Mini-Review/Systematic Review

Virtual rehabilitation is better than conventional physical therapy to improve the functionality of the gait in elderly people? Systematic review and meta-analysis

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Abstract - Aim To compare the Timed Up and Go (TUG) test variables and walking speed between elderly people that carried through the training using virtual reality, sedentary (control), and those submitted to the Conventional physical therapy (exercise therapy). Systematic revision with meta-analysis of clinical essays. Methods: The recommendations of The PRISMA STATEMENT were used; having been consulted the following databases: PubMed/Medline, Excerpta Medica DataBase Guide (IT BASES), Web of Science, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Physiotherapy Evidence Database (PEDro). Participants: Healthy Elderly People. Intervention: Virtual reality or Conventional physical therapy. Group control: physical inactivity. Measures of result: TUG test and walking speed. Results: 11282 generated articles of the initial search, 16 articles had entered for the meta-analysis, including 711 participants. The meta-analysis resulted the four following comparisons: [1] Virtual Reality versus Control (TUG), not significant (the IC 95% (-4.29 to 0.66) I² = 94%) and [2] Virtual Reality versus Control (walking speed), not significant (IC 95% (-0.14 to 0.56) I² = 98%); [3] Virtual Reality versus Conventional physical therapy (TUG), significant, in favor of Conventional physical therapy (IC 95% (-1.02 a -0.06) I² = 20%) and [4] Virtual Reality versus Conventional physical therapy (walking speed), significant in favor of Virtual Reality (IC 95% (0.06 a 0.17) I² = 0%). Conclusion: This demonstrates that the investigated subject needs more studies with a better methodological research design to develop more results in the literature. Register Review: PROSPERO (CRD42021247922).

Keywords: biomechanics, virtual reality, aged, gait.

Introduction

The life expectancy and the longevity of the elderly people population have increased. Aging leads to a reduction of functional capacity, increasing the possibility of chronic-degenerative illnesses. A setting that has become frequent, letting the elderly people with functional and structural limitations, as well as loss of autonomy and independence¹.

Approximately 81% of the 98% of the fractures in the hip area in elderly people are caused by falls². Although many fall risk factors are known, usually it is classified into two categories: ambient (inherent), which can include possible fall factors as lighting, irregular surface, high surface, and obstacles. Another category that can be defined is personal (inherent): gender³-⁵, muscular strength⁶, time of reaction⁷, sight⁸, sedentarism⁹, a decrease of balance and mobility¹⁰. Other factors, as speed, gradual fatigue, or fatigue during a task lead to increasing the complexity of the execution of the gait, making it more difficult¹¹.

The pace is considered a complex motor task that involves cognitive factors, and with the aging process it gradually gets worse¹². The space-time settings of the gait are modified negatively by aging. Changes in the reduction of the walking speed and the length of the step, increase of the variation of the step in the double support time, and in the width of the step are related to a greater tendency to fall¹³-¹⁵. Moreover, muscle shortening, support base extension, reduction on the step height,
Virtual rehabilitation is better than conventional physical therapy in the gait?

It is already known that virtual reality can improve the functional mobility of healthy elderly people. Despite this information occurring in systematic reviews with meta-analyses, when functional tests are combined assessed (such as Timed Up & Go Test (TUG), Four-Step Square Test (FSST), walking speed, gait cadence, 6-minute walk test, and 8-foot up and down test) and for shifts (5 times Sit-to-Stand test (5STS) and chair test (CST))

However, there are no articles confirming this information, regarding the tests distinctly.

Virtual rehabilitation still shows negative and positive sheds of evidence, with conflicting and still insufficient results.

Aging causes physiological changes that can negatively influence the functional capacity of the elderly person, leading to a decline in extent motion, time-space parameters, strength, muscle power, among other changes. Thus, leading to a balance deficit and causing gait variations. In this sense, we raise two questions: Is virtual reality capable of improving elderly people's gait? Being able to improve the elderly people's gait, will it be more effective than conventional physical therapy?

