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Effectiveness of and user experience with web-based interventions in increasing physical activity levels in people with Multiple Sclerosis: A systematic review

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Running Head: Web-based interventions in MS

Title: Effectiveness and user experience of web-based interventions in increasing physical activity levels in people with Multiple Sclerosis: A comprehensive systematic review

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Title: Effectiveness and user experience of web-based interventions in increasing physical activity levels in people with Multiple Sclerosis: A comprehensive systematic review

Abstract 275 words

Background: Supporting people with MS to achieve and maintain recommended levels of physical activity is important but challenging. Web-based interventions are increasingly used to deliver targeted exercise programmes and promote physical activity.

Purpose: To systematically review current evidence regarding the effectiveness and user experience of web-based interventions in increasing physical activity in people with multiple sclerosis.

Data Sources: MEDLINE, EMBASE, CINAHL, AMED, PEDro, PsychInfo, Web of Sciences, The Cochrane Library and grey literature were searched from 1990-September 2016.

Study Selection: English language articles reporting use of web-based interventions to increase physical activity in adults with MS were included. Eligible quantitative studies were of any design and reported a measure of physical activity. Qualitative studies exploring users' experiences, in any context were included. Of the 881 articles identified, nine met the inclusion criteria.

Data Extraction: Two reviewers independently assessed methodological quality and extracted data using standardized critical appraisal and data extraction instruments from the Joanna Briggs Institute Meta Analysis of Statistics Assessment and Review Instrument (JBI-MASTARI).

Data Synthesis: Meta-analysis of self-reported physical activity questionnaire data from four studies demonstrated a SMD of 0.67 95%CI [0.43, 0.92] indicating a positive effect in favour of the web-based interventions. Narrative review of accelerometry data from three studies indicated increases in objectively measured physical activity. No qualitative studies met the inclusion criteria.

Limitations: Of the nine included articles only two different interventions, used with people who were ambulant were reported.

Conclusions: Web-based interventions have a short term positive effect on self-reported physical activity in ambulant people with MS. Evidence is not currently available to support or refute their use in the long term or with people who are not ambulant.

Keywords: internet, multiple sclerosis, physical activity

Abbreviations: MS-multiple sclerosis

Body of manuscript 4984 words

Introduction

Multiple Sclerosis (MS) is a progressive neurological condition that can result in wide-ranging impairments that may impact negatively upon activity and participation levels. Evidence demonstrates that people with MS are more sedentary and physically inactive than those in the general population, even in the early stages of the disease.[1,2] This is thought to be due to a combination of factors which include the direct effect of MS-related impairments, and the general deconditioning and functional deterioration which occurs as the disease progresses.

It is now well established that targeted exercise and increased levels of physical activity can result in a range of physical [3,4,5,6,7] and emotional [8,9] benefits for people in the early stage of MS, although this is yet to be established for those in the progressive phase of the disease. [10,11] Such increases in physical activity are important to minimize the complications and comorbidities associated with living a more sedentary lifestyle.[12] Furthermore, recent literature has suggested possible neuro-protective properties of exercise in people with MS.[13] Accordingly, there has been an increased emphasis within clinical practice to incorporate exercise programmes, and facilitate engagement with physical activity.[14] This approach aligns with public health guidelines,[15] developed to promote physical activity participation in the general population at a sufficient level to achieve health benefits.

Evidence based physical activity guidelines recommend that people with MS who have mild to moderate disability should aim to participate in 30 minutes of moderate intensity aerobic activity twice a week and progressive resistance training involving major muscle groups twice a week.[16] There are no current guidelines regarding the prescription of physical activity levels for people with MS who have higher levels of disability.

Ensuring that adequate levels of physical activity are sustained in the long term is challenging, both for people with MS and for those involved in their management.[17] Choice of activity, advice and support, control over level of engagement[18] and the ability to develop ‘self-support’ [19] have been identified as key factors to facilitate participation with physical activity. The low levels of physical activity in people with MS[20] has also prompted researchers to identify the barriers to participation that people with MS experience. Fatigue, lack of time, and the effort and travel distance required to access rehabilitation venues are reported as barriers.[21,22] In parallel, health services across the world face ever-increasing financial pressures, enforcing reconsideration of cost effective, evidence-based service delivery.

Innovations in technology, such as the use of the internet, are increasingly being used as a method for delivering physical activity interventions. Reviews of such web-based interventions in the general population, as well as in conditions such as obesity, rheumatoid arthritis and diabetes, have indicated promising results.[23,24] More recently, two systematic reviews of randomised controlled trial studies in MS, evaluating a broad spectrum of telerehabilitation interventions (including gaming interventions, telephone support and the use of pedometers), suggest that these distance-based interventions may be effective in increasing physical activity, [25,26] but that further robust research in this area is needed. However, the broad nature of these reviews means that it is not possible to evaluate the effectiveness of specific types of telerehabilitation interventions. Qualitative work[27] and process evaluation questionnaires[17] have been undertaken to explore the feasibility and acceptability of such web-based interventions, and provide helpful information to guide their on-going development. User feedback is important to optimise their effectiveness in enabling people with MS to increase and sustain physical activity levels in the long term.

