Review Article

Self-directed exercise programmes in sedentary middle-aged individuals in good overall health; a systematic review

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Abstract

Many chronic diseases and illnesses are caused by the lifestyle, including the physical activity habits, of an individual. As such, consistent high levels of exercise should be encouraged across the lifespan, to limit the risk of developing one of these conditions and allowing for healthy aging to occur. Exercise prescriptions that encourage high completion and adherence rates in an independent manner and improve health related outcomes should be provided to individuals. To date, no review has identified optimal prescriptions of exercise to achieve this in sedentary middle-aged adults and this is important, given the higher risk of developing illnesses in this population as they age. This review examines the effects of prescriptions of self-directed (SD) exercise has on adherence and health related outcomes in sedentary middle-aged individuals in good general health currently and aims to identify the most suitable forms of planned SD exercise that can be carried out independently. A systematic search of the electronic database PubMed was conducted. Randomised controlled trials published in English between February 2007 and February 2017 examining healthy, sedentary middle-aged participants only were included. Studies were critically appraised using the PEDro scale and data were presented on standardised tables. Twenty-one articles examining different aerobic activities, combined training and non-traditional exercise prescriptions were included. This review summarised in detail the effects SD exercise interventions had on sedentary middle-aged individuals alongside the adherence to the prescriptions. SD exercise was seen to be beneficial for improving metabolic outcomes physical characteristics, cardiorespiratory fitness and functional measures.

1. Introduction

Exercise is vital for treating and preventing chronic illnesses (Pedersen and Saltin, 2015; Zanuso et al., 2017; Helmrich et al., 1991; Booth et al., 2000; Garber et al., 2011; O’Neill and O’Driscoll, 2015). However, poor adherence away from the environments where exercise is supervised such as research or healthcare settings is expected to contribute to rates of chronic conditions soaring over coming decades (Wild et al., 2004). Increasing adherence to exercise programmes in sedentary middle-aged individuals in good health in more natural day to day environments may limit the future prevalence and impact of chronic diseases. Lifestyle changes in this population may lead to large long-term benefits for the individuals alongside healthcare systems by reducing the need to provide supervision to the individuals to encourage adherence.

Although reviews have examined the effects of exercise in middle-aged populations, none have identified which planned self-directed (SD) exercise prescriptions can yield a high adherence and improve health related outcomes in the population thoroughly to date (Cavill et al., 2012; Yang et al., 2012; Bolam et al., 2013; Swift et al., 2014). Reviewing supervised exercise programmes provides an insight into the cellular effects of specific programmes but it is not known if these programmes are transferable away from supervised environments. Providing supervision for all individuals is not sustainable or reflective of what occurs in a real-life setting, where individuals usually exercise and it may alter adherence rates and outcomes. In SD programmes, individuals carry out exercise independently with minimal or no contact with practitioners or study staff. The practitioner provides a programme to the patient but it is the patient’s responsibility to complete the exercise as prescribed with little or no supervision and/or instruction from healthcare personnel which minimises the burden on healthcare systems. A recent review has identified that these forms of
exercise are beneficial in type 2 diabetic individuals and so evidence is required to assess which prescriptions may encourage motivation and adherence most effectively and how best they can be used as a preventative tool for chronic diseases in at risk groups such as sedentary middle-aged individuals (Byrne et al., 2017).

This review examines the effects of planned and SD exercise on adherence, metabolic, functional and anthropometric outcomes and cardiorespiratory fitness in sedentary but healthy middle-aged individuals. It aims to identify effective forms of SD exercise in this population in improving health related outcomes to minimise the risks of illness with aging.

2. Methods

2.1. Study design

This review which has not been registered was guided by the PRISMA guidelines (Moher et al., 2009). A systematic search of PubMed was conducted to identify literature published between February 2007 and February 2017. Search terms were split into categories using the population, intervention and possible outcomes of the intervention headings of the PICOT (Population, Intervention, Comparison, Outcome, Time) method. Correct truncation and Medical Subject Headings (MeSH) terms were used. A “not” category was added to the search to ensure only papers relating to exercise interventions for healthy sedentary adults were retrieved. Two authors independently assessed eligibility and agreement was reached for each article. Reference lists of papers identified in the search process were also searched. The search terms and inclusion/exclusion criteria are presented in Supplementary Material. A list of definitions is presented in Table 1.

