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The effectiveness of technology-supported exercise therapy for low back pain: a systematic review.

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Abstract

Various technological systems have been developed to assist exercise therapy for low back pain. The aim of this systematic review is to provide an overview and to assess the effectiveness of the available technology-supported exercise therapy (TSET) programs for low back pain. The electronic databases Pubmed, Embase, Cochrane Central Register of Controlled Trials, PEDro, IEEE and ACM were searched until January 2016. Randomized controlled trials (RCTs) using electronic technological systems simultaneously with exercise therapy for patients with low back pain were included. Twenty-five RCTs met the inclusion criteria. Seventeen studies involved patients with chronic low back pain, and EMG-biofeedback was the most prevalent type of technological support. This review shows that TSET appears to improve pain, disability and quality of life for patients with low back pain, and that a standard treatment combined with an additional TSET-program might be superior to a standard treatment alone. However, TSET seems not more effective compared to other interventions or a placebo intervention for improving these outcomes, which may partially be explained by the analytical approach of the current TSET-programs. For most technologies, only a limited number of RCTs are available, making it difficult to draw firm conclusions about the effectiveness of individual technological systems.

Key words: Low back pain – Rehabilitation – Technology - Exercise therapy

1. Introduction

Despite numerous treatment options, low back pain (LBP) remains an important health related problem with a substantial impact on daily functioning. The life time prevalence of LBP is reported to be as high as 84%, whereas the estimated prevalence of chronic LBP (CLBP) is about 23%.[1] Furthermore, in the industrialized countries CLBP is a leading cause of work absenteeism resulting in high economic and healthcare costs.[2]

Because of demographic changes, the prevalence of LBP is likely to increase in the future,[3,4] which in turn will contribute to the growing pressure on the healthcare system. The latter begs for innovative approaches that support both patients and therapists in their effort to obtain and offer high quality rehabilitation. Up till now, exercise therapy is commonly used as the treatment of choice in the rehabilitation of LBP.[5] Despite the positive effects on pain and disability, not all patients benefit from this type of treatment and the effect sizes are only small to moderate.[6-8]

In the neurological field, rehabilitation technologies have been developed for two decades and have proven to yield improvement in patients with stroke.[9,10] Apart from the use of surface electromyography (sEMG) and real-time ultrasound imaging (RUSI), the interest in technologies that support exercise therapy for LBP has emerged only in recent years. Various systems are available that provide extrinsic feedback to enhance the accuracy of exercise performance. This seems logical as patients with LBP often show an impaired internal feedback system, which leads to spinal control problems.[11] Currently, the feedback provided by physical therapists is usually based on palpation or inspection, however, the reliability of these assessments can vary considerably.[12-14] Therefore, it is thought that providing more accurate feedback by using technology could improve treatment outcomes.[15,16] Technology also aims to increase treatment adherence, which has been shown to be a predictor of treatment success of exercise programs for patients with CLBP.[17,18] This might be achieved by providing automated feedback messages based on objective information about the training frequency and intensity gathered by technological systems, as this has already been demonstrated for other health problems.[19,20] In addition, technological systems can offer a more stimulating setting for the patient to practice, such as virtual reality environments.[21]

Despite the recent development of electronic systems to support exercise therapy for LBP, a detailed overview of the effectiveness of the various technology-supported exercise therapy (TSET) programs is currently lacking. Therefore, the aim of this systematic review is (1) to inventory the available electronic technological systems supporting exercise therapy for LBP that have been evaluated in randomized controlled trials, and (2) to assess the effectiveness of technology-supported exercise therapy (TSET) for LBP, compared to other forms of rehabilitation, placebo interventions or no treatment.

2. Materials and methods

DATA SOURCES AND SEARCHES

This systematic review was conducted according to the PRISMA-guidelines (see Supplemental digital content 1). A systematic search was performed up until January 2016 in the Pubmed, PEDro, EMBASE, Cochrane central register of controlled trials (CENTRAL), IEEE and ACM databases. The following key-words (truncation indicated with an asterisk symbol) were combined in various ways to identify relevant articles: low back pain, (bio)feedback, internet, whole body vibration, electrical stimulation, ultrasonography (ultrasound), technology, robotics, telemedicine, virtual reality, smartphone, mobile app*, sensor(s), motor control, exercise therapy and stabilization exercise. A detailed search strategy can be found in Supplemental digital content 2.