This systematic review with meta-analysis intended to review: [1] Virtual reality versus the placebo group (which did not perform any type of physical activity) and [2] Virtual reality versus conventional physical therapy performed to improve the performance of the elderly people's gait.

**Method**

The preparation of this systematic review with meta-analysis was carried out according to the recommendations of The PRISMA STATEMENT and carried out orderly, explicit, capable of reproduction and aiming to collaborate with future researches, systematizing the knowledge already acquired. The script “The PRISMA checklist” is present in Annex 01. This systematic review was recorded on the International prospective register of systematic reviews PROSPERO (CRD42021247922).

**Search strategy**

A systematic review of the literature was conducted to identify clinical studies that examine the use of a virtual reality strategy compared to a control group (physical inactivity) and a virtual reality strategy compared to conventional physical therapy executed to improve the performance of the elderly people's gait. Aiming to observe the TUG test and walking speed. Studies that used the comparison of two modalities of interventions, such as virtual rehabilitation and conventional physical therapy. The former is defined as the use of advanced technologies, such as computers and multimedia outlying, to provide an interactive and multidimensional simulated environment for the users perceive as like real-life experiences. The latest
is defined by any intervention that uses isolated physical exercise as a method of therapy. The databases consulted were PubMed/Medline, Excerpta Medica Guia DataBASE (EMBASE), Web of Science, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Physiotherapy Evidence Database (PEDro), without date or language restrictions. The search was conducted until January 2021. After previous readings it was created a set of keywords to perform the search. The set of keywords used in each database is specified in Annex 2. The set of initial keywords aimed to search for the theme.

**Inclusion and exclusion criteria**

Only health elderly volunteers participated in the present study. Pathological populations of any order, such as musculoskeletal, cardiovascular, hormonal, metabolic or neurological, as well as participants in post-surgical protocols or drug studies or amputees. For intervention (I), it was compared interventions performed through virtual reality versus the control group (physical inactivity) as well as virtual reality versus conventional physical therapy, including elderly people from 65 years old, healthy, independent, and initially untrained. Control group or placebo were the chosen comparison (C). Outcomes (O) and study design (S) were, respectively, gait speed and TUG in randomized controlled trials.

Inclusion criteria were studies that compared interventions performed through virtual reality versus a control group (physical inactivity) and virtual reality versus conventional physical therapy, including elderly people from 65 years old, healthy, independent, and initially untrained. Studies that measure gait performance using the TUG test and tests of walking speed were included.

**Studies selection**

The studies selection was performed by two authors (X1 and X2), if there was a tie in the decision, it would be given to a third author (X3) involved to tiebreak it. Rayyan QCRI, the Systematic Reviews web app (free web app for systematic review management) was used (https://rayyan.qcri.org). The studies selection started with the first sorting of titles and abstracts, and a second sorting of the full articles’ text. If an eligible study was published in a language not known by the authors (English, Portuguese, and Spanish), every possible effort would be made to obtain a translation. When this was not practical, articles would be excluded.

**Study quality**

The quality of included studies was assessed by extracting PEDro scores from the physiotherapy evidence database (www.pedro.org.au). The PEDro scale is an 11-item scale designed to rate the methodological quality (internal validity and statistical information) of randomized trials. Each item, except item 1, adds one point to the total score (range 0-10 points). When an essay was not included in the database, it was scored by a reviewer who completed the PEDro Scale training tutorial.

**Assessment**

Two results were obtained from the studies: walking speed and TUG test. To evaluate the aptness of combining studies in a meta-analysis was recorded the time of result measurements and the procedure results used to gauge the different walking speed. The reference values for the TUG are: normal, less than 10 s (in case of using canes and walkers, the time is considered from 10 s to 19 s); risk of falling, from 10 s to 19 s, and the cut-off point for this test is > 13.5 s, which indicates that the individual has a high risk of falls.

**Data analysis**

The information on the method (i.e., design, participants, intervention, and measures) and the results (i.e., number of participants and means (standard deviation, SD) of walking speed results) were obtained by two reviewers and verified by a third one. When the information was not available in the published essays, the details were requested from the corresponding author.