2.2. Critical appraisal of included studies

Two reviewers separately assessed the quality of studies using the PEDro scale (Maher et al., 2003; Bhogal et al., 2005; de Morton, 2009). Results were compared if a study was not already in the database and consensus was reached. The results of the critical appraisal scores are presented in Supplementary Material S1.

2.3. Data extraction

Data regarding adherence, metabolism, body composition, cardiorespiratory fitness and functional outcomes were analysed using the differences in means as the principal summary measures. Data from each exercise group were analysed and compared in subgroups, which were split according to the type of exercise conducted following the search. When necessary, the authors of papers were contacted to clarify information but no response was received from some.

3. Results

The search retrieved 51,855 papers. Nineteen of these remained following filtering, reading of abstracts and screening for eligibility.

<table>
<thead>
<tr>
<th>Table 1 Definitions.</th>
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<tr>
<td><strong>Middle-aged</strong></td>
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<td><strong>Nordic walking</strong></td>
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<td><strong>Self-directed (SD) exercise</strong></td>
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<td><strong>NTE</strong></td>
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<td><strong>HIIT</strong></td>
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<td><strong>MICT</strong></td>
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3.1. Methodological quality of included studies

The PEDro scale scores range from 4/10 to 8/10. The mean score was 5.24 ± 1.14. Full details of critical appraisal scores can be seen in Table S1.

3.2. Characteristics of included studies

Most papers used some form of walking as the intervention. Three of these studies used Nordic walking, a form of walking usually conducted using walking poles. One of these also included a standard walking intervention group. Fritz et al. reported on the effects of the intervention on 3 different overweight groups: individuals with T2DM, impaired or normal glucose tolerance (IGT or NGT). The group with T2DM was excluded (Kukkanen-Harjula et al., 2007; Fritz et al., 2013; Fritz et al., 2011; Drexel et al., 2008).

Other exercise modalities included are hopping, yoga, stretching, a home based aerobic video/stepping exercise, combination training, walking or swimming, or other forms of aerobic exercise including running, cross training, stationary cycling, elliptical machine and treadmill training. Intervention period lengths range from 6 weeks to 1 year. The 21 papers included present the findings of 19 studies. A paper which also presents the findings of 1 of these studies was excluded as it presented results that were not within the scope of the review (Coghill and Cooper, 2008). Thirteen studies made up of 16 papers include aerobic training groups. Two studies used a combination of aerobic and resistance training (Kho et al., 2015; Pressler et al., 2010) and 4 included non-traditional exercise (NTE) modalities.

One study presented the results of a trial that assessed the effects of continuing 2 weeks of supervised high intensity interval training (HIIT) or moderate intensity continuous training (MICT) for a further 4 weeks in a SD environment (Jung et al., 2015). Data from the entire study were analysed in the review as the initial period quantified only a small portion of the intervention. A summary of the included studies and statistically significant effects of the interventions are presented in Tables S2–S6. The main findings of the review are summarised in Table 2.
3.3. Effects of the interventions

3.3.1. Adherence & completion rates

Completion and adherence rates during SD periods rates of the 28 groups are shown in Table 3. Mean completion was 86.2% across groups. Mean adherence was not calculated due to inconsistencies in its reporting.

Completion and adherence rates and reporting of adherence varied for NTE studies (Bailey and Brooke-Wavell, 2010; Kearney et al., 2014; Kanaya et al., 2014; Wu et al., 2011). In one study, yoga group participants were more adherent to classes and home practice than the stretching group during the first 6 months, where greater supervision was provided (63% vs 47%, $P = 0.04$). However, between 6 and 12 months the difference reduced (61% vs 55%, $P = 0.51$). Home practice was higher during the initial period with more contact with study staff for both groups although there was also a significant difference between groups in this period as the yoga group carried out more home practice. For both groups, class adherence was higher in the maintenance phase than the initial 6 months, although there were fewer classes in this period. The yoga group had higher adherence to total group classes and group classes in the initial 6 months compared to the stretching group (Kanaya et al., 2014). In another paper, a stretching group recorded less vector magnitude counts/minute and were less physically active over the entire study than a walking group (Kearney et al., 2014). Adherence to different frequencies of hopping was high and similar between groups.