This systematic review focused on studies of any design that investigated the use of interventions delivered via the internet that aimed to increase physical activity (as defined by Casperson)[28] in people with MS. It sought to establish their effectiveness in increasing physical activity, over the short (≤ three months) and long term (> three months), [25] and whether levels of activity met MS specific guidance.[16] This systematic review was conducted according to an *a priori* published protocol ref CRD42016054084. [29]

The original aim of this systematic review was to comprehensively explore the use of web-based interventions in increasing physical activity levels in people with a diagnosis of multiple sclerosis (MS), including both qualitative and quantitative data. As the literature search only yielded quantitative papers, it was not possible to address the qualitative objectives. Therefore, only the quantitative elements of the review are reported in this paper.

The quantitative objectives were to identify:

- The effectiveness of web-based interventions in enabling people with MS to increase their physical activity levels as evaluated by measures of physical activity.
- If short or long-term web-based interventions enable people with MS to achieve the physical activity levels recommended in guidelines for adults with MS whilst they are being used.
- If the use of web-based interventions enable people with MS to maintain recommended levels of physical activity after the intervention has ceased, at short and long-term follow-up.

Methods

Data Sources and Searches

Searches aimed to find both published and unpublished studies. A three-step search strategy was utilized. An initial limited search of MEDLINE, AMED and CINAHL was undertaken followed by an analysis of the text words contained in the title and abstract, and of the index terms used to describe articles. A second search using all identified keywords and index terms was then undertaken across all included databases. Thirdly, the reference list of all identified reports and articles was searched for additional studies. Studies published in English since 1990 were considered for inclusion. This date restriction is in place as the World Wide Web was established in 1989, and therefore web-based interventions were not possible prior to this. Two independent reviewers screened abstracts and full text articles for eligibility for inclusion, and any duplicates were removed.

Initial keywords used:

1) Web-based OR internet-based OR www OR world wide web OR e-learning OR telerehabilitation OR telemedicine OR eHealth
2) Multiple sclerosis OR MS OR neurological condition OR neurolog*
3) Physical activity OR exercise OR physical fitness OR walking OR motor activity OR rehabilitation OR physiotherapy

The full search strategy is provided in Appendix 1.

Databases searched were MEDLINE (Ovid), EMBASE (Ovid), CINAHL (EBSCO), AMED (EBSCO), PEDro, PsychInfo, Web of Sciences, The Cochrane Library, and The Cochrane Central Register of Controlled Trials (CENTRAL). The search for unpublished studies included hand searches of reference lists of all identified articles and searches using Google Scholar, Conference Papers Index and clinical trials registers via www.controlled-trials.com and http://clinicaltrials.gov. In two cases, authors were then contacted directly to request the full papers for inclusion.

Study Selection

This review considered studies that included adults over the age of 18 with a diagnosis of MS, regardless of MS type, time since diagnosis or level of disability. It considered both experimental and epidemiological study designs including randomized controlled trials, non-randomized controlled trials, quasi-experimental studies, before and after studies, prospective and retrospective cohort studies and case control studies.

Studies that investigated the use of web-based interventions that were exercise or lifestyle activity based, and/ or incorporated a behaviour change or coaching approach to increase physical activity were reviewed. Studies reporting an active comparator, usual care or waitlist control and those without such comparators were included. Interventions describing any regimen of frequency or intensity of delivery were included. Studies that described use of the Internet to deliver virtual assessments or gaming interventions (such as Wii or Xbox) were not included.

Studies were considered if they included measures of physical activity such as accelerometer, pedometer or Global Positioning System data or physical activity questionnaires. Adherence/ compliance outcomes, when measured alongside physical activity data were also included, for example by recorded numbers of logins to web-based interventions or completion of activity diaries. The purpose of this review was not to evaluate the effectiveness of web-based interventions at the level of impairment, hence outcomes such as weight loss, reduced blood pressure, increased cardiovascular fitness or muscle strength were not considered.

Data Extraction and Quality Assessment

Papers selected for retrieval were evaluated by two independent reviewers using a two-stage process to assess relevance and quality. Standardized critical appraisal instruments from the Joanna Briggs Institute Meta Analysis of Statistics Assessment and Review Instrument (JBI-MAStARI) were used (accessed via https://www.jbisumari.org/). Any disagreements that arose between the reviewers were resolved through discussion, or with a third reviewer where required. The outcomes of the quality assessments were summarised by calculating the number of items that were marked as present for each study. In keeping with the aim to be as comprehensive as possible, a cut-off point for inclusion was not set for the quality review stage; however, the outcome of the quality assessment was considered when making inferences from the data synthesis.

Data were extracted from papers using the standardized data extraction tool from JBI-MAStARI. The data extracted included specific details about the interventions, populations, study methods and outcomes of significance to the review question and specific objectives.

Data synthesis and Analysis

Where possible, data were combined in statistical meta-analysis to obtain a pooled standardized mean difference with 95% confidence interval (95% CI). Where standard deviations were not reported, they were imputed from the reported standard error using the formula $SD = SE \times \sqrt{N}$.[30] Because of the small sample sizes and variability of sample characteristics within the studies,[31] a random-effects generic inverse variance analysis was undertaken. The pooled data set was analysed for heterogeneity using a combination of visual inspection and consideration of the chi-squared statistic, setting a P value of 0.10.[32] Where statistical pooling was not possible, the findings are presented in narrative form, including tables and figures to aid in data presentation.

Results

Study Selection

One reviewer (RD) performed the searches in September 2016. In total, 881 records were identified, which after removal of duplicates resulted in 618 titles and abstracts being screened for eligibility. The results of the searches are presented in the study selection flow chart (Figure 1), with specific details of the included studies in Table 1.