The post-intervention scores were used to achieve the combined estimate of the intervention effect using the fixed effects model. In the case of divergence, a scale with a value of I² close to 0% to 40%: may not be important; 30% to 60%: may represent moderate divergency; 50% to 90%: may represent substantial divergency; 75% to 100%: considerable divergency. The post-hoc sensitivity analysis was performed if the result of the random-effects model was different from the fixed effect model. The analyses were conducted using the software R. When insufficient data was available for study results to be included in the combined analysis, the difference between the groups was reported. For all measure results, the critical value for statistical significance was established at a level of 0.05 (two-tailed). The combined data for each result were reported as weighted mean difference, with a 95% IC.

**Results**

**Selection of studies**

After applying the search strategy in all databases, the literature search produced 11282 potentially eligible articles, but 451 were duplicated. The identification process is presented in Figure 1. After the initial screening, 10831 articles were analyzed individually by peers and 10803 were eliminated according to the exclusion criterion, leaving only 28 articles for a full reading. Of the 28 articles selected, 12 were excluded after full reading for
Virtual rehabilitation is better than conventional physical therapy in the gait? not meeting the pre-established inclusion criteria. Therefore, 16 articles were left to produce this systematic review.39-54 (Figure 1).

Study characteristics included

Of the sixteen articles, 711 elderly people were included. Walking speed and TUG were evaluated. These sixteen articles are described in Table 1.

Methodological quality assessment

The mean PEDro score of the essays was 5.18 (ranging from 3 to 7) (Table 2). 78% had random allocation, 14% covert allocation, 100% similar groups at baseline, 0% blind participant and blind therapist, 35% blind assessment, 50% <15% dropouts, 42% intention to treat, 92% had difference reported between groups, 92% punctual balance and reported variability.

Participants

A total of 711 elderly people with a mean age of 72.6 years old.

<table>
<thead>
<tr>
<th>Autor</th>
<th>Participants</th>
<th>Age</th>
<th>Country</th>
<th>Intervention</th>
<th>Supervision</th>
<th>Variables</th>
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Table 1 - continued

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<th>Intervention</th>
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Table 2 - PEDro criteria and scores for included articles.

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<th>Participant blinding</th>
<th>Blinded therapist</th>
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<th>&lt; 15% dropouts</th>
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(continued)
Association effects

Virtual Reality versus Control – TUG

The association effect on Virtual Reality versus Control and TUG test was analyzed by combining post-intervention data from six trials involving 199 participants. Analyzing the result in Figure 2, we have the value of the I² statistic (I² = 94%) and the p value of the Cochran Q test (p value < 0.01). The p-value found was lower than the 5% significance level, indicating statistical evidence of heterogeneity and the I² statistic value suggests a high heterogeneity (>70%) between studies. Due to the high heterogeneity, the random effects model is the most indicated in this meta-analysis.

Analyzing the forest plot (Figure 2) it can be seen that the studies by Fakro et al.43 and Sadeghi et al.50 presented different results from the others with weights of 13.9% and 19.3%, respectively.

Additionally, we have the value of the absolute difference between means (MD = -1.81) with their respective 95% confidence interval (-4.29 to 0.66). The p value associated with this test was equal to 0.1512. These results suggest that there is no difference between Virtual Reality and Control when the timed up and go variable is evaluated.

Virtual reality vs. control - walking speed

The association effect on Virtual Reality versus Control and walking speed was analyzed. Combining post-intervention data from four trials involving 168 participants. Analyzing the result in Figure 3, we have the value of the I² statistic (I² = 98%) and the p value of the Cochran Q test (p value < 0.01). The p-value found was lower than the 5% significance level, indicating statistical evidence of heterogeneity and the I² statistic value suggests a high heterogeneity (>70%) between studies. Due to the high heterogeneity, the random effects model is the most indicated in this meta-analysis.

Analyzing the forest plot (Figure 3) it can be seen that the studies by Sapi et al.51 and Sadeghi et al.50 present different results from the others with weights of 10.2% and 30.1%, respectively.

