** (0.45 lower to 1.31 higher)	⊕⊕⊕◯ MODERATE	Critical
Centre of Gravity											
1	Randomised trials	serious[e]	not serious	not serious	not serious	none	14	8	SMD **0.05 higher** (0.82 lower to 0.92 higher)	⊕⊕⊕◯ MODERATE	Important
Balance score (sec)											
1	Randomised trials	serious[e]	not serious	not serious	not serious	none	14	8	SMD **0** (0.87 lower to 0.87 higher)	⊕⊕⊕◯ MODERATE	Critical

CI: Confidence interval; **MD:** Mean difference; **SMD:** Standardised mean difference.
Explanations.
a. Interventions with different times.
b. Data from Clausen et al. (2020) study are unclear.
c. Sample only with young men.
d. Some imprecision of the results.
e. Without blinding of participants and personnel.

being 100; the higher the value, the better the function and the lower the symptoms (McHugh et al., 2020).

The Lysholm Knee Scoring Scale (LKSS) is a widely used instrument to assess knee function and activity level in various knee pathologies, especially in knee ligament injuries (Panagopoulos et al., 2020). The total score is the sum of each answer to the eight items out of a possible score of 100. Possible scores range from 0 to 100, where 100 corresponds to no symptoms or disability (McHugh et al., 2020).

Of the studies included in this review, not all results could be compared and included in the meta-analysis. However, all the analyses, some shown in Fig. 3, allowed the allocation of the necessary outcomes to build the GRADE evidence profile of the included studies.

Two studies investigated the comparison of exergames versus usual rehabilitation care with regard to pain, using the visual analogue scale. Of the two studies included (Ahmed et al., 2020; Gokeler et al., 2014), one reported a significant positive association (Clausen et al., 2020) which was not evidenced in the other study (Ahmed et al., 2020). The difference in grouped means for pain was 0.24 (95% CI = −1.01 to 1.48; $p < 0.75$; I2 = 0%). The GRADE of evidence was categorized as low quality.

With regard to proprioception deviation, our meta-analysis showed a significant standardised mean difference of −1.73 (95% CI = −4.75 to 1.28, I2 = 95%). The GRADE of evidence was categorized as of moderate quality. Two studies evaluated strength recovery in the operated limb. Of the two studies included (Clausen et al., 2020; Gokeler et al., 2014), one reported a significant positive association (Clausen et al., 2020) which was not shown in the other study (Gokeler et al., 2014). The difference in grouped means for strength was 0.12 (95% CI = −0.46 to 0.70; $p < 0.56$; I2 = 0%). The GRADE of evidence was categorized as moderate quality. Other results are presented based on data from single studies. The results showed that after the intervention a non-significant standardised mean difference was found regarding the deficit of concentric and eccentric coordination deviation, anterior excursion, functional score (LEFS), centre of severity (GOG), balance score, International Knee Documentation (IKDC) score, Lysholm activity scale score, and knee flexion excursion. At the end of the 8-week follow-up with exergames, there was a significant standardised mean difference in relation to the flexion angle difference for 30, 60, and 90° (Ahmed et al., 2020).

4. Discussion

This is the first systematic review, meta-analysis, with GRADE evaluation to assess the effectiveness of exergames compared to usual rehabilitation after ACL reconstruction. In this review, few randomised clinical trials with a control group were found that compared the use of exergames with other strategies for rehabilitation after reconstruction of the ACL.

