



Review

The use of periodization in exercise prescriptions for inactive adults: A systematic review

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ARTICLE INFO

Available online 6 May 2015

Keywords:

Health
Periodized exercise
Sedentary
Intervention
Aerobic training
Resistance training

ABSTRACT

Background. Periodization of exercise is a method typically used in sports training, but the impact of periodized exercise on health outcomes in untrained adults is unclear.

Purpose. This review aims to summarize existing research wherein aerobic or resistance exercise was prescribed to inactive adults using a recognized periodization method.

Methods. A search of relevant databases, conducted between January and February of 2014, yielded 21 studies published between 2000 and 2013 that assessed the impact of periodized exercise on health outcomes in untrained participants.

Results. Substantial heterogeneity existed between studies, even under the same periodization method. Compared to baseline values or non-training control groups, prescribing periodized resistance or aerobic exercise yielded significant improvements in health outcomes related to traditional and emerging risk factors for cardiovascular disease, low-back and neck/shoulder pain, disease severity, and quality of life, with mixed results for increasing bone mineral density.

Conclusions. Although it is premature to conclude that periodized exercise is superior to non-periodized exercise for improving health outcomes, periodization appears to be a feasible means of prescribing exercise to inactive adults within an intervention setting. Further research is necessary to understand the effectiveness of periodizing aerobic exercise, the psychological effects of periodization, and the feasibility of implementing flexible non-linear methods.

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Introduction

Regular exercise is a key behavior in the prevention and treatment of a variety of conditions, such as type 2 diabetes (Albright et al., 2000), hypertension (Pescatello et al., 2004), and certain types of cancer (Kushi et al., 2006). The 2008 Physical Activity Guidelines for Americans (PAGA) recommends that adults should accumulate 150 min of moderate or 75 min of vigorous aerobic exercise per week, or a combination of the two for health benefits (American College of Sports Medicine, 2013). Regarding resistance exercise, individuals should train each major muscle group at a moderate intensity at least twice per week (American College of Sports Medicine, 2013). Despite health benefits, less than 10% of adults in the United States attain the minimum amount of aerobic exercise (Tucker et al., 2011) and resistance exercise (Loustalot et al., 2013). Low adherence is often attributed to work/life issues, such as a perceived lack of time (Anderson, 2003) or feeling “too tired” (Heesch et al., 2000; Korkiakangas et al., 2011; Stutts, 2002). Thus, it is critical that researchers explore novel, effective approaches to improving exercise behavior. In this regard, much insight could be gained from approaches used in sport conditioning, where exercise prescriptions are designed to be physiologically and psychologically sustainable using periodization.

Periodization is a widely accepted organizational strategy for both aerobic and anaerobic training in athletes. The use of periodization is reported by the majority of strength professionals in Division 1 collegiate athletics (Durell et al., 2003) (93%), the National Basketball Association (Simenz et al., 2005) (90%), the National Hockey League (Ebben et al., 2004) (91%), Major League Baseball (Ebben et al., 2005) (83%) and the National Football League (Ebben and Blackard, 2001) (69%). Periodization promotes systematic variation in training specificity, intensity and volume, organized within shorter, more easily managed cycles or “periods” within an overall program (Wathan and Earle, 2008). A *macrocycle*, which constitutes the total training period (1–4 years), is divided into several *mesocycles* (lasting several weeks to several months), which are further divided into *microcycles* (lasting approximately 1 week).

Periodized training aims to promote improvements while preventing the onset of overtraining syndrome (Haff, 2004), which is characterized by physical and mental symptoms (Stone et al., 1991). Physiologically, the progressive overload, planned recovery, and variety inherent to periodization promote fitness gains while preventing physical signs of overtraining syndrome: severe fatigue, performance decrements, and injury (Kibler and Chandler, 1994; Kraemer et al., 2002; Kubukeli et al., 2002; Stone, 1990). Likewise, excessive and/or monotonous training can induce psychological symptoms, such as mood disturbances, depression, apathy, mental fatigue and emotional instability (Davis, 1995; Fry et al., 1994; Smith, 2003; Wathan and Earle, 2008). Negative psychological

states are problematic as substantial evidence suggests that mood state is directly related to performance outcomes (Beedie et al., 2000) and associated with non-compliance (Stone et al., 2000).