Additionally, we have the value of the absolute difference between means (MD = 0.21) with their respective 95% confidence interval (-0.14 to 0.56). The p value associated with this test was equal to 0.2402. These results suggest that there is no difference between Virtual Reality and Control when the Gait Speed variable is evaluated.

Table 2 - continued

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Y = Yes; N = No

Included studies were rated using the PEDro scale. The studies were considered to be “low risk” of bias if they had a score ≥ 6 points. Studies scoring <6 points were defined to be “high risk” of bias35-36.

Figure 2 - Forest plot (model of random effects) for the variable Timed Up and Go (post).

Figure 3 - Forest plot (model of random effects) for the variable Gait Speed (post).
Virtual reality versus conventional physical therapy – TUG

The association effect on Virtual Reality versus Conventional physical therapy and TUG test was analyzed by combining post-intervention data from seven trials involving 298 participants. Analyzing the result in Figure 4, we have the value of the I² statistic (I² = 40%) and the p value of the Cochran Q test (p value = 0.13). The p value found was higher than the 5% level of significance, indicating that there is no statistical evidence of heterogeneity, and the value of the I² statistic suggests moderate heterogeneity between the studies.

Analyzing the forest plot (Figure 4) it can be seen that the study by Yang et al.54 and Sadeghi et al.50 present different results from the others with weights of 10.0% and 15.8%, respectively.

Additionally, we have the value of the absolute difference between means (MD = -0.54) with their respective 95% confidence interval (-0.02 to -0.06). The p value associated with this test was equal to 0.0272. As the p value is less than 5% of significance, we have strong evidence of the difference between Virtual Reality and Conventional Physiotherapy when the timed up and go variable is evaluated. In addition, the value of the meta-analytic measure of -0.54 indicates that the variable “Time Up and Go” in the Conventional Physiotherapy group is higher on average, 0.54 units, compared to the Virtual Reality group.

Virtual reality vs. conventional physical therapy - walking speed

The association effect on Virtual Reality versus Conventional physical therapy and TUG test was analyzed by combining post-intervention data from six trials involving 224 participants. Analyzing the result in Figure 5, we have the value of the I² statistic (I² = 0%) and the p value of the Cochran Q test (p value = 0.98). The p value found was higher than the 5% level of significance, indicating that there is no statistical evidence of heterogeneity and the value of the I² statistic suggests non-heterogeneity (close to 0%) between studies. On this low heterogeneity, possibly a random effect model is no longer indicated, but what has to be taken into account is if the objective of this research is to make extrapolations to other populations, if this is the objective, the random effect model continues being the most suitable for modeling.

Additionally, we have the value of the absolute difference between means (MD = 0.12) with their respective 95% confidence interval (0.06 to 0.17). The p value associated with this test was equal to 0.0001. As the p-value is less than 5% of significance, we have strong evidence of the difference between Virtual Reality and Conventional Physiotherapy when the Gait Speed variable is evaluated. In addition, the value of the meta-analytic measure of 0.12 indicates that the variable “Gait Speed” in the Virtual Reality group is higher on average, 0.12 units, compared to the Conventional Physiotherapy group.
Discussion

In the present study, two physiotherapy modalities are compared, namely, virtual reality and conventional physiotherapy based on exercises. This systematic review provides evidence that there is no significant difference when comparing virtual reality versus control (physical inactivity) under the TUG and walking speed variables, yet with a divergence of $I^2 = 94\%$ and $I^2 = 98\%$ respectively. Furthermore, the results of comparing virtual reality versus conventional physical therapy, the TUG variable is significantly favorable to virtual reality (0.54 units) with the absolute value difference between means (MD = -0.54) with its respective confidence interval of 95% (-1.02 to -0.06), yet with little important heterogeneity (40%). The walking speed variable is significantly favorable to conventional physical therapy (0.12 units), the absolute value difference between means (MD = 0.12) with its respective confidence interval of 95% (0.06 to 0.17), but with a nonimportant heterogeneity (0%).