Completion in groups using a variety of aerobic activities alongside or excluding walking varied. One study reported no dropouts and all participants in another completed a short-term supervised run-in period (Masuo et al., 2012; Jung et al., 2015). 5.9% and 33.3% of the MICT and HIIT groups dropped out respectively in the SD period (Jung et al., 2015). Adherence in these trials was high and HIIT yielded a higher adherence than MICT (Jung et al., 2015). Authors of 1 study only indicated that adherence was “excellent” (Masuo et al., 2012). Nordic walking yielded high completion. Three participants in one study were excluded from follow up analysis due to non-adherence. However, exact adherence and a comparison between crossover periods was not presented (Drexel et al., 2008). Similarly, exact adherence was not reported by Fritz et al. but logbooks were obtained from 91% of participants and 78% and 67% of NGT and IGT participants respectively reported $\geq 80\%$ adherence (Fritz et al., 2013; Fritz et al., 2011). In one study 94% of prescribed sessions were conducted across Nordic walking and normal walking groups (Kukkonen-Harjula et al., 2007). In
Table 2

Main findings.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
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<tr>
<td>General</td>
<td>SD exercise was found to be beneficial for sedentary individuals in good overall health for measures of metabolism, physical characteristics, functional outcomes and cardiorespiratory fitness. Future research should ensure that completion rates and adherence to prescribed exercise is accurately recorded. Where possible objective measures of daily physical activity and intensity of physical activity should be documented and where this is not possible subjective measures should be used. Further work is required to examine the efficacy of SD resistance exercise in the population as no eligible studies included in the current review included a resistance exercise programme alone as the exercise intervention. Providing some level of autonomy to patients regarding the SD exercise prescription may increase adherence and overall levels of physical activity. Prescriptions of short accumulated bouts should be considered to encourage adherence while also improving or preventing declines in health status. HIIT may also be considered as a useful prescription in establishing a high adherence to exercise in the short term. Non-traditional forms of exercise such as yoga, regular hopping sessions or home-based exercise bouts involving an instructional video and/or stepper are largely effective in improving physical characteristics, metabolic and functional outcomes.</td>
</tr>
<tr>
<td>Non-traditional exercise</td>
<td>Regular SD hopping activities should be considered in sedentary pre-menopausal women to improve and maintain bone mineral density at the femoral neck.</td>
</tr>
<tr>
<td>Non-walking aerobic activities (+/−walking)</td>
<td>Intervention programmes that included a variety of aerobic activities alongside walking or instead of walking were effective in improving or preventing declines in functional outcomes, measures of metabolism and cardiorespiratory fitness, and participants’ physical characteristics. Studies with a longer intervention period are needed to examine the long-term efficacy of HIIT compared to MICT in the population.</td>
</tr>
<tr>
<td>Standard walking</td>
<td>Standard walking interventions were successful in improving or preventing declines in physical characteristics, metabolism and cardiorespiratory and functional outcomes. SD walking should always be considered as a prescription to provide to sedentary individuals due to its low cost, wide ranging health benefits and high completion and adherence rates.</td>
</tr>
<tr>
<td>Nordic walking</td>
<td>Nordic walking was seen to improve or prevent declines in all the outcomes included in the review. Uphill and downhill Nordic walking provide similar magnitude benefits for measures of metabolism and systemic inflammation but some qualitative differences may exist in the effects they yield on metabolic outcomes which should be explored further.</td>
</tr>
<tr>
<td>Combined training</td>
<td>SD cardiorespiratory training is effective in improving physical characteristics and cardiorespiratory fitness and in preventing declines or improving metabolic outcomes in sedentary middle-aged individuals. When given greater autonomy, participants appear to prefer aerobic activity over resistance type training and so some instructions to counteract this should be given to patients. HIIT = High intensity interval training, MICT = Moderate intensity continuous training.</td>
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another normal walking study, longer bouts (LB) yielded a higher, although not statistically, mean adherence of 11% compared to short bouts (SB). 70.6% of LB participants and 47.1% of SB participants who completed the study completed ≥80% of the program (Serwe et al., 2011).

In a combination training trial where participants all worked for the same company, the intervention group received a schedule through a website calendar function and could postpone or cancel workouts (Pressler et al., 2010). They chose from different endurance activities and conducted resistance exercise in a facility of their choice. Weeks were repeated if goals were not met. Controls accessed the same platform, but had no set schedule. 91% of the participants registered at the company’s gym completed the study. Intervention participants deacti-vated 22.7 ± 10.6/48 workouts of 54.6 ± 22.6 min length and documented 9.5 ± 14.6 extra workouts of 64.4 ± 65.8 min. This totalled 32.2 ± 19.6 workouts of 63.5 ± 23.0 min mean length. The controls completed 43.1 ± 28.7 sessions (p = 0.15 vs. intervention group) of 72.7 ± 41.4 min (p = 0.16 vs. intervention group).