Insert figure 1

Insert table 1

Critical Appraisal Results

Insert table 2

Methodological quality

Insert table 3

Summaries of the appraisal of study quality are included in tables 2 and 3. Standards of reporting were generally good with both case series articles being marked as ‘Yes’ for all questions. Within the randomised controlled trials, the median number of ‘yes’ scores was 10 of a possible 13 items (inter-quartile range 8.75-10.25). The most frequently omitted methodological items related to blinding of research assessors and management of incomplete outcome data. Blinding of both participants and treating therapists was not reported to have been undertaken in any trial, a common finding in reviews of rehabilitation trials.[40]

Description of the participants

The total number of participants recruited from the included studies was 346. Baseline characteristic data was available for 340 participants, of whom 68% were female, with a mean (SD) age of 45.7 (9.4) years and disease duration of 8.9 (7.0) years. Participants were ambulatory with the majority (75%) walking unaided. Disability status was described using the Patient Determined Disease Steps (PDDS) scale [41] in all but one study[39] where the Expanded Disability Status Scale[42] was used. Four studies only included participants with a classification of Relapsing Remitting MS.[34,35,17,36] The remaining studies included people with both progressive and relapsing remitting sub-types[1,37,38,2, 39] (four of which reported on the same study sample). Tallner[39] excluded those with a primary progressive disease course. Eight of the nine studies were based in the USA, with one in Germany.[39]

Study designs

Seven of the included articles report on RCTs of internet based interventions with waitlist controls (Table 1).[1,2,17,34,37,39] Four of these [1,2,37,38] report different aspects of the same study, and hence to avoid double counting of data, of these only Pilutti et al[37] has been used within the meta-analysis. The other two included studies are single group design where participants are the waitlist controls from previously reported studies. [35,36] Only one of the studies[39] described their sample size calculation.

Description of web-based interventions

Eight of the nine articles report on studies that were part of the development process of a behavioural intervention designed to increase physical activity by promoting additional walking as part of everyday life. The intervention was initially trialled as a 12-week multimedia internet intervention[34,35] that focused on four information modules based on the Social Cognitive Theory: Getting Started, Planning for Success, Beating the Odds and Sticking with it. Content of the modules was made accessible during the intervention period in a titrated fashion and was supported with group chat sessions and a telephone line and email address to provide direct contact with the study team. The professional background of the study team is not described. Subsequent studies[17,36] described the addition of seven one-to-one video coaching sessions via Skype with the aims of increasing participant website login, and reinforcing, and clarifying website content with them. The coach was a doctoral student with expertise in behavior change and experience in conducting physical activity research in people with MS. In these five-to-ten minute sessions the participant and coach reviewed and progressed goals and discussed strategies to aid behaviour change based on the website content that had already been accessed. [17,36] In the latest reported study,[37] the intervention was delivered over six months and included 15 of the video coaching sessions. Intervention group participants in this study also wore a pedometer and completed a logbook and goal tracker spreadsheet to motivate and record physical activity as part of the programme.

Tallner et al [39] describe a different intervention approach delivered via the internet; a six-month, individually prescribed, twice-weekly strength training and weekly endurance training (jogging, walking, cycling or swimming) programme. The trainers were physical therapists or exercise therapists with experience of rehabilitation of people with MS and trained in the exercise prescription and study processes. Participants received supervision, and had their exercise programmes progressed online using a standardized progression scheme, delivered via a messaging service in the web-based software (not in real time) with further email and telephone support if required. None of the articles published after the development of the TIDieR guidelines [43] made reference to them in reporting their interventions,[2,39] although a summary of the intervention components is provided within each article.

Description of outcomes

Physical activity

Physical activity was measured using both self-report and objective measures. Three different standardized and validated self-report measures were used. The Godin Leisure Time Exercise Questionnaire (GLTEQ) was reported in six articles, [2,17,34-37] the International Physical activity Questionnaire (IPAQ) in five,[1,2,35,36,38] (three of which report the same sample[1,2,38]) and the Baecke Questionnaire in one.[39] The

GLTEQ[44] includes three items that measure the frequency of light, moderate and vigorous leisure-time physical activity completed for at least 15 minutes over the previous seven days, which are weighted and summed (0-119). The IPAQ[45] has six items that measure the frequency and duration of vigorous, moderate and walking physical activity over a seven-day period which are then weighted and summed (0-117). The sport score of the Baecke Quesionnaire[46] is the product of the frequency, intensity and duration of a participants reported sports activities. In each of these measures, higher values indicate increased levels of physical activity.

Accelerometers, worn at the waist during waking hours, were used to collect objective physical activity data over seven days in three studies [35-37] and are reported as part of a composite measure in a secondary analysis article.[2] The activity counts per day (for days when the accelerometers were worn for at least 10 hours) were converted into minutes of moderate to vigorous physical activity (MVPA) per day using validated cut-off points.[47,48] In addition, pedometer steps-per-day data, as a descriptive measure of change in physical activity were available from intervention group participants in four studies [17,35-37] where higher numbers of steps per day demonstrate greater levels of activity. Although no MS specific step count recommendations are available, a value of 7100 steps/ day is suggested to equate to someone achieving 30 minutes MVPA from the healthy older adult and special group population literature.[49]

Compliance

Compliance with using the interventions was reported in six studies[1,17,34-36,39] as numbers or percentages of website logins or percentage of participants completing their prescribed programme.

Process evaluation

Process evaluation questionnaires were incorporated at the end of two studies.[17,35] Information regarding overall satisfaction of the intervention, the website and the staff delivering the programme was collected.