Several non-periodized and periodized training models exist (Bompa and Haff, 2009). Non-periodized models can be uniform, linear progressive or random. Uniform workloads have little-to-no variation in volume and intensity over time. With linear progressive training, volume remains consistent or increases while intensity progressively increases. Random training allows for unsystematic changes in volume and/or intensity with no consideration beyond introducing variety. The two primary periodized models are traditional and undulating. Traditional periodization promotes wave-like progression (periods of overload interspersed with periods of recovery), typically moving from general training (high volume/low intensity) towards specific training (low volume/high intensity) (Kraemer and Ratamess, 2004). Undulating periodization allows for more frequent changes in volume and intensity, typically across a 7–10 day span (Kraemer and Fleck, 2007). Two more recently developed periodized models are flexible non-linear periodization (FNLP) and block periodization. FNLP, a more recently developed method, is similar to undulating periodization, wherein daily workload intensity and volume are based upon the participant’s pre-exercise mental/physical state (i.e. “readiness”) (Kraemer and Fleck, 2007). For block periodization, a high concentration of workloads is organized within a given period to target improvement in a relatively small number of variables in order to bring about a cumulative training effect over multiple blocks (Issurin, 2010). Although the bulk of published research on periodized models has focused on strength and power in trained participants, prior evidence, including a meta-analysis that analyzed over 100 studies, points to periodized programming as yielding superior fitness and performance results compared to non-periodized programs (Fry et al., 1992a,b; Rhea and Alderman, 2004).

Given the popularity and practicality of periodized training for athletes, it may be feasible and beneficial to prescribe periodized exercise to inactive adults to improve health outcomes. Currently, PAGA recommendations are often adapted into non-periodized prescriptions, consisting of linear progression and/or uniform workloads. For example, sedentary participants enrolled in behavioral weight loss programs typically begin walking shorter durations at a moderate intensity with duration increasing overtime until the target volume is reached, wherein, participants are asked to maintain the volume indefinitely (Jakicic et al., 2003, 2009; Jeffery et al., 2003). Resistance training interventions for sedentary individuals will often consist of one or more sets of 8–12 repetitions, progressively increasing resistance when more than 12 repetitions can be completed (Avila et al., 2010; Slentz et al., 2011; Straight et al., 2012). While such non-periodized programs typically result in

favorable health and fitness outcomes, long-term adherence is poor (Middleton et al., 2013), necessitating further research into more behaviorally sustainable approaches to exercise prescription. Although inactive adults are likely to experience positive health benefits in response to any type of physical activity, including periodized training, this literature has not yet been thoroughly examined in regard to which periodization methods have been successfully applied in untrained populations, the type and magnitude of health improvements experienced, the occurrence of adverse events, and adherence. In addition to summarizing these components, an in-depth examination would identify gaps in research that can be targeted in future interventions. Thus, the purpose of this review is to summarize and discuss studies that have prescribed periodized aerobic and/or anaerobic exercise for sedentary adults and measured health-related outcomes independent of, or in addition to fitness-related outcomes, such as muscular strength or aerobic fitness.

Methods

A systematic review of published literature was conducted between January and February of 2014 to assess the impact of periodized exercise training in sedentary adults. The conduct of the systematic search and reporting of results was guided by the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Liberati et al., 2009).

Search strategy

Peer-reviewed articles were retrieved using PubMed and Sport Discus databases, with no constraints on publishing dates. The terms “periodization” and “periodized” were paired with exercise-related terms (“exercise,” “physical activity,” “fitness,” “resistance,” “health promotion,” “aerobic,” “anaerobic,” “rehabilitation,” and “physical therapy.”) to identify publications with any of these combinations within the text. This approach yielded 36 individual searches in total. Additionally, reference lists from articles identified through database searches were examined to maximize coverage of the literature.