3.3.2. Physical characteristics

Three NTE studies improved physical characteristics (Bailey and Brooke-Wavell, 2010; Kanaya et al., 2014; Wu et al., 2011). One reported improvements during group class and home-based yoga periods and during the group class period of a stretching intervention, although the stretching group had a lower baseline body mass index (BMI) (Kanaya et al., 2014). Elsewhere, all participants in a home-based exercise group decreased waist circumference (WC) from baseline and men had lower WC at 9-month follow-up while women in the intervention group had lower WC than controls (Wu et al., 2011). A daily hopping intervention improved bone health (Bailey and Brooke-Wavell, 2010).

A combined exercise group with more autonomy regarding its exact prescription reduced body fat more than the group given greater scheduling (Pressler et al., 2010). The group also improved its BMI and WC while the group with more support only improved in WC. Elsewhere, a reduction in body weight seen in the second combined exercise study was comparable to that which occurred in the diet control group, although the time course for was different (Khoo et al., 2015).

Improvements in physical characteristics were also seen in 2 of 3 studies which used other forms of aerobic activity alongside walking (Masuo et al., 2012; Turner et al., 2010; Thompson et al., 2009). Weight and BMI improved for both studies and waist to hip ratio and total fat mass improved in the study in which they were measured. Contrast-ingly Jung et al. saw no changes in either the HIIT or MICT groups although the duration of the SD exercise period was only 1 month (Jung et al., 2015). Interestingly, exercise alone was more effective than diet alone for improving total body fat mass and waist-to-hip ratio. However, diet alongside exercise were more effective for improving BMI and total body fat mass and diet alone improved BMI more than the exercise group (Masuo et al., 2012).

WC improved in all 3 Nordic walking groups in which it was as-sessed (Kukkonen-Harjula et al., 2007; Fritz et al., 2013; Fritz et al., 2011). Similarly, BMI was seen to improve in 3 out of 4 groups in which it was assessed, irrespective of the terrain (Fritz et al., 2013; Fritz et al., 2011; Drexel et al., 2008). The group that did not reduce its BMI was a group with IGT and also failed to reduce their weight although...
improvements in WC were noted (Fritz et al., 2013; Fritz et al., 2011). Elsewhere, Nordic walking groups did reduce weight in groups without glucose tolerance impairments (Kukkonen-Harjula et al., 2007; Fritz et al., 2013; Fritz et al., 2011).

SD walking elicited several benefits regarding physical characteristics (Coghill and Cooper, 2008; Kukkonen-Harjula et al., 2007; Serwe et al., 2011). Some of these, were seen to be comparable to those elicited by a Nordic walking intervention in a similar population (Kukkonen-Harjula et al., 2007). Nonetheless, not all walking interventions improved physical characteristics (Kearney et al., 2014; Puglisi et al., 2008; Krause et al., 2014). SD accumulated brisk walking did not improve body composition and both groups in the Krause et al. study did not improve (Krause et al., 2014). Likewise, the SB group in the Serwe et al. trial did not experience improvements and LB participants only improved hip circumference compared to controls (Serwe et al., 2011).

3.3.3. Cardiorespiratory fitness & functional outcomes

The only NTE study that recorded cardiorespiratory fitness measured observed no improvements (Kearney et al., 2014). Home based stepping/video guided exercise did improve functional outcomes (Wu et al., 2011). Different frequencies of hopping improved neuromuscular function (Bailey and Brooke-Wavell, 2010).

Combination training improved cardiorespiratory fitness (Khoo et al., 2015; Pressler et al., 2010). Interestingly, differences between groups with different levels of autonomy regarding their exact prescriptions were seen. Peak volume of oxygen consumed (VO2peak) and heart rate (HR) during bicycle ergometry significantly improved in a group with less autonomy. Contrastingly, a group with more autonomy experienced improvements in peak ergometer performance. Both groups displayed improvements in performance at the anaerobic lactate threshold and there were trends towards improvements seen for mean HR during ergometry and peak ergometer performance in the groups (Pressler et al., 2010).