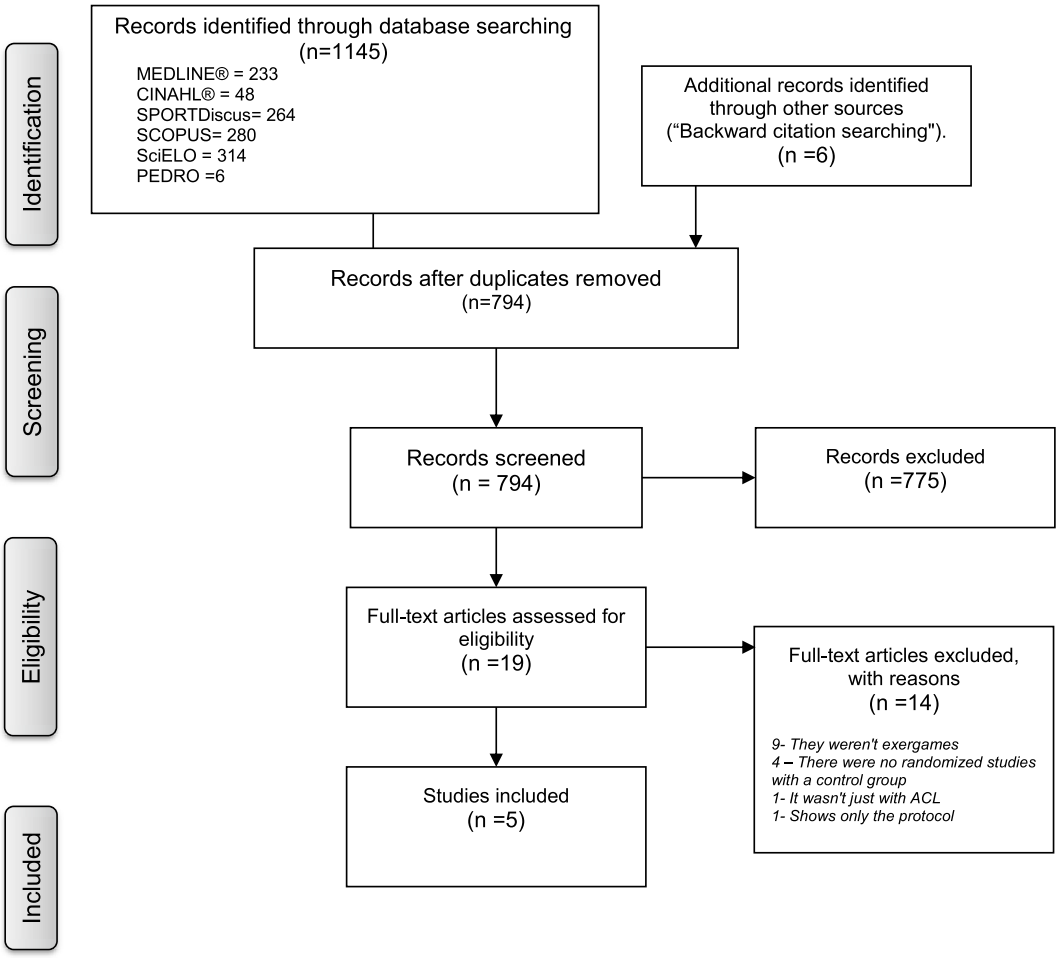

Fig. 1. - Process of identification and inclusion of articles – PRISMA *Flow Diagram*.

Recent advances in health technology have resulted in the gradual introduction of computer-assisted interventions in rehabilitation, through the implementation of biofeedback on hardware platforms and biofeedback augmented motion capture systems. However, these interventions have had less impact in orthopaedics (Byra and Czernicki, 2020), with most reports on the application in neurology patients (Prosperini et al., 2020) or in older adults (Janhunen et al., 2021).

In this review, three of the studies used the Nintendo Wii® (Ahmed et al., 2020; Baltaci et al., 2013; Karakoç et al., 2019). Originally conceived as play software to promote health and fitness, the Wii Fit series drew attention to rehabilitation due to characteristics which might promote well-being (Tripette et al., 2017). The use of Wii exergames has shown promise as an intervention to improve physical function, cognition, and psychosocial outcomes (Chao et al, 2015). Promising early observations have encouraged health professionals in various health care areas to test the Wii Fit software in various populations (Tripette et al., 2017).

Regarding the effectiveness of exergames for rehabilitation after ACL reconstruction, the pooled effect estimate for proprioception deviation was −1.73 (95% CI -4.75 to 1.28, $p < 0.0004$) (Ahmed et al., 2020; Baltaci et al., 2013). However, these results should be interpreted with some caution, with the GRADE of evidence categorized as low quality, because they are a sample of young men only.