Effectiveness of interventions in increasing physical activity levels

Both self-report and objective data is available from the included studies and these will be presented separately.

Self-report Physical Activity Questionnaires

Self-reported physical activity questionnaire data was available from four different study samples (n=277 complete data sets). Participants in the intervention groups participated in significantly more self-reported physical activity compared with controls: $p=0.001$, $d=0.77$ [37]; $p=0.01$, $d=0.72$ [34]; $p=0.001$, $d=0.33$ [39] and $p<0.001$, $d=0.98$, [17] which remained statistically significant at three-month, follow up ($p<0.001$, $d=0.79$). These data were pooled in a meta-analysis (figure 2). The pooled SMD

0.67 95%CI [0.43, 0.92] indicates a positive effect in favour of the web-based interventions.

Self-report physical activity questionnaire data was also available from the two single group studies. One, [35] the waitlist control group from the initial pilot study, demonstrated a small and non-significant increase in GLTEQ scores (p=0.07, d= 0.34) and a significant improvement in IPAQ scores (p=0.03, d= 0.43). In the second follow-up single group study[36] a statistically significant and large increase in GLTEQ scores (p<0.0015, d=0.83) and IPAQ scores (p<0.001, d=1.12) was demonstrated on completion of the treatment period, which had not been seen in the period of no treatment.

Accelerometry data

Accelerometry data was only available from one RCT [37] and the two single group studies [35,36] and is therefore reported here narratively. Pilutti[37] presented accelerometry data which indicated that participants in the intervention group achieved a moderate but non-significant increase in time spent undertaking MVPA compared with controls (p=0.07, d=0.43). This equated to an average increase of just under six minutes a day of extra MVPA compared with controls. Reporting on the same study, Motl [2] conducted a secondary analysis in which a composite score of PA was created combining GLTEQ, IPAQ and accelerometry. This composite physical activity data was analysed using a one-way ANCOVA, controlling for baseline physical activity scores, and demonstrated that the intervention group had significantly higher levels of physical activity compared with those in the waitlist control group after the six-month intervention ($p<0.001$, $np^2=0.12$), which the authors report to be a “practically meaningful effect”.[2] The pre- and post-intervention accelerometer data from two single group studies[35,36] demonstrated statistically significant increases in both total activity (counts per day ($p=0.002$, $d= 0.68$)[35] and $p<0.001$, $d=0.92$[36]; and total step counts per day $p<0.001$, $d=1.03$[36]).

Intervention group pedometer data were reported from three studies[17,36,37] all of whom report increases in weekly pedometer step counts. Two of the studies note that the increases occurred during the first six weeks of the 12-week interventions and were maintained to the end.[17,36] The magnitude of these increases range from 22% or an average of 1387 steps per day[35] to 46% (1869 steps),[36] both in excess of the minimal clinically important difference which would indicate a change in ambulation and clinical/health outcomes in MS.[50] As there is no control-group pedometer data, it is not possible to comment on whether these increases were due to the intervention.

Achievement of recommended levels of physical activity

Although all articles describe the importance of physical activity in people with MS and one[39] makes direct reference to exercise prescription recommendations [51] none report physical activity levels in line with recommendations for either the general [52] or MS [16] populations. Four[17,34-36] of the nine articles were however, published before the publication of the MS-specific guidelines. Detailed information regarding the type and intensity of physical activity undertaken is only reported in one study, [39] where participants were individually prescribed strength and self-selected endurance-training programmes based on their fitness level. A standardized progression scheme was used to facilitate strength training overload, and guidance was given regarding endurance training intensity levels in line with recommendations.[51] There is no detail provided as to whether this was achieved or whether this data was collected.

Dlugonski et al[17] report intervention group pedometer data that demonstrated that the sample walked an average of 6368 steps per day in the final week of the 12-week intervention. Data from the follow-up single group study[36] however, report that 67% of the participants exceeded 7100 steps/ day over a week; above the value suggested[49] to be required for accumulating 30 minutes of MVPA each day for older adults and special populations.

Maintaining physical activity levels in the short and long-term

Compliance data was collected by six of the included studies and is summarized in table 4. In the U.S. behavioral intervention studies, compliance with the early stages of the intervention [34,35] decreased during the intervention periods, but this was demonstrated to be improved by the addition of video coaching sessions during development of the intervention programme.[1,17,36] In the German exercise-based study, however, although web-based one-to-one support was available for each participant, compliance with documented training sessions in the online activity journal declined after four weeks, falling to 36% of documented sessions after three months. However, it is not possible to establish if participants were continuing to exercise and not documenting their engagement with the programme, or if they were no longer adhering to their exercise programme.

Only one study[17] collected follow up physical activity data (self-report physical activity at three months) which demonstrated that the increase in physical activity post intervention ($p<0.001$, $d=0.98$) was sustained at three months ($p<0.001$, $d=0.79$).

Process Evaluation

Twelve of the 21 participants provided feedback in one study[35] and 21 of the 22 who completed the intervention in another.[17] Participants in both studies reported a high degree of satisfaction with the programme as a whole, the staff involved, and an overall willingness to recommend the intervention to others. They reported less satisfaction with the intervention website, citing disinterest[35] in the online group chat sessions, and difficult to use forum section, as reasons for this and suggested that the programme would benefit from more interaction with other participants.

Discussion

The purpose of this systematic review was to examine the effectiveness of web-based interventions in enabling people with MS to increase their physical activity levels. Further, to ascertain if any increases were in line with recommended levels for adults with MS[16] and were maintained at short and long term follow-up.[25] The review also set out to include a qualitative component, but as no studies were found that met the inclusion criteria, it is not possible to achieve this aim of the review.