Inclusion/exclusion criteria

Articles were included for review upon meeting the following criteria: 1) published in English, 2) participants were untrained/inactive adults, 3) contained at least one exercise prescription that adhered to a recognized method of periodization (traditional, undulating, flexible non-linear, or block periodization), and 4) assessed health variables independent of or in addition to performance variables, such as strength or aerobic capacity. K.S. conducted the full literature search, and K.S., D.F. and W.B. completed the initial screening of screened titles and abstracts. All authors assessed the publications deemed suitable to be read in full and agreed upon the final selection of papers to be included in this review and contributed to the development of this manuscript.

Analysis

The literature search yielded 1708 publications, 1264 of which were excluded as duplicates. We then excluded 373 based on preliminary screening of titles and abstracts. A total of 71 publications were read in full. We excluded 51 studies based on the following criteria: recruited trained/physically active individuals (34), recruited children or adolescents (4), provided no data to assess periodization method (1), did not adhere to an accepted method of periodization (3) or assessed only performance-based outcomes (9). By reviewing citations of included articles, 1 additional study meeting inclusion criteria was discovered (Maddalozzo and Snow, 2000). For the final analysis, 21 studies met all inclusion criteria (See Fig. 1).

Results

Characteristics of each study, which are organized in chronological order, are highlighted in Table 1, including descriptions of sample, intervention and periodization methods used. Within the text, studies are organized based upon the primary aims of the study (e.g. improving traditional or emerging risk factors for cardiovascular disease, bone mineral density, pain, and disease severity), with each relevant periodization method discussed accordingly. Overall, traditional periodization was used in 12 studies, block periodization was used in 7 studies, undulating periodization was used in 4 studies, and a combination of traditional and undulating periodization was used in 1 study.

Traditional cardiovascular disease risk factors

Traditional periodization

Two studies prescribed traditional periodized resistance training and one study prescribed periodized aerobic training in conjunction with a Mediterranean diet to assess the impact on traditional risk factors (Augusto Libardi et al., 2012; de Lima et al., 2012; Landaeta-Diaz et al., 2013). Body mass index (BMI) was unaffected by resistance training for muscular strength or muscular endurance (Augusto Libardi et al., 2012; de Lima et al., 2012). However, when assessing body composition, young adult women engaging in 12 weeks of muscular endurance resistance training experienced a significant, 13% loss in percent body fat (%BF) (de Lima et al., 2012). Periodized aerobic training enhanced reductions, compared to diet-only controls, in BMI (9% vs. 5%) and %BF (11.5% vs. 7%) (Landaeta-Diaz et al., 2013). Regarding blood biomarkers, 16 weeks of strength training reduced total cholesterol and LDL-cholesterol from at-risk values to ideal levels in both men and women (Augusto Libardi et al., 2012). While diet and diet-plus-aerobic exercise induced similar reductions in systolic blood pressure, fasting blood glucose, total cholesterol, and LDL-cholesterol, the addition of periodized exercise reduced diastolic blood pressure (13.5%) and triglycerides (25%) to significantly greater degrees compared to diet alone (4% and 7%) (Landaeta-Diaz et al., 2013). Further, the addition of aerobic training improved health-related quality of life beyond improvements seen with diet alone (Landaeta-Diaz et al., 2013).

Undulating periodization

Two studies examined the effects of undulating strength training during weight loss (Kraemer et al., 2007) or muscular endurance training alone (de Lima et al., 2012) on traditional risk factors. While dieting for 8 weeks induced a significant loss in %BF (approximately 4%) in obese men and women, the addition of undulating strength training enhanced this effect, leading to 8% and 6% reductions in %BF in men and women, respectively (Kraemer et al., 2007). Young adult women assigned to undulating muscular endurance training experienced a 10% decrease in percent body fat over 12 weeks (de Lima et al., 2012). Undulating strength training for 8 weeks promoted improvements in total cholesterol and LDL-cholesterol similar to result from dieting alone and significantly increased HDL-cholesterol, promoting significant reductions in TC/HDL ratio (men 12%, women 11%) compared with no improvement in controls (Kraemer et al., 2007). It was further noted that the addition of exercise also augmented reductions in circulating leptin levels (men 38%, women 30%) compared in improvements seen in diet-only controls (men 11%, women 15%) (Kraemer et al., 2007). Conversely, eight weeks of dieting, with or without resistance training had no effect on fasting glucose or insulin levels (Kraemer et al., 2007).