The studies that used varied forms of SD aerobic activity alongside or instead of walking were largely effective in improving cardiorespiratory fitness. Similar improvements in cardiorespiratory fitness at follow up were observed after HIIT and MICT. Relative maximum

Table 3

<table>
<thead>
<tr>
<th>Paper</th>
<th>Persistence/completion score (%)</th>
<th>Adherence score (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bailey and Brooke-Wawell (2010) - 2/ week (of hops completed)</td>
<td>76.2</td>
<td>84</td>
</tr>
<tr>
<td>Bailey and Brooke-Wawell (2010) - 4/ week (of hops completed)</td>
<td>59.1</td>
<td>90</td>
</tr>
<tr>
<td>Bailey and Brooke-Wawell (2010) - 7/ week (of hops completed)</td>
<td>72.7</td>
<td>86</td>
</tr>
<tr>
<td>Kearney et al. (2014) - walking</td>
<td>86.5 completed intervention (different levels of contact not specified), 73.1 returned for follow up period 4 months later (different levels of contact not specified)</td>
<td>NR</td>
</tr>
<tr>
<td>Kearney et al. (2014) - stretching</td>
<td>80 completed intervention, 60 returned for follow up period 4 months later</td>
<td>NR</td>
</tr>
<tr>
<td>Kanaya et al. (2014) - yoga</td>
<td>90 of starters at 12 months</td>
<td>72 - (home practice completed in maintenance period)</td>
</tr>
<tr>
<td>Kanaya et al. (2014) - stretching</td>
<td>86.4 attended clinic testing after 6 months</td>
<td>63 - (home practice completed in maintenance period)</td>
</tr>
<tr>
<td>Wu et al. (2011)</td>
<td>97.1 (95.6% at 3 months but one returned at 9 months)</td>
<td>NR</td>
</tr>
<tr>
<td>Coghill and Cooper (2008)</td>
<td>100</td>
<td>96.7</td>
</tr>
<tr>
<td>Puglisi et al. (2008)</td>
<td>100</td>
<td>NR</td>
</tr>
<tr>
<td>Krause et al. (2014)</td>
<td>100</td>
<td>92 - Across groups</td>
</tr>
<tr>
<td>Kukkonen-Harjula et al. (2007) - Nordic walking</td>
<td>95</td>
<td>94 - (data from both groups pooled)</td>
</tr>
<tr>
<td>Kukkonen-Harjula et al. (2007) - Normal walking</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Serwe et al., (2011) - long bouts</td>
<td>85</td>
<td>80% (SD 26%)</td>
</tr>
<tr>
<td>Serwe et al., (2011) - short bouts</td>
<td>85</td>
<td>69% (SD 31%)</td>
</tr>
<tr>
<td>Williams et al. (2014) - prescribed pace</td>
<td>79.3</td>
<td>Exact NR</td>
</tr>
<tr>
<td>Williams et al. (2014) - self paced walking</td>
<td>90</td>
<td>Exact NR</td>
</tr>
<tr>
<td>Khoo et al. (2015)</td>
<td>95</td>
<td>NR</td>
</tr>
<tr>
<td>Pressler et al. (2010) - More support</td>
<td>75.8</td>
<td>47.3 (deactivated)</td>
</tr>
<tr>
<td>Pressler et al. (2010) - Less support</td>
<td>69.2</td>
<td>67.1 completed in total</td>
</tr>
<tr>
<td>Maxwell et al. (2012)</td>
<td>100</td>
<td>89.8 (if using same schedule as intervention group, no exact schedule given to control group)</td>
</tr>
<tr>
<td>Jung et al. (2015) - HIIT</td>
<td>100 completed supervised period – 66% returned after 1-month unsupervised period</td>
<td>NR</td>
</tr>
<tr>
<td>Jung et al. (2015) - MICT</td>
<td>94.1 completed supervised period, same for unsupervised</td>
<td>71.3</td>
</tr>
<tr>
<td>Fritz et al. (2013, 2011) - NGT</td>
<td>90.6</td>
<td>NR</td>
</tr>
<tr>
<td>Fritz et al. (2013, 2011) - IGT</td>
<td>85.7</td>
<td>NR</td>
</tr>
<tr>
<td>Drexel et al. (2008)</td>
<td>93 (non-compliant participants excluded)</td>
<td>94.1 - A complete physical activity record was available for 15/26 in the exercise group who began the intervention (20 finished it).</td>
</tr>
<tr>
<td>Turner et al. (2010)/Thompson et al. (2009)</td>
<td>76.9</td>
<td>Mean adherence for the 15 out of 20 for whom data is available and completed the study was 94.1%</td>
</tr>
<tr>
<td>Arbour and Martin Ginis (2009, 2008)</td>
<td>94.6</td>
<td>Not possible to calculate</td>
</tr>
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HIIT = High intensity interval training, IGT = Impaired glucose tolerance, MICT = Moderate intensity continuous training, NGT = Normal glucose tolerance, NR = Not reported, SD = Standard deviation.
volume of oxygen consumed (VO2max) and resting HR were also improved in other groups (Turner et al., 2010; Thompson et al., 2009).