After removal of duplicates, two reviewers (T.M. and A.T.) independently screened the titles and abstracts of the obtained articles for eligibility. The relevant studies were read in full length to make a decision about the inclusion. Authors of papers were contacted for more information if this was necessary. The references of included articles and retrieved systematic reviews were screened for additional papers.

STUDY SELECTION

Study design

Randomized controlled trials (RCTs) written in English or Dutch were included.

Subjects

Studies containing an adult population with (sub)acute or chronic LBP of musculoskeletal origin were included. LBP lasting less than six weeks was defined as acute LBP, between six and 12 weeks as subacute LBP and more than 12 weeks as CLBP.[22] Trials including healthy subjects or patients with pelvic girdle pain, and studies on post-operative rehabilitation were excluded. If patients were described as having back pain, and no specific sub-analysis was made for LBP, the article was excluded.

Outcomes

To be included, at least one of the following outcomes had to be reported: pain, disability or quality of life.

Interventions

Studies had to compare TSET to other interventions, a placebo intervention or no treatment. Any type of exercise therapy routinely used for the treatment of LBP was included, as long as it was supported by technology. This implies that the technology had to be used simultaneously with the exercise therapy. Because the development of current and future technologies mainly focusses on electronic systems (e.g. sensors), only studies using technological devices with an electronic component were included. Purely mechanical systems, such as traditional fitness equipment, were not the scope of this review. Combined therapies were allowed as long as the independent effects of TSET could be assessed.[22] This implies that if a standard therapy was combined with an additional TSET-intervention, the control group should have received the same standard intervention as the TSET-group. For example, a study that compared physical therapy and TSET with physical therapy and stabilization exercises could be included in the review. If the control group would have received manipulative therapy and stabilization exercises, this study could not be included.

DATA EXTRACTION AND SYNTHESIS

The data extraction was performed independently by two reviewers (T.M. and A.T.), using a standardized form. The extracted data included the number of subjects, age, gender, duration of symptoms, technology-supported intervention, control intervention, outcomes (pain, disability and quality of life), measurement times and follow-up times.

When possible, effect sizes (Hedges' g) were calculated for between group differences. For this calculation, the sample sizes, means and standard deviations from continuous data were extracted. If the required information could not be retrieved from the articles, authors were contacted to provide the missing data. Effect sizes (ES) were interpreted according to Cohen's classification[23]: an ES of 0.2 was interpreted as small, 0.5 as medium, 0.8 as large.

Results were described as post-intervention, short term (closest to three months follow-up), intermediate term (closest to six months follow-up) or long term (closest to one year follow-up).[22]

RISK OF BIAS ASSESSMENT

The risk of bias was assessed using the checklist from the Cochrane Back Research Group (CBRG), which consists out of 12 items.[22] Before evaluating the included articles, a risk of bias assessment try-out was conducted on similar articles. Positive scores were given on items that fulfilled the criteria, and negative scores if this was obviously not the case. If there was insufficient information, items were labelled unsure. Following the guidelines of the CBRG, a study was categorized as having a low risk of bias if it had six or more positive items and no major flaws. Otherwise the study was classified as having a high risk of bias. The assessment was done independently by two reviewers (T.M. and A.T.). If any disagreements persisted after discussion, a third reviewer would be contacted for consensus. No studies were excluded based on their risk of bias assessment.

3. Results

SYSTEMATIC SEARCH

A sensitive search strategy was used and yielded 6195 records. After removal of duplicates and screening on title and abstract, 96 papers were withheld for full-text reading. Finally, 25 articles were included in this review. A flowchart of the selection process can be found in Figure 1.

[INSERT Fig. 1 - *Prisma flowchart* HERE]

RISK OF BIAS

A high level of agreement was reached on the risk of bias assessment resulting in a kappa value of 86% (95% CI = 0.81, 0.91) across the items. Out of the 25 included studies, 12 papers had a low risk of bias. Despite being described as RCTs, only eight studies reported an adequate randomization process and a concealed allocation. Blinding of therapists and outcome assessors was adequate in only four papers, while blinding of participants was adequate in five papers. Details on the risk of bias assessment are presented in Table 1.

[INSERT TABLE 1 – *Risk of bias of included of included studies* HERE]

INVENTORY AND CHARACTERISTICS OF TSET FOR LBP

Most of the studies (17/25) involved a CLBP population. Two studies used patients with acute LBP,[24,25] two studies from the same cohort used subjects with sub-acute LBP,[26,27] and four studies included patients with both (sub)acute and chronic LBP.[28-31] Ten different types of supportive technologies were described. EMG-Feedback (EMG-FB) was used in nine papers, while for the other technologies a maximum of three studies per technology was available. Table 2 provides an overview of the different TSET-programs with comparisons. A detailed description of the study characteristics can be found in Supplemental digital content 3.