Emerging cardiovascular disease risk factors

Traditional periodization

Four studies assessed the effects of periodization on emerging risk factors for cardiovascular disease, particularly markers of inflammation (Ahmadizad et al., 2014; Botero et al., 2013; Prestes et al., 2009; Schaun

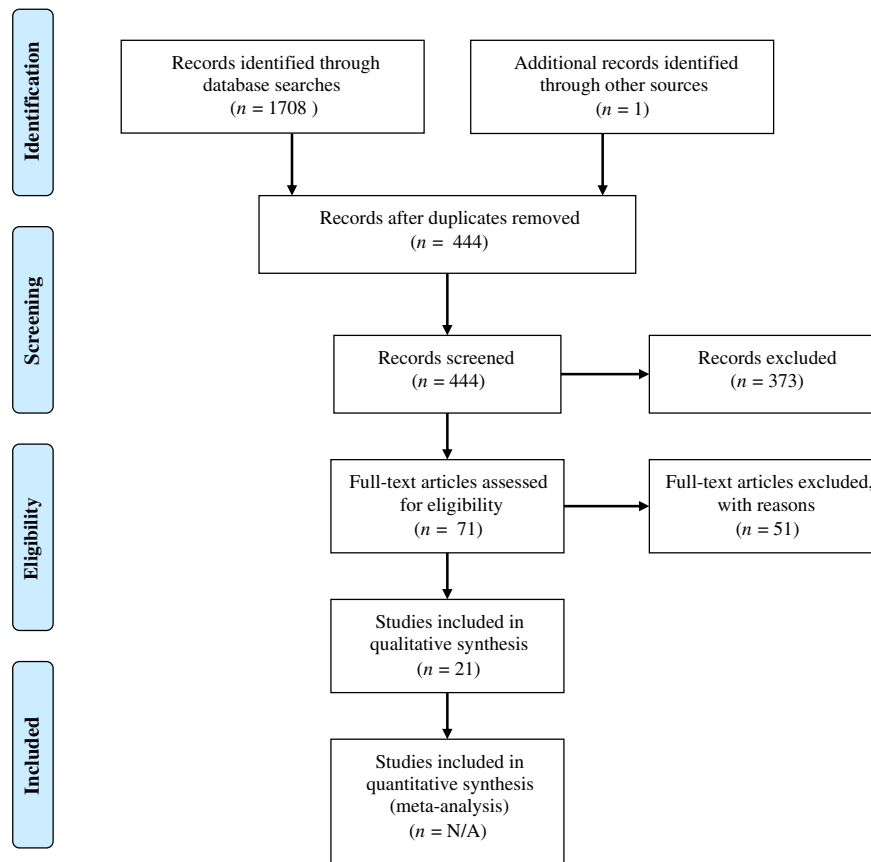


Fig. 1. PRISMA flowchart for the selection of included studies determined between January and February 2014. The number of studies (i.e. *n*) is reported for each stage. N/A = not applicable.

et al., 2011) and oxidative stress (Schaun et al., 2011). Eight weeks of traditional periodized strength training had no effect on circulating levels of leptin or adiponectin in overweight, young adult males, despite a 7% reduction in percent body fat (Ahmadizad et al., 2014). Conversely, training for 16 (Prestes et al., 2009) and 48 (Botero et al., 2013) weeks showed marked improvement in leptin and resistin levels in postmenopausal women, with a 3% decrease in percent body fat with the longer training duration. Regarding pro-inflammatory cytokines, 16 weeks of resistance training significantly reduced interleukin-6 concentration, with no effect on interleukin-15 or tumor-necrosis-factor- α (Prestes et al., 2009). Concurrent training (aerobic plus traditional periodized resistance exercise) over 12 weeks had no effect on flow-mediated dilation, but did improve markers of oxidative stress in middle-aged men, in addition to improving HDL- and LDL-cholesterol to a greater extent (9% and 12%) than observed with aerobic training alone (3% and 9%) (Schaun et al., 2011).