Some groups increased VO2peak and power output following Nordic walking (Kukkonen-Harjula et al., 2007; Fritz et al., 2013; Fritz et al., 2011). Further analysis revealed that those with higher adherence (≥80%) improved their exercise capacity compared to controls (Fritz et al., 2013; Fritz et al., 2011). Improvements in HR, VO2peak, lactate during exercise testing and submaximal performance were comparable to a normal walking group. Normal walking improved leg strength more than Nordic walking (Kukkonen-Harjula et al., 2007).

Functional outcomes were assessed in 3 of 11 normal walking groups and leg strength improved in one (Kukkonen-Harjula et al., 2007; Serwe et al., 2011). Separately, 6-minute walk test distances improved in SB and LB groups although only the LB group improved relative to controls (Serwe et al., 2011). Cardiorespiratory fitness was assessed for 8 of these groups (Kearney et al., 2014; Krause et al., 2014; Kukkonen-Harjula et al., 2007; Serwe et al., 2011; Williams et al., 2014). Actual or predicted VO2max did not improve in any group but one group improved VO2 at 3 mmol of blood lactate suggesting that the aerobic fitness did increase (Kearney et al., 2014; Krause et al., 2014). Submaximal exercise performance also improved (Kukkonen-Harjula et al., 2007; Serwe et al., 2011; Williams et al., 2014). Actual or estimated peak VO2 improved in 3 groups and this occurred irrespective of if the walking was at a self-determined or prescribed pace. Further, no difference in estimated peak VO2 was observed at follow up between a group with a prescribed moderate intensity or a self-paced intensity (Kukkonen-Harjula et al., 2007; Williams et al., 2014). Self-guided brisk walking also improved HR and lactate during submaximal testing while accumulated SB improved pulse wave velocity and NOx and were more effective for cardiorespiratory fitness than stretching (Kearney et al., 2014; Kukkonen-Harjula et al., 2007).

3.3.4. Metabolic outcomes

4 NTE studies assessed metabolic outcomes (Kearney et al., 2014; Kanaya et al., 2014; Wu et al., 2011). Yoga was improved glycated haemoglobin (HbA1c), high density lipoproteins, (HDL), fasting insulin, fasting glucose and homeostatic model of assessment for insulin resistance (HOMA-IR) and was more beneficial than stretching for fasting glucose. Triglycerides were the only metabolic outcome improved by stretching across 2 groups (Kearney et al., 2014; Kanaya et al., 2014). Home based stepping and video led exercise improved blood pressure (BP) and HDL alongside adiponectin after 9 months compared to baseline although it was not more beneficial than diet and exercise education regarding. Both groups showed a trend towards an increase in glucose and HOMA-IR although no group or group by time effects were seen (Wu et al., 2011).

SD combined exercise training improved glucose in two of 3 groups (Kho et al., 2015; Pressler et al., 2010). In one study, the group with more support did not improve any metabolic outcome and the group with less support improved their diastolic blood pressure (DBP) (Pressler et al., 2010). Adiponectin and leptin improved in another group and insulin, HOMA-IR, C-Reactive protein (CRP), and chemerin all improved more in this group compared to a diet group. The chemerin decrease was associated with reductions in fat mass, HOMA-IR, and CRP and the improvements in leptin and adiponectin were associated with reduced fat (Kho et al., 2015).

Aerobic activity alongside or instead of walking improved blood pressure (Masuo et al., 2012; Jung et al., 2015). HIIT and MICT improved systolic blood pressure (SBP) after 4 weeks while DBP showed a trend towards improving although improvements were seen for DBP at 4 weeks elsewhere (Masuo et al., 2012). However, in another study, no improvements in BP, lipids, glucose, insulin, HOMA-IR, oxidative stress or hormonal activity were seen although levels of significance were set to $ P \leq 0.02$, $0.04< P < 0.001$. Despite this, the group improved in IL-6 and alanine aminotransferase and a separate study reported improvements in leptin, HOMA-IR and plasma norepinephrine (32. 37, 38).