Effectiveness in enabling increased physical activity levels

The results of the meta-analysis of self-report physical activity data demonstrated that web-based interventions had a moderate positive effect on physical activity in participants with mild disability. Self-report measures are recognised to have limitations in terms of social desirability and recall biases in their use.[53] Further, the GLTEQ measures only leisure-time exercise of longer than 15-minute duration and the Baecke Sports score, only time in recognised sports; neither therefore capture the important shorter bursts of activity that people engage in throughout their day. To our knowledge, there are no established minimal clinically important differences (MCID) for self-report measures of physical activity and hence understanding the meaningful change also remains difficult. These issues highlight the importance of collecting more complete, objective data to accurately picture a person's daily lifestyle activity and help provision of the most appropriate physical activity advice.

Participants in all included studies had minimal disability, with a high percentage reporting no limitations to walking. Hence, it is not possible to comment on whether such interventions would be effective for people with higher levels of disability. Indeed, results from a secondary analysis of data from Pilutti et al[2] demonstrated a disability x time effect suggesting that their six-month intervention was most effective for those whose mobility was least affected. Other analyses went further, suggesting a greater effect for people with Relapsing Remitting MS and normal weight. In many countries, the population of people with MS who access healthcare systems have typically higher levels of disability and as such, this raises the question whether web-based interventions can also be beneficial for this group. Further, it may also challenge current practice, pointing to provision of physical activity promotion and rehabilitation input at earlier stages of the disease.

Participants from most of the included studies completed the PAR-Q[54] , a tool designed to help people evaluate their medical fitness prior to engaging in physical activity. Whilst fitness to exercise is very important, none of the studies asked participants about their attitude or readiness to engage in increased physical activity. It may be important to incorporate such questions prior to using such interventions in practice, where targeting a population ready to engage may have greater clinical and cost benefits.

Walking was the most common type of physical activity encouraged in the included studies. In order to describe the amount of activity undertaken at recommended levels, data was presented as steps per day or time spent undertaking MVPA. Those that reported time spent in MVPA calculated this according to defined cut-off points[1] of numbers of steps/ minute that would equate to MVPA. It is suggested that for people whose disability levels are higher, the increased effort of walking[55] may mean that the number of steps/ minute to reach MVPA is lower.[2,48] There is no available data regarding required numbers of steps per day for people with MS to achieve 30 minutes of MVPA, so reference is made to 7100 steps per day over one week, the figure obtained from the older adult and special groups literature. [49] For those people where it is too challenging to engage in sufficient walking to achieve health benefits, accessing other types of physical activity to achieve an adequate duration and intensity of activity is important.[1] This was incorporated in to the Tallner [39] intervention, where choice of endurance activity included activities such as cycling, swimming and cross training.

Achievement of recommended levels of physical activity

Physical activity guidelines for people with MS with mild to moderate disability recommend that people should aim to undertake 30 minutes of moderate intensity aerobic activity twice a week and progressive resistance training involving major muscle groups twice a week. [16] The findings of this review are such that it is not possible to suggest whether web-based interventions facilitate people with MS to meet these guidelines. Although some[17,35-37] of the eight articles describing the US behaviour intervention development included accelerometer or pedometer data (that could be used to estimate time undertaking MVPA), none report whether any of the web-based modules or coached sessions discussed or prescribed strength training. The final article[39] described a targeted exercise programme including both strength and endurance components that could therefore have facilitated meeting recommendations, but do not present data as to whether prescribed levels were achieved, sufficiently intensive, or performed for long enough.

One of the potential benefits of a web-based intervention is that it may be used to help people maintain activity levels in the long term. As such, the issue of compliance is an important one to consider. The importance of appropriate support to facilitate engagement with exercise is well recognised. [56,39] In the included studies such support was provided by: experienced doctoral students (whose clinical background in not stated) in the behavioural intervention studies; [17,36,37] and physical therapists or exercise therapists in the targeted exercise intervention study.[39] The opportunity to engage with web-based support through a messaging service, with email and telephone options as required, did not appear to help participants adhere to the programme in the latter study[39] where adherence with documenting training sessions had already begun to reduce after four weeks. During the development of the U.S behavioural intervention however, the addition of web-based individual coaching sessions as part of the intervention was demonstrated to be instrumental in increasing compliance.[17] It is perhaps the case therefore, that planned, face-to-face sessions were key to the delivery of successful online support. This gives rise to the question as to whether it was the coaching itself or its role within the intervention package that made the difference. A further area of note is whether measuring compliance as numbers of log-ins or attendance at a coaching session truly represents the level of engagement with an exercise programme or indeed adherence with increased physical activity.

Maintenance or physical activity levels in the short and long-term

It is not possible to comment on whether the web-based interventions enabled people to sustain recommended levels of physical activity in the long-term due to the lack of data. Only one study[17] included any follow-up beyond the post intervention assessment and that was short term, at three months. The statistically significant increases in self-reported physical activity, which remained at three months is promising, but longer term follow-up data is required to enable thorough discussion of this issue.