[INSERT TABLE 2 - *Summary of TSET-programs and their comparisons* HERE]

EFFECTIVENESS OF TSET

Pooling of data was considered inappropriate because of the substantial number of studies with a high risk of bias and because of clinical heterogeneity of the studies.[22] Therefore, no meta-analysis was performed, but effect sizes for individual studies are provided in Tables 3, 4 and 5. Positive effect sizes have to be interpreted in favor of the TSET-intervention, whereas negative effect sizes favor the comparison (i.e. other intervention, placebo or waiting list).

ACUTE LBP

One study compared a standard EMG-FB program to individualized cognitive behavioral therapy (CBT), with both groups also receiving standard conservative care.[24] The EMG-FB group had significantly less improvement in pain post-treatment (ES= -0.86) and at intermediate term (ES= -0.40), but no differences were found for disability compared to the CBT-group.

One study showed that the addition of RUSI-supported multifidus muscle training to standard medical care did not result in a greater reduction in pain and disability post-treatment and at six weeks follow-up.[25] However, the TSET-group experienced significantly less LBP recurrences during a three year follow-up period.[32]

SUB-ACUTE LOW BACK PAIN

Two studies from the same cohort of office workers assessed the effects of adding a web-based exercise program to standard preventive occupational care.[26,27] Disability (ES= 1.61) and quality of life significantly improved after the intervention in the TSET-group, but not in the control group, and a significant between group difference was present.

CHRONIC LOW BACK PAIN

Standard treatment and TSET vs. standard treatment alone

Three out of four studies showed beneficial effects on pain when a TSET-program was added to a standard treatment (ES range= 0.38, 0.75).[33-35] The two studies reporting quality of life[33,34] showed better results for the TSET-group (ES= 0.38) and mixed results were reported for disability in two studies (ES range= 0.06, 0.27).[33,35] The positive effects were found in studies with an additional whole-body vibration intervention[33,35] or a motor learning program with postural feedback.[34] Adding lumbar extensor strengthening exercises with EMG-FB to a two week physical therapy program did not result in a greater reduction in pain.[36]

[INSERT TABLE 3 - *Effect sizes comparing a standard treatment and TSET to a standard treatment alone* HERE]

TSET vs. other interventions

Eight studies compared TSET to other interventions.[37-44] TSET reduced pain significantly more than other interventions in two studies,[37,38] five studies found no differences,[38-40,42,43] and in one paper TSET was less effective.[44] Concerning disability, four studies showed no differences,[39,40,42,43] and in one paper TSET was less effective.[44] No differences in quality of life were found in one study.[39]

In four studies, patients were asked to increase or decrease muscle activity from the paravertebral extensors, while they were provided with EMG-FB from these muscles. No differences were found between EMG-FB and education[38] or CBT[40] for pain or disability. Compared to relaxation exercises, EMG-FB was less effective for reducing disability[44] and mixed results were shown for pain reduction.[38,44]

Trunk stabilization exercises with EMG-FB resulted in a significantly greater improvement in pain than trunk stabilization exercises without technological support (ES= 0.91).[37] In contrast, no differences in the reduction of pain and disability were found between whole-body vibration and strengthening exercises,[42] between transversus abdominis muscle training with RUSI and sling exercises or general strengthening,[43] and between an internet-mediated walking program and a standard walking program.[39] The latter study also reported no between group differences in quality of life.

In three studies, the technological support was the single difference between the experimental and control intervention.[37,39,44] In one paper the TSET intervention led to a greater reduction in pain,[37] one trial found no differences,[39] and TSET was less effective in another study.[44]

[INSERT TABLE 4 - *Effect sizes comparing TSET to other interventions* HERE]

<u>TSET vs. placebo or waiting list</u>

Six out of seven studies reporting pain as an outcome found no differences between TSET and a placebo[44,45-47] or a waiting list,[45,48,49] whereas four out of five studies showed no differences in disability.[44,47-49] In one study, the TSET-group improved significantly more on both outcomes.[40]

Four studies used paravertebral muscle control exercises with EMG-FB as technological support. EMG-FB exercises led to a greater reduction in pain and disability than a waiting list control group at post-treatment evaluation (ES range= 0.85, 1.19), but not at intermediate term in one study.[40] No significant between group differences in pain[44,45,49] or disability[44] were found in the other studies.