Uphill and downhill Nordic walking produced several beneficial metabolic effects that were similar in magnitude although slightly different qualitatively. In a crossover study, larger improvements occurred in the initial training period (Drexel et al., 2008). However, in NGT and IGT populations in another study, minimal changes were reported. NGT individuals improved in HDL and the IGT individuals improve their plasma glucose in an OGTT, but this change was not seen to be different to controls. Encouragingly, IGT individuals with higher adherence improved systolic blood pressure compared to controls and baseline (Fritz et al., 2013; Fritz et al., 2011).

One study observed no changes in BP or lipids after 6 months of accumulated SB of walking although BP was healthy at baseline (Kearney et al., 2014). Another walking intervention involving incremental increases of 10 min improved triglycerides and soluble intercellular adhesion molecule-1 (Puglisi et al., 2008). Elsewhere, SB were slightly more beneficial for BP than longer bouts of same aggregate length as SBP and DBP improved in the SB group and only DBP improved in the LB group after 8 weeks and the improvement in SBP in the SB group was significant compared to controls (Serwe et al., 2011). Nonetheless, a similar LB intervention only improved SBP (Coghill and Cooper, 2008). Walking at moderate intensity in a 30-minute bout enhanced levels of nNOS and tNOx in an obese group. However, walking at different intensities did not improve glycaemia, lipids, glutathione metabolism, markers of oxidative stress, protein damage, adiponectin, leptin or TNF-α in the study. Similarly, no change was seen for tumor necrosis factor alpha, IL-6 and monocyte chemoattractant protein-1 in another trial (Puglisi et al., 2008; Krause et al., 2014).

4. Discussion

Exercise prescriptions that yield high adherences and allow physical activity to be incorporated into lifestyle of sedentary middle-aged individuals are needed. These prescriptions must also produce health benefits to prevent, delay or minimise the impact of chronic illnesses on individuals and society.

The adherence programmes yield should be considered by practitioners. Although in different formats, completion rates were reported for all groups. These varied from 59.1%–100%. This variability may be linked to many factors including length of the study period, injury, illness, travel, time of year or the degree to which the exercise was conducted in a SD manner. Equally, these issues may affect the adherence to the programmes and therefore the effectiveness of the interventions observed at follow up assessments may also in turn be diminished. Data for one study in Table 3 is over-reported as participants who did not achieve a specific adherence were excluded from analysis (Drexel et al., 2008). Additionally, some studies did not record exact adherence and some did not report adherence for individual groups which prevents comparisons. Exact adherence was only available for 12 groups. Within these, adherence ranged from 63%–96.7% which is consistent with the literature.

Some studies provided physical activity data of participants away from exercise sessions which is also important for health status. It can be the case that individuals do not adhere to an intervention but increase activity overall. Likewise, individuals may decrease overall activity if they believe carrying out a specific prescription is sufficient for health status. One walking group recorded a 100% completion rate and adhered to 96.7% of sessions at 120% of the requested intensity and also recorded a reduction of 12% ($ p < 0.01$) in energy expenditure compared to baseline (Coghill and Cooper, 2008). Therefore, overall physical activity should be recorded when evaluating specific programmes as their effectiveness may be minimised by increased sedentary behaviour. Prescriptions should not replace physical activity habits and should be prescribed as an aside to minimise sedentary behaviour and boost adherence to prescriptions (Garber et al., 2011). Similarly, exercising at desired intensities is important. Some groups...
failed to achieve this and if it was achieved was not reported in others which may have impacted outcomes (Serwe et al., 2011; Williams et al., 2014). A recent review suggested that higher intensity SD aerobic exercise or accumulated SB were more efficacious in type 2 diabetics (Byrne et al., 2017; Eriksen et al., 2007; Karstoft et al., 2013; Karstoft et al., 2014). The authors of one study in the current review identified that SD exercise at a higher intensity may be more beneficial for NO-related outcomes (Krause et al., 2014). A separate study in the review also reported that HIIT yielded a higher adherence by those who completed the intervention than MICT. This also supports the argument for further examining the efficacy of short high intensity bouts, although a larger percentage of participants in the MICT group completed the SD period. Further evidence is needed to identify the efficacy of SD HIIT in the population over longer periods although numerous studies support its use in supervised environments (Milanović et al., 2015; Gibala et al., 2012).