The authors revealed that the mean error of the difference in proprioception was significantly lower after performing the Wii Fit exergames protocol (Ahmed et al., 2020). Similar results were found in an intervention with older adults in which, after eight weeks of training, knee proprioception significantly improved in the intervention group for various angles of the knee joint (Sadeghi et al., 2017). Exergames contain more repetition of weight shift and active angle movements for articulations that improve the performance of tasks during their use (Ahmed et al., 2020). Proprioception is vital for people to perform daily tasks (Sadeghi et al., 2017), and exergames through visual and tactile co-stimulation can facilitate proprioceptive improvement (Ahmed et al., 2020). However, a difference with the traditional proprioceptive rehabilitation material is that the Wii cannot tilt (Tripette et al., 2017).

Analyzing other results, there was no difference between the exergame intervention and the control group for pain (Clausen et al., 2020; Karakoç et al., 2019) and strength (Clausen et al., 2020; Gokeler et al., 2014), with the GRADE of evidence categorized as moderate and low quality, respectively. However, strength recovery is an important parameter in functional outcomes (Gokeler et al., 2014).

The other results presented were based on data from individual studies and only confirm the intervention with exergame in the 90° angular flexion difference (Ahmed et al., 2020). In the remaining results for the deficit of concentric and eccentric coordination deviation, anterior excursion (Baltaci et al., 2013), functional score (LEFS) (Karakoç et al., 2019), center of gravity (GOG)) (Karakoç et al., 2019), and balance score (Karakoç et al., 2019) there was no difference between the exergame intervention and the control group. For all these items, the GRADE of evidence was categorized as moderate quality because the intervention complements conventional rehabilitation, essentially due to the randomization bias of the studies. This can also be observed in Fig. 2 with the Cochrane risk-of-bias tool used to assess the included

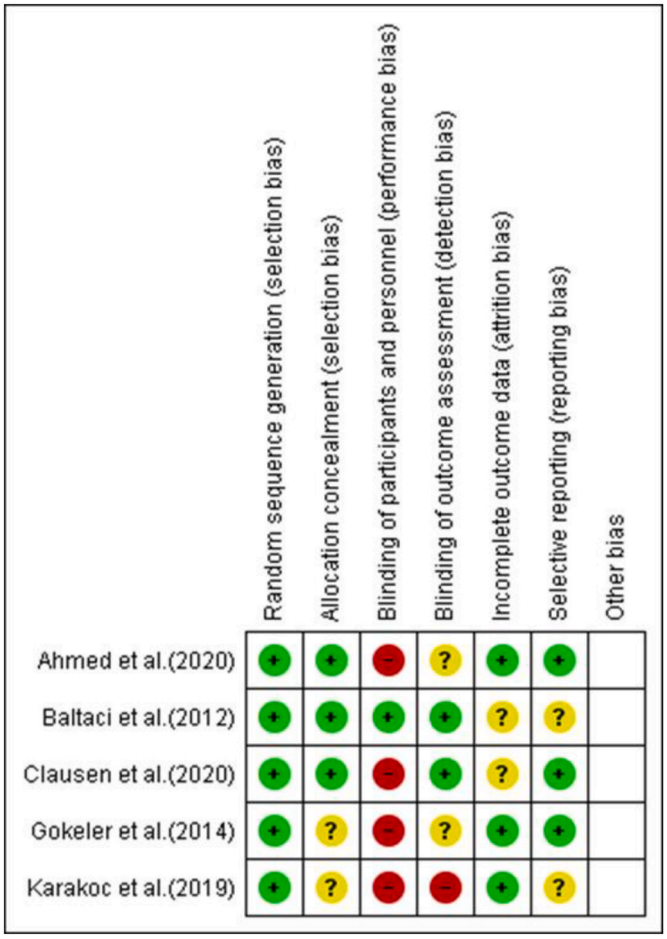

Fig. 2. Assessment of the quality of included studies risk of bias summary.

studies.