Undulating periodization

One study prescribed an undulating periodized program in order to impact non-traditional risk factors for cardiovascular disease in overweight men (Ahmadizad et al., 2014). Daily undulating periodization resulted no change in circulating adiponectin or leptin, despite significant reductions in percent body fat (9%), waist-to-hip ratio (3%), fasting glucose (4%) and fasting insulin (24%) (Ahmadizad et al., 2014).

Block periodization

One study utilized a block periodization model to assess changes in non-traditional risk factors for cardiovascular disease in sedentary young adults (Henagan et al., 2012). Although no significant change in percent body fat occurred (-1.5%), weekly undulating periodized resistance training resulted in significant anti-inflammatory effects, including

reduced monocyte cell surface melanocortin receptor expression and reduced circulating C-reactive protein from a moderate to low-risk concentrations, both of which were positively correlated with change in percent body fat (Henagan et al., 2012).

Bone mineral density

Traditional periodization

Two studies assessed the effects of traditional periodized resistance training on changes in BMD in older adults (Maddalozzo and Snow, 2000) and premenopausal women (Vanni et al., 2010). Men undergoing periodized, high intensity training experienced a significant increase in lumbar spine and total body BMD (2.3% and 0.25%) compared those undergoing non-periodized moderate intensity training (-0.1% and -0.8%), while both groups experienced similar, significant improvements in BMD at the greater trochanter (Maddalozzo and Snow, 2000). Conversely, no effect of periodized resistance training was noted in BMD of premenopausal or postmenopausal women (Maddalozzo and Snow, 2000; Vanni et al., 2010). Further, no improvements in percent body fat were noted for men or women of either study.

Undulating periodization

One study designated a training program as “undulating” (Vanni et al., 2010). However, because undulations in intensity and volume occurred once every four weeks (forming blocks of muscular endurance, strength, and hypertrophy training) the authors felt that it was more appropriate to discuss within the context of block periodization.

Block

Four studies examined the effects of block periodization on markers of BMD in women using blocks of strength and power training (Rosario

Table 1

Sample and intervention characteristics of identified studies. Descriptive information for 21 studies includes sample population size and demographics, intervention design, and adherence information where applicable. All studies were identified between January and February 2014.