The association on virtual reality versus control showed no statistical difference concerning the TUG test. This meets with the work presented by Booth et al.\textsuperscript{55} that found the same result in the meta-analysis. What differs their study with the present one submits a high divergence generated by four studies, while Booth et al.\textsuperscript{55} meta-analysis submitted no divergence in two studies in a population of 80 participants. Furthermore, the walking speed variable also showed no significant difference in association with virtual reality versus control. This fact can be justified by the methodological factor and a low number of studies involved. Other findings of this meta-analysis in association with virtual reality versus conventional physical therapy, the TUG variable proved favorable to the virtual reality group, the same happened with Fang et al.\textsuperscript{56}, in the meta-analysis. Booth et al.\textsuperscript{55}, found no significant difference. This finding should be sustained due to its comparison presenting a divergence of 0% under two studies and a small population of 44 individuals. The association with virtual reality versus conventional physical therapy on the walking speed variable pointed to statistically significance in favor of conventional physical therapy, which has been present in the literature\textsuperscript{57}. However, Booth et al.\textsuperscript{55} did not find a significant difference in this variable, yet its divergence was substantial, but the statistical tests were based on three studies with a population of 68 participants. The results of our review may be in line with which says that virtual reality therapy may become a complementary therapy to conventional physical therapy\textsuperscript{58}.

There was an inconsistency in the results measures that showed there is no statistical difference in the relation of virtual reality versus control (physical inactivity). We believe that this is due to the low number of studies (4 studies for TUG and 3 studies for walking speed). This shows that more studies are need to assess the TUG tests and walking speed separately, providing better methodological research designs to improve the quality of existing evidence. We do not know if the same happens for the association of virtual reality versus conventional physical therapy. The TUG and walking speed variables showed different results. We do not know if this is due to chance or methodological factors, such as no divergence was found in both analyses, a low number of articles was included in the analysis, and finally an average PEDro of articles below 5.18 for all the analyses. Considering the studies available for a meta-analysis, it may be more appropriate to consider, in a future study, only the comparison of data from treatments that used virtual reality with those that used conventional physical therapy\textsuperscript{58}.

It is clear in the literature that virtual reality is a recent and promising technique and can improve the mobility and functional mobility of healthy elderly people\textsuperscript{31}. In this way, we can say that virtual reality rehabilitation does not exist as a gold standard in relation to the methodology of games\textsuperscript{59}. Thus, through a critical analysis of the studies, it might be suggested that generally, the time of neuromuscular and motor-sensory adaptation requires a longer time for response. Some studies may present insufficient intervention time to obtain satisfactory results related to gait's mobility demands. Virtual reality, in particular interactive game systems, potentially have more motivational influence and present itself as an efficient strategy to better engage elderly people in physical exercise programs\textsuperscript{58}. 

![Figure 5 - Forest plot (model of random effects) for the walking speed variable (post).](image-url)
Interventions performed through virtual reality have clinical benefits, such as double task training, cognitive and motor skills stimulation, a possibility of a new experience as they offer a stimulating and challenging environment. The present study has some limitations, such as the low methodological quality of the studies that proposed to study the theme and limited samples. In addition, there are still few studies on the present theme of this systematic review. The strength of this review is to present the current evidence on the topic involving rehabilitation with virtual reality, as well as providing evidence on how the physiotherapy intervention is presented in this context.

The TUG test is commonly used and recommended in clinical practice to assess fall risk. In this sense, some prospective studies use logistic regression techniques to associate the TUG test and the probability of future falls. The assessment of walking speed is also a method of verifying the fall tendency in elderly people, thus, the low walking speed is directly linked to the greater fall propensity and gait stability.

Conclusion

This systematic review with meta-analysis shows us that conventional physical therapy is more efficient to increase gait speed, while virtual reality therapy has been shown to be more efficient to improve the response to the TUG test. This was observed when conventional physical therapy was compared to virtual reality treatment. However, when these therapies are compared to a control group the results are inconclusive. This shows that the subject investigated needs more studies with better methodological research designs to generate more results in the literature. However, we should not dismiss virtual reality, as it is a promising new technique that can improve the mobility and functional mobility on healthy elderly people.

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Virtual rehabilitation is better than conventional physical therapy in the gait? 

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