Although no other data were found to support the superiority of exergames over traditional rehabilitation, exergames did not aggravate the effects of rehabilitation. In other words, no statistically significant differences were found in the different variables under analysis. As also commented by other authors, the most important finding of the study was that the intervention program versus conventional rehabilitation after ACL reconstruction has the same results in relation to the evaluated results (Baltaci et al., 2013). That is, in both groups, with or without exergame, the functional results are similar, which allows us to conclude that there are no risks with its use and that it is possible to obtain the same gains, which is the main finding of our review.

However, clinical observations show that patients can get bored with repetitive exercises in the rehabilitation program (Karakoç et al., 2019). Exergames are commonly seen as fun and motivating and can be used to improve adherence (Reis et al., 2019). Patients have previously reported that they actively participated in the games, found them pleasant, and did not feel exhausted (Karakoç et al., 2019). One of the biggest criticisms made to the analysis of different studies lies precisely in the absence of their assessment regarding adherence, usability, and satisfaction. It would be necessary to consider methods and measures to assess game involvement when using interfaces for user-computer interaction (Cordeiro et al., 2017). This is because games can improve the entire rehabilitation process, in addition to the fact that, in most published studies, patient compliance has been very high, indicating a high motivation to train with exergaming devices (Clausen et al., 2020). In fact, games are fun and offer an appropriate level of challenge and appropriate feedback for a wide range of skills (Baltaci et al., 2013).

Although sensitive results for pain have not been obtained, exergames through gamification can reach significant levels of pain distraction, thus increasing adherence to rehabilitation (Kungwengwe et al., 2020; Qiu et al., 2017).

In the specific case of Nintendo Wii© games, it can be said that they are easy to use and cheap (Baltaci et al., 2013; Karakoç et al., 2019). Commercially available games and systems also come at a lower cost and with a greater variety, making it possible to adapt their use to different rehabilitation settings without installation needs (Baltaci et al., 2013). In addition, the authors also report that the device design is user-friendly and that people of different age groups can use the device autonomously after initial instruction (Clausen et al., 2020). Patients can also define exercise difficulty based on their needs (Kungwengwe et al., 2020). On the other hand, it gives health professionals control over game-based exercise tools according to the phases of rehabilitation in ACL reconstruction.

Concerning the rehabilitation phase, in all studies, the intervention takes place in the immediate postoperative period, except in the study by Gokeler et al. (2014), which extends into the later period.

Some limitations should be noted in this review, particularly the small samples with great variability of instruments used to evaluate the results. Participants were mostly active men who may have had greater motivation for exercise and rehabilitation. The lower quality of some studies is related to the lack of information regarding the blinding of participants, professionals involved, and the evaluators. Following GRADE scoring principles, the overall quality of evidence for efficacy was primarily rated as moderate and low. All studies should include a preoperative assessment, which provides a baseline assessment of the patient's clinical condition (functionality, amplitude, etc.) prior to ACL reconstruction.

5. Conclusion

Our review indicated that there is no conclusive and comprehensive evidence that exergame interventions are more effective in the short term than standard treatment in the rehabilitation of patients after ACL reconstruction. Results that favoured the intervention were identified only for differences in proprioception and flexion angle. Future research should expand the duration of games and lengthen the duration of follow-up evaluations to provide evidence of their long-term effectiveness. In addition, assessments other than physical parameters should be included, along with larger and more diversified samples. Variables such as adherence, gameplay, usability, and user satisfaction should be included in future studies, because, as these authors ask, "*couldn't gamification go beyond a single objective of motor rehabilitation*? (Fernandes et al., 2021). The development of more gamified resources for use in rehabilitation in the person undergoing ACL reconstruction is also recommended.

6. Clinical implications

- There is no conclusive evidence that interventions with games are more effective in the short term than standard treatment in the rehabilitation of patients after ACL reconstruction.
- Results favoured the intervention for proprioception and flexion angle.