For both pain and disability, strengthening exercises with EMG-FB,[48] breathing exercises with respiratory FB,[46] and a single session of transversus abdominis muscle training with repetitive peripheral magnetic stimulation[47] were not more effective than a waiting list,[48] or a placebo (sham) intervention.[46,47]

[INSERT TABLE 5 - *Effect sizes comparing TSET to a placebo or a waiting list* HERE]

MIXED POPULATION

Three studies compared TSET to another intervention and included patients with both (sub)acute and chronic LBP. A TSET-program containing Wii-fit exercises led to greater reductions in pain and disability than physical therapy in one study (ES range= 0.88, 1.47).[30] Two studies comparing a conventional exercise program with exercises supported by postural feedback[28] or video-instructions[31] showed no between group differences in disability[28,31] and most aspects of quality of life.[31] The addition of motor control exercises supported by postural feedback to guideline-based physical therapy led to greater improvements in pain (ES= 1.27) and disability (ES range= 1.74, 1.87) than guideline-based physical therapy alone.[29]

No differences in disability[28,31] and quality of life[31] were found in two studies where the technological support was the single difference between the interventions.

4. Discussion

The aims of this review were to give an overview and to assess the effectiveness of the available TSET-programs for patients with LBP. Twenty-five RCTs were included that compared TSET to other forms of rehabilitation, a placebo intervention or no treatment. EMG-FB was used to support exercise therapy in nine papers, while few studies were available for the other technologies.

With regard to effectiveness, the results of this review show that TSET appears to improve pain, disability and quality of life in patients with subacute and chronic LBP, but seems not to provide beneficial effects for patients with acute LBP. When a TSET-program was added to a standard treatment, this was superior to a standard treatment alone. In most cases, however, TSET did not yield better results compared to other interventions or a placebo intervention (sham FB). Furthermore, when the technological support was the single difference between interventions, no between group differences could be found. One explanation for the lack of additional benefit from technological support, might be that these TSET-programs mostly adopted a narrow approach to exercise therapy, i.e. training of one particular function of a specific muscle or muscle group. For example, four out of seven studies comparing TSET to a placebo intervention used sEMG-FB to control paravertebral muscle activity and one study used a single session of transversus abdominis muscle training. Although alterations in paravertebral sEMG[50] and transversus abdominis muscle function[51,52] have been reported in patients with CLBP, it can be questioned whether these minimal interventions are sufficient to improve complex problems such as CLBP.

There is growing consensus that exercise therapy for LBP should be tailored to the patient's specific needs.[53-55] This implies that functional exercises, relevant for the individual patient have to be integrated in the rehabilitation process. Only one RCT[29] could be retrieved that incorporated technology into this functional approach, and therefore, the implementation of technological systems into functional movements or activities poses an important challenge. In this respect, O'Sullivan et al.[56] showed that patients with sitting-related CLBP experienced less pain when they received real-time postural feedback while watching a DVD, which was associated with an altered sitting behavior. In an attempt to reduce flexion postures and movements, Ribeiro et al.[57] investigated the effects of a wearable posture-monitor providing feedback on spinal flexion positions during daily life. Subjects receiving constant feedback significantly reduced spinal flexion after a 4-week intervention period. So, although there is evidence that real-time postural feedback from technological systems can improve spinal posture and reduce aggravating movements during daily life, its long term benefit on pain and disability needs further investigation.

The combination of a standard treatment with a TSET-program was superior to a standard treatment alone. This is in line with other research showing that a multimodal intervention leads to better outcomes than a unimodal intervention for patients with CLBP.[58] However, it should be noted that in five out of eight studies the standard treatment alone did not lead to significant improvements.[26,27,29,33,36] Adding a TSET-program to these ineffective treatments clearly improved pain (ES range= 0.27, 1.87) and disability (ES range= 0.76, 1.27).[26,27,29,33] The additional benefits of a TSET-program were less obvious when the standard treatment alone was already effective (ES_{pain}= 0.76, $ES_{disability}$= 0.06).[25,34,35] These results highlight the importance of including a form of (technology-supported) exercise therapy in the rehabilitation of patients with LBP. The supplementary effects might be more pronounced in patients who did not improve by means of their previous treatment, but are more likely to depend on the patient population and the content of both the (technology supported) exercise therapy and the standard rehabilitation. Indeed, some patients may not respond well to exercise therapy,[59] and might be better off with other types of treatment.[60]