Author group (year)	Sample description	Study design, duration and training frequency	Training program overview	Attrition (%), compliance (%), & adverse events
Maddalozzo and Snow (2000)	Inactive men (n = 28, 55 years) and postmenopausal, obese women (n = 26, 53 years)	UT; 24 weeks; 3 sessions per week	<i>Traditional (RT)</i> Weeks 1–6: 3 sets of 10 reps at 70% 1RM Weeks 7–10: 3 sets of 6 reps at 80% 1RM Weeks 11–12: 3 sets of 2–4 reps at 90 + % 1RM Week 13: Recovery/transition *12 week sequence repeated twice <i>Non-periodized control (RT)</i> 3 sets of 10–15 reps at 40–60% 1RM <i>Block (RT)</i>	Attrition: 22% Compliance: 92% in experimental, 94% in control Adverse events: None
Rosario et al. (2003)	Sedentary, obese early (n = 10, 51 years) and late (n = 11, 60 years) postmenopausal women	UT; 12 months; 3 sessions per week	<i>Block (RT)</i> Weeks 1–8: Learning technique block Weeks 9–10: hypertrophy block (3 sets at 8–12RM) Weeks 11–16: Strength block (3 sets at 5–8RM) Weeks 17–22: Power block Weeks 23–28: Eccentric strength block Weeks 29–36: Plyometric block Weeks 37–48: Maintenance + fat reduction via circuit training	Attrition: 34% Compliance: 95% Adverse events: NR
Marshall and Murphy (2006)	Untrained, overweight adults (N = 20, 39 years) with chronic nonspecific low back pain	UT; 12 weeks; 3 sessions per week	<i>Traditional (RT-swiss ball)</i> Weeks 1–4: 2–3 sets of 8–10 reps of lower intensity isometric exercises Weeks 5–8: 2–3 sets of 6–8 reps of controlled concentric/eccentric exercises Weeks 9–12: 2–3 sets of 6–8 reps of dynamic exercises <i>Daily undulating (RT)</i> Different training loads (3 sets at 10–12RM, 8–10RM, 6–7RM or 3–5RM) at each session <i>Control:</i> Non-training	Attrition: 10% Compliance: NR Adverse events: NR
Kraemer et al. (2007)	Sedentary, obese men (n = 22, 27 years) and women (n = 20, 33 years) undergoing weight loss	RCT; 8 weeks; 3 sessions per week	<i>Traditional (RT)</i> Weeks 1–4: 3 sets at 12–14RM Weeks 5–8: 3 sets at 10–12RM Weeks 9–12: 3 sets at 8–10RM Weeks 13–16: 3 sets at 6–8RM	Attrition: NR Compliance: NR Adverse events: NR
Prestes et al. (2009)	Sedentary, postmenopausal women (N = 35, 63 years)	UT; 16 weeks; 2 sessions per week	<i>Traditional (RT)</i> Weeks 1–4: 3 sets at 12–14RM Weeks 5–8: 3 sets at 10–12RM Weeks 9–12: 3 sets at 8–10RM Weeks 13–16: 3 sets at 6–8RM	Attrition: NR Compliance: NR Adverse events: NR
Kell and Asmundson (2009)	Untrained, overweight adults (N = 27, 37 years) with chronic nonspecific low back pain	RCT; 16 weeks; 3 sessions per week	<i>Traditional (RT)</i> Week 1: 2 sets of 15 reps at 53% 1RM Week 9: 3 sets of 12 reps at 60% 1RM Week 15: 3 sets of 8–12 reps at 72% 1RM <i>Traditional (AT)</i> Step loading, such that intensity and volume were increased weekly for 3 weeks, following by a recovery week at lower volume and intensity <i>Control:</i> Non-training control	Attrition: 18% Compliance: NR Adverse events: NR
Kulig et al. (2009)	Adults (N = 98, 40 years) who had undergone single-level lumbar microdiscectomy	RCT; 12 weeks; 3 days per week	<i>Block (RT)</i> Weeks 1–2: Learning block Weeks 3–4: Muscular strength block – 1–3 sets of 4 reps holding extension position for 30 s Weeks 5–7: Muscular endurance block – 1 set of 6–10 reps holding extension position maximally Weeks 8–9: Muscular strength block Weeks 10–12: Muscular endurance block <i>Control:</i> Non-training	Attrition: 9% in experimental, 65% in control Compliance: NR Adverse events: None
Vanni et al. (2010)	Premenopausal women (N = 27, 40 years)	RCT; 28 weeks; 3 sessions per week	<i>Traditional (RT)</i> Weeks 1–4: 3 sets at 18–20RM Weeks 13–16: 3 sets at 12–14RM Weeks 25–28: 3 sets at 6–8RM <i>Block (RT)</i> Weeks 1–4: 3 sets at 18–20RM Weeks 13–16: 4 sets at 10–12RM Weeks 25–28: 4 sets at 6–8RM	Attrition: 7% in Traditional, 13% in Block Compliance: 100% Adverse events: NR
Bebenek et al. (2010)	Inactive, obese postmenopausal women (N = 103, 52 years)	RCT; 12 months; 3 sessions per week	<i>Block (AT + RT)</i> Weeks 1–6: Initial conditioning <i>Bone block (4–6 weeks)</i> Session 1: high impact aerobics at 75–85% HRmax Sessions 2–3: high impact/high loading exercise + AT at 75–85% HRmax + plyometric jumps + isometric training + dynamic circuit training <i>Endurance blocks (10–12 weeks)</i> Session 1: 60 min AT at 65–75% HRmax Session 2: 45 min AT 75–85% HRmax Session 3: 20 min AT at 75–85% HRmax + 25 min RT *Endurance + bone block sequences repeated four times Wellness control Low frequency/intensity AT, RT, relaxation/coordination activities, flexibility	Attrition: 16% in experimental, 14% in experimental + supplement, 29% in control Compliance: 65% for both experimental groups Adverse events: None