Strengths and limitations of this review

One of the strengths of the review was that it set out to include both qualitative and quantitative studies of any design, not only randomised controlled trials. This systematic review has enabled clarification of the existing body of literature, which can be sometimes difficult given the wide-ranging publication sources. It has identified that, of the nine articles published, there is multiple secondary reporting of a single study, resulting in six independent data sets (two of which were single group studies). It has identified that the included studies, in essence, report on just two different interventions. The web-based intervention inclusion criterion was chosen because of the very distinct role such interventions can provide and the specific challenges they present. This was in contrast to two previous technology based systematic reviews in MS [25, 26] and resulted therefore in this focused review only including a small number of studies, which could be considered a limitation.

Conclusion

This systematic review suggests that web-based interventions have a positive effect on self-reported physical activity in ambulant people with MS, in the short term. There is insufficient evidence to comment on their effectiveness on objective physical activity data or whether increases in physical activity equate to disease specific or worldwide physical activity recommendations. Due to the lack of follow-up data, it is also not possible to suggest whether such interventions can have an effect on physical activity levels in the long-term. Similarly, it is not possible to comment on whether they can be effective for people with higher levels of disability, but it may be that web-based interventions have greatest impact on physical activity when used in the early stages of the disease.

Implications for practice and research

Web-based interventions may be helpful in facilitating ambulant individuals with MS to increase their physical activity levels, at least in the short term. Evidence is not currently available to either support or refute the use of web-based interventions in enhancing physical activity levels in individuals with MS who are not ambulant. The importance of the user experience should be considered in the on-going development and evaluation of web-based interventions in the MS population. Research into the short and long-term effectiveness of such web-based interventions, especially for those with higher levels of disability, is required. Finally, determining the most effective support methods to maximise compliance with web-based interventions is vital.

Conflict of interest

The authors declare no conflict of interest.

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Table 1: Summary of articles reporting included studies

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Table 4: Compliance data reported

Table 1. Summary of articles reporting included studies

Study/ Year/ Country	Study design	Number of Participants (total, %female)	Disability level	Disease course	Intervention	Physical Activity Outcomes (all participants unless stated)
Motl et al 2011[34] USA	RCT with waitlist control	54, 90% (data reported from 48)	PDDS 0-5	RRMS	12-week multimedia internet intervention, twice weekly online chat sessions, patient forum, telephone and email support	GLTEQ, intervention group compliance
Dlugonski et al 2011[35] USA *	Single group	21, 90% (control group from Motl et al 2011)	PDDS 0-5	RRMS	12-week multimedia internet intervention, twice weekly online chat sessions, patient forum, telephone and email support (same intervention as Motl et al 2011)	GLTEQ, IPAQ, 7-day accelerometer, compliance
Dlugonski et al 2012[17] USA‡	RCT with waitlist control	45, 87%	PDDS 0-6	RRMS	12-week internet delivered behavioral intervention plus 7 video coaching sessions	GLTEQ, intervention group; pedometer, compliance
Motl and Dlugonski[36] 2011* USA	Interrupted time series Single group	18, 89% (control group from Dlugonski 2012)	PDDS 0-4	RRMS	12-week internet delivered behavioral intervention plus 7 web-based video coaching sessions (same intervention as Dlugonski et al 2012)	GLTEQ, IPAQ, 7 day accelerometer, pedometer, compliance
Pilutti et al 2014[37] USA	RCT with waitlist control	82, 76% (data reported from 76)	PDDS 0-6	RRMS and progressive MS	6-month multi-component behavioral intervention plus 15 web-based video coaching sessions	GLTEQ, 7-day accelerometer, intervention group pedometer

Study/ Year/ Country	Study design	Number of Participants (total, %female)	Disability level	Disease course	Intervention	Physical Activity Outcomes (all participants unless stated)
Klaren et al 2014[38] USA†	RCT (secondary analysis)	70 (of the 82 in the Pilutti study) 78% female	PDDS 0-6	RRMS and progressive MS	6-month multi-component Behavioral Intervention plus 15 web-based video coaching sessions (same intervention as Pilutti et al 2014)	Question 7 of IPAQ
Sandroff et al 2014[1] USA†	RCT with waitlist control (secondary outcomes)	Same 82 from Pilutti study, data reported from 76. 76% female	PDDS 0-6	RRMS and progressive MS	6-month multi-component behavioral intervention plus 15 web-based video coaching sessions (same intervention as Pilutti et al 2014)	IPAQ. Compliance
Motl et al 2015 [2] USA†	RCT with waitlist control	Same 82 from Pilutti study, data reported on 76 76% female	PDDS 0-6	RRMS and progressive MS	6-month multi-component behavioral intervention plus 15 web-based video coaching sessions (same intervention as Pilutti et al 2014)	Composite PA score from GLTEQ, IPAQ and 7-day accelerometer
Tallner et al 2016[39] Germany	RCT with waitlist control	126, 75% (data reported from 108)	EDSS 0-4	RRMS and SPMS	6-month programme 2x week strength training, 2–3 sets per exercise. Endurance training x1 week. Home-based and supervised via the internet	Baecke Questionnaire, compliance

RCT: randomised controlled trial; EDSS: Expanded Disability Status Scale; PDDS: Patient Determined Disease Steps Scale; RRMS: relapsing remitting multiple sclerosis; MS: multiple sclerosis; SPMS: secondary progressive multiple sclerosis; GLTEQ Godin Leisure Time Exercise Questionnaire; IPAQ: International Physical Activity Questionnaire; PA Physical Activity.

*waitlist in single group study following the main study, † studies report secondary outcomes or secondary analysis of the original sample data.

‡ Data collected at baseline at post intervention except Dlugonski et al[17] where a three-month follow up was conducted.