The authors of one reviewed study observed a self-paced group averaging 26 min of walking and 83 kcals of exercise-related energy expenditure extra per week than a prescribed intensity group. Moreover, differences in exercise intensities were minimal and aerobic fitness improvements were similar (Williams et al., 2014). Similarly, a separate group, who were given more autonomy to self-prescribe their type and quantity of exercise, carried out more sessions of longer duration, although the completion rate was slightly lower (Pressler et al., 2010). Likewise, another group who had the choice of carrying out stepping exercise or using an instructional exercise video and could decide on the intensity, duration and frequency of sessions recorded a completion rate of 97.1%. Similarly, Jung et al. participants who chose their own form of aerobic activity improved metabolic and diabetic risk factors (Wu et al., 2011; Jung et al., 2015). These findings suggest that giving patients greater autonomy, with some level of prescription, may produce high adherences. Nonetheless, Pressler et al. reported that only a small number of participants completed 10 or more resistance training sessions in the group with greater autonomy. This suggests that practitioners should remind patients of the benefits of varying the modality. Further, larger improvements in metabolism, although minimal, were seen in the group with less autonomy (Pressler et al., 2010).

One study in the current review reported that individuals in a LB exercise group increased their physical activity more than a SB group although both increased from baseline (Serwe et al., 2011). The LB group also exercised at a higher intensity and followed recommended HR ranges with greater consistency (Serwe et al., 2011). This difference in consistency may have been because it takes several minutes for HR to reach a steady state when exercise is first initiated or due to participants' attitudes towards the prescriptions. Furthermore, the third and final prescribed exercise session of the day was frequently skipped in the SB group which suggests that longer bouts, rather than SB of equal aggregate length should be preferred. However, others reported high completion rates of 86.5% and 100% in a SB walking group and a group who gradually increase the quantity of walking starting from short 10-min bouts, respectively, although exact adherence was not recorded in either (Kearney et al., 2014; Puglisi et al., 2008). Improvements in metabolic and cardiorespiratory outcomes were also observed in the studies. Similarly, despite the lower adherence to the SB intervention seen by Serwe et al., improvements in BP, fitness and body composition were reported (Serwe et al., 2011). Previous T2DM studies have also recorded 98% adherence in a group carrying out 3 bouts of 10 min although this study was shorter (Eriksen et al., 2007). This suggests that shorter bouts should be considered as a prescription.

4.1. Limitations

Exercise interventions prevent blinding of participants and study staff. This reduced PEDro scores but, the authors of the current review do not believe this affected bias or outcomes in individual or across studies.

Not all studies assessed the same outcomes and there was no homogeneity of participant characteristics or study design, including duration, across studies making comparisons difficult. An exact definition of middle-aged is varied within the literature and divergences across studies regarding inclusion criteria existed. The variance in age ranges in studies resulted in data from a small number of participants who are in older or younger populations being included in the review. The impact of diet and medications being taken by participants in studies on was not within the scope of the review.

The few studies included in the review suggest that further research focusing on SD exercise is needed. Likewise, studies examining SD resistance exercise are needed. A search of more databases may also have identified additional studies although PubMed is an extensive database.

5. Conclusions

SD exercise was successful in improving cardiorespiratory fitness, functional outcomes, physical characteristics, and metabolism or at least preventing deteriorations. Inconsistencies in reporting adherence makes it challenging to compare how effective providing specific exercise prescriptions or types of exercise were in encouraging adherence. Future work should ensure this is reported thoroughly to allow practitioners to make informed recommendations to patients. Future work should also accurately report levels of physical activity away from prescribed exercise sessions and outcomes should be reported with greater consistency across studies.

Some evidence suggests that giving patients greater autonomy over their exercise within certain parameters may boost adherence. Walking, in any form, appears to yield high completion rates and adherence. This should be considered as a prescription to provide to previously sedentary individuals although other forms of exercise, including NTE should not be omitted when designing a programme as they may be more beneficial for specific outcomes. Future work should assess if combinations of different modalities can yield adherence and rounded health benefits as this may be the most efficacious.

Conflicts of interest

Hugh Byrne, Brian Caulfield and Giuseppe De Vito declare that they have no conflicts of interest relevant to the content of this review.

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Appendix A. Supplementary data

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