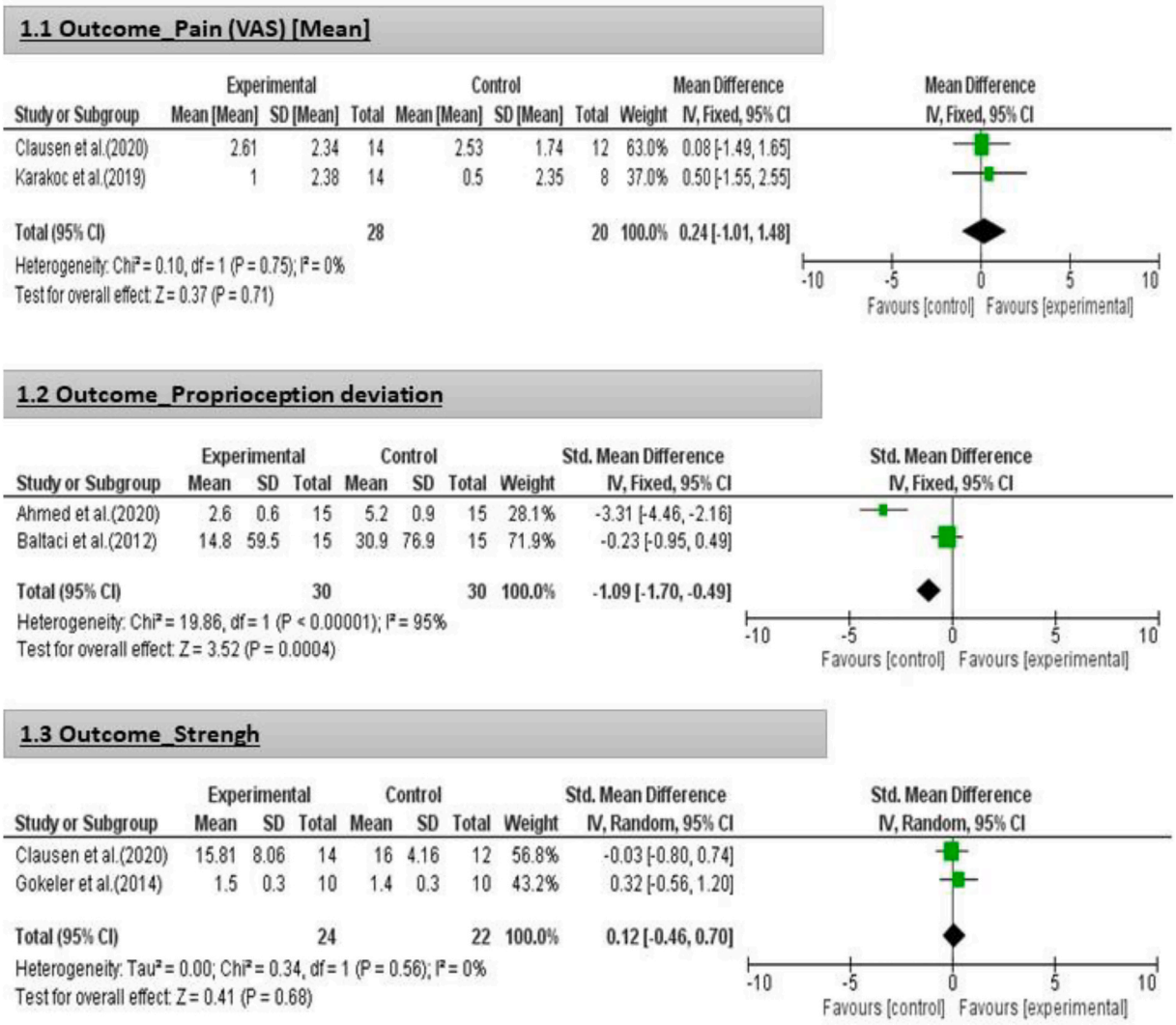

Fig. 3. Comparison of exergames versus usual rehabilitation care *(Pain, Proprioception deviation, Strength)*.

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Author contributions

All authors have agreed on the final version of the manuscript and have met at least one of the criteria: contributions to conception, data collection, analysis, and interpretation, and drafting the article, or critically revising.

Conflict of interest statement

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Ethical statement

Not applicable.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijotn.2021.100917.

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