Table 2: Methodological Quality Assessment: Case Series Designs

Quality Criterion	Dlugonski 2011[35]	Motl and Dlugonski 2011[36]	%
Clear inclusion criteria	Y	Y	100
Standard, valid and reliable measurement of the condition?	Y	Y	100
Consecutive and complete inclusion of participants	Y	Y	100
Clear reporting of demographic information	Y	Y	100
Clear reporting of clinical information	Y	Y	100
Clear reporting of outcomes or follow up results	Y	Y	100
Clear definition of the condition/disease of interest in the case series	Y	Y	100
Clear reporting of the presenting site(s)/clinic(s) demographic information	Y	Y	100
Appropriate statistical analysis	Y	Y	100
Total number of ‘yes’ scores (maximum 9)	9	9	

Table 3: Methodological Quality Assessment: Randomized Controlled Trial Designs

Quality Criterion	Dlugonski 2012[17]	Klaren 2014[38]	Motl 2011[34]	Motl 2015[2]	Pilutti 2014[37]	Sandroff 2014[1]	Tallner 2016[39]	Completion %
True randomization used for assignment of participants	Y	Y	Y	Y	Y	Y	Y	100
Concealment of allocation to treatment group	Y	Y	Y	U	Y	U	Y	71.42
Treatment groups similar at the baseline	Y	Y	Y	Y	Y	Y	Y	100
Blinding of participants to group assignment	N	N	N	N	N	N	N	0
Blinding of those delivering treatment to group assignment	N	N	N	N	N	N	N	0
Blinding of outcomes assessors to group assignment	U	Y	Y	U	U	N	Y	42.85
Identical group treatment other than the intervention of interest	Y	Y	Y	Y	Y	Y	Y	100
Complete follow up, or use of strategies to address incomplete follow-up	Y	Y	Y	N	N	N	N	42.85
Analysis of participants in the groups to which they were randomized	Y	Y	Y	Y	Y	Y	Y	100
Measurement of outcomes in the same way for treatment groups	Y	Y	Y	Y	Y	Y	Y	100
Outcomes measured in a reliable way	Y	Y	Y	Y	Y	Y	Y	100
Use of appropriate statistical analysis	Y	Y	Y	Y	Y	Y	Y	100
Was the trial design appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?	Y	Y	Y	Y	Y	Y	Y	100
Total number of ‘yes’ scores (maximum 13)	10	11	11	8	9	8	10	

Table 4: Compliance data reported in six of the included studies

Study	Compliance measure	Outcomes	Conclusions
Motl 2011[34]	% participants logged in per week Average (SD) number of weeks participants logged in	96% in weeks 1 and 2, declined throughout 12 weeks 52% in weeks 8, 10, 11 71(+/- 15%) over 12 week period 8.6 (+/- 3.0)	Very weak correlation with change in PA (r=0.10, p= 0.64)
Dlugonski 2011[35]	% participants logged in per week Average (SD) number of weeks participants logged in	76% week 1, 81% week 2, 52% weeks 10-12 7.5 (+/- 4.3) over the 12 weeks	Significant correlation between number of weeks logged on and change in accelerometer data (r=0.42, p=0.03) but not with changes IPAQ (r=0.10, p=0.32) or GLTEQ (r=0.08, p=0.36)
Dlugonski 2012[17] (7 video coach sessions)	% participants logged in per week Average (SD) number of weeks participants logged in Average number of video coaching sessions attended	~73% participants logged in ≥ 10 weeks of the 12 week intervention 10 (+/- 2.7) 6.8 (range 6-7) 77% of participants attended all 7.	Weekly log in moderately and significantly correlated with change in weekly pedometer step counts between weeks 1 and 12 (r=0.43, p=0.05) Negligible and non-significant correlation with weekly log in and change in self-report PA (r=-0.03, p=0.90)
Motl and Dlugonski 2011[36] (7 video coach sessions)	Average (SD) number of weeks participants logged in Average (SD) Number of video coaching sessions attended	10.6 (+/- 3) of 12 week intervention 6.6 (+/- 0.6) scheduled sessions	Moderate and significant correlation between weekly log in and number of coaching session attended (r=0.45, p<0.05) and between weekly log in and change in GLTEQ score (r=0.51, p<0.05), but non-significant correlation with weekly log in and change in IPAQ score (r= 0.35, p=0.08)
Sandroff 2014[1] (15 web-based video coach sessions)	% participants who participated in: all intervention features Website log in Uploading step counts Attended video coach sessions	overall compliance 88.6% 80% 88%	No further information regarding time points or possible correlations
Tallner 2016[39]	% participants who documented at least 80% of prescribed training programme during: Month 0-3	 73%	Gradual decrease in compliance from week 4 onwards. Along with reduced compliance was increase in dropout rate (0-3 months 14%, 4-6 months 39%)