Because the available technologies have changed over the years, it might be argued that interventions using more recently developed systems could result in better outcomes. Seven out of ten studies that were published before 2005 used EMG-FB as technological support,[24,36,38,40,44,45,49] whereas only two studies investigated the effects of EMG-FB in the past decade.[37,48] This suggests that a greater variety of technologies is currently available, but may also result from the lack of effectiveness of TSET-programs using EMG-FB.[24,36, 40,44,45,48,49] Looking at the more recent trials, two smaller studies (n= 60) with a high risk of bias showed that TSET was more effective than other treatments,[30,37] whereas four studies (n= 743), three with a low risk of bias, indicated that there was no difference between interventions.[28,31,39,43] Therefore, our overall conclusion remains that TSET is not more effective than other treatments, also when only recent studies are considered.

Future directions

The rehabilitation of CLBP is a long process often involving a home-exercise program. The problem is that up to 50-70% of patients with CLBP do not adhere to home exercise prescriptions.[61,62] Improving these numbers seems warranted, because the level of adherence has been reported to be a predictor of treatment success for patients with CLBP.[18,63] The use of technological applications that support therapy at home may offer an additional value for promoting adherence, as research in other patient populations has shown.[19,20] However, only five of the included studies provided patients with technological support in the home situation,[28,29,31,39,46] and only two of these studies reported data on adherence to home exercises.[28,39] Hügli et al.[28] showed that there was no difference in time spent on home exercises between subjects who practiced in a game-environment and subjects who performed conventional exercises. Krein et al.[39] compared two pedometer-supported walking programs, where one group had also access to a specific website and received automated feedback messages on walking goals. Only 20-25% of patients logged-in to the website or uploaded pedometer data for more than 80% of recommended times, and this online support did not result in a significant increase in daily walking distance. These results suggest that simply providing patients with LBP with technological support at home does not automatically lead to an improved adherence. Consequently, specific interventions are probably needed.[64]

Treatment effects might also be enhanced by offering reliable feedback on the quality of exercise performance by using technology.[15,16] Patients with CLBP often display altered movement patterns at the spine,[65] making the evaluation and correction of these patterns key components in the rehabilitation.[53] Besides clinical judgement by a therapist,[66] movement patterns can be assessed with kinematic measurements.[67,68] However, the feasibility of kinematic assessment and feedback provision during exercises, especially in the home-environment, is limited because of several reasons. Most of the kinematic assessment tools are complex, require a standardized set-up and are used in laboratory situations. More simple devices have been developed to address these disadvantages, but they may not be suited for precise kinematic assessment during three-dimensional movements.[69] Of course, it can be argued how precise feedback needs to be in a clinical setting. Rather than constantly keeping a fixed neutral lordosis in the lumbar spine, patients should prevent excessive end range movements and postures.[53] Preliminary results show that the latter can be achieved for movements in the sagittal plane by feedback from portable technological devices.[56,57] Therefore, we believe that these types of technological systems are worthwhile pursuing further.

Study limitations

Because the field of rehabilitation technology is rapidly changing and we only included RCTs, this review does not provide an exhaustive overview of the available technological systems that support exercise therapy for patients with LBP. Furthermore, 68% of the studies used a CLBP population, and besides EMG-FB, a limited number of studies per technology could be retrieved. This makes it difficult to draw firm conclusions on the effectiveness of the technologies other than EMG-FB, and on the effects of TSET on (sub)acute LBP. Only five studies were found where the technological support was the single difference between the TSET and control intervention. This means that in the majority of the studies, the TSET-program was compared to a different exercise program or a non-exercise intervention. Consequently, the results on the additional effects of the technological support itself could only be based on few studies. Finally, about half of the studies had a high risk of bias and an adequate power-calculation was lacking in most of the papers, limiting the strength of our conclusions.

5. Conclusions

The additional benefit from technological support on pain, disability and quality of life is limited, also when only recently published trials are considered. Only the addition of a complementary TSET-program to a standard treatment resulted in significantly greater improvements on these outcomes. The lack of supplementary effectiveness of technological systems may partly be explained by the fact that the current technologies are mostly used during analytical exercises and are not introduced into functional rehabilitation or in the home environment.

Author contributions

The systematic search, screening of articles, data extraction and risk of bias assessment was performed by T.M. and A.T. The draft was written by T.M., and A.T. and S.B. revised the manuscript for content and language. All authors discussed the results and commented on the manuscript.

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