	Months4-6	36%	

Figure 1: PRISMA[33] flow diagram of search and study selection

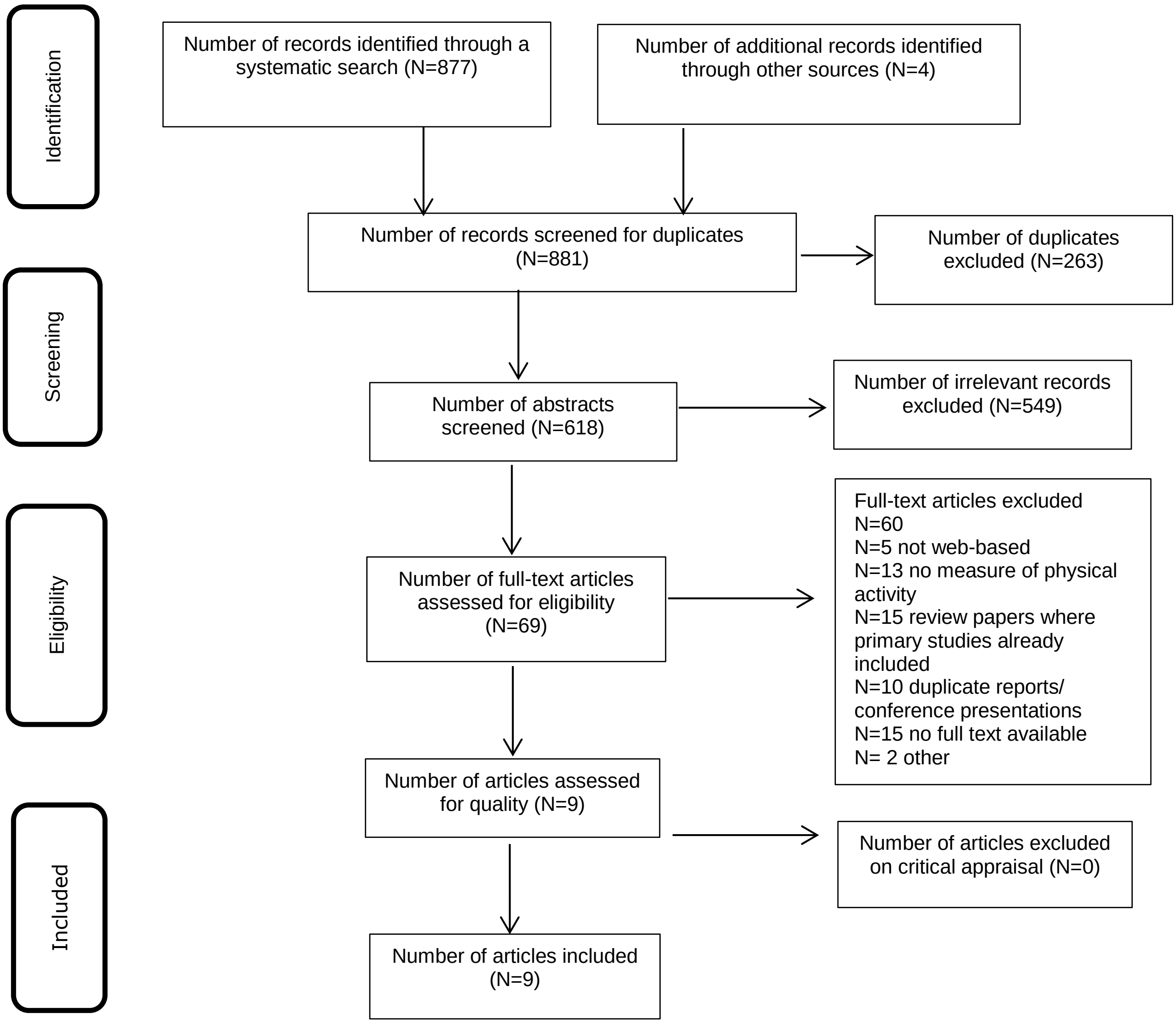
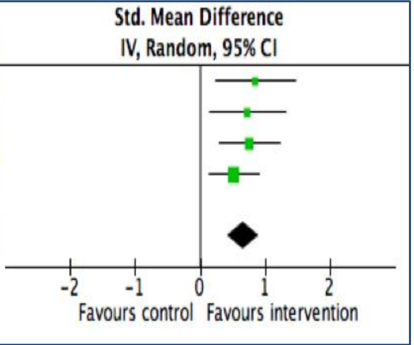


Figure 2: Meta-analysis of self-reported physical activity questionnaire data

	Experimental			Control				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Dluglonski 2012	28.2	15.6	22	15.4	13.9	23	15.8%	0.85 [0.24, 1.47]
Motl 2011	24.7	18.8	23	12.4	14.2	25	17.2%	0.73 [0.14, 1.32]
Pilutti 2014	27.2	18.25	37	13	18.74	39	27.2%	0.76 [0.29, 1.23]
Tallner 2016	3.24	2.73	49	1.9	2.39	59	39.8%	0.52 [0.14, 0.91]
Total (95% CI)			**131**			**146**	**100.0%**	**0.67 [0.43, 0.92]**

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 1.09$, df = 3 (P = 0.78); $I^2 = 0\%$

Test for overall effect: Z = 5.43 (P < 0.00001)



Std: Standardised; IV: inverse variance; df: degrees of freedom; CI: confidence interval

Appendix I: Search strategy

Medline (Ovid)
Search on 22/09/2016

Search	Query
#1	multiple sclerosis [tiab] OR multiple sclerosis [Mesh] OR MS [tiab] OR neurological condition [tiab] OR neurology* [tiab]
#2	internet [mesh] OR “web based” [tiab] OR “internet based” [tiab] OR telerehabilitation [tiab] OR telemedicine [tiab] OR www [tiab] OR “world wide web” [tiab] OR elearning [tiab] OR eHealth [tiab]
#3	#1 AND #2
#4	“Physical activity” [tiab] OR exercise [tiab] OR “physical fitness” [tiab] OR walking [tiab] or “motor activity” [tiab] OR rehabilitation [tiab] OR physiotherapy [tiab]
#5	#3 AND #4
Limit from 1990- current and English, language	