(continued on next page)

Table 1 (continued)

Author group (year)	Sample description	Study design, duration and training frequency	Training program overview	Attrition (%), compliance (%), & adverse events
Schaun et al. (2011)	Sedentary, obese men (N = 20, 54 years)	RCT; 12 weeks; 3 sessions per week	<i>Traditional (AT + RT)</i> Weeks 1–2: 20 min cycling at 65% HRR; 1 set at 15RM Weeks 3–4: 20 min cycling at 70% HRR; 1 set at 12 RM Weeks 5–8: 20 min cycling at 75% HRR; 1 set at 10 RM Weeks 9–12: 20 min cycling at 80% HRR, 1 set at 8RM <i>Control (AT)</i> Non-periodized cycling for 30 min at 65% HRR	Attrition: NR Compliance: NR Adverse events: NR
Kell et al. (2011)	Untrained, overweight adults (N = 239, 43 years) with chronic nonspecific low back pain	RCT; 13 weeks; 2, 3, or 4 days per week	<i>Traditional (RT-backstrong apparatus)</i> Week 1: 2 sets of 15 reps at 53% 1RM Week 9: 3 sets of 12 reps at 60% 1RM Week 15: 3 sets of 8–12 reps at 72% 1RM <i>Control: Non-training control</i>	Attrition: 14% Compliance: 84% Adverse events: NR
Zebis et al. (2011)	Untrained, overweight adults (N = 537, 42 years) working in industrial production units	RCT; 20 weeks; 3 sessions per week	<i>Traditional + undulating (RT)</i> Weeks 1–12 (traditional) Progressing from 2 sets at 18–20RM to 2 sets at 10RM Weeks 13–20 (undulating) 3–4 sets at either 10, 12, or 15RM <i>Control: Non-training controls</i>	Attrition: 12% in experimental. 4% from control Compliance: 85% Adverse events: NR
Augusto Libardi et al. (2012)	Sedentary, overweight men (n = 25, 48 years) and women (n = 25, 52 years)	RCT; 16 weeks; 3 sessions per week	<i>Traditional (RT)</i> Weeks 1–8: 3 sets at 10RM Weeks 9–16: 3 sets at 8RM <i>Control: Non-training</i>	Attrition: NR Compliance: NR Adverse events: NR
de Lima et al. (2012)	Sedentary, non-obese women (N = 28, 25 years)	RCT; 12 weeks; 4 sessions per week	<i>Traditional (RT)</i> Week 1: 3 sets at 30RM Week 2: 3 sets at 25RM Week 3: 3 sets at 20RM Week 4: 3 sets at 15RM *4 week sequence repeated 3 times <i>Daily undulating (RT)</i> Odd weeks Days 1, 2: 3 sets at 30RM Days 3, 4: 3 sets at 25RM Even weeks Days 1, 2: 3 sets at 20RM Days 3, 4: 3 sets at 15RM <i>Control: Non-training</i>	Attrition: NR Compliance: NR Adverse events: NR
Landaeta-Diaz et al. (2013)	Sedentary, obese adults (N = 45, 58 years) with metabolic syndrome	RCT; 12 weeks; 3 sessions per week	<i>Traditional (AT)</i> Cycling progressed from shorter exercise intervals (1 min) and longer active rest (4 min) to continuous (30 min) and no active rest Walking duration progressed from 25 to 60 min. Intensity increased every four weeks (65%, 70%, 75%, and 80% HRmax. The first week at a higher intensity was accompanied by a decrease in duration in order to adjust <i>Control: Non-Training (diet only)</i>	Attrition: 17% in control. 5% in experimental Compliance: NR Adverse events: None
Henagan et al. (2012)	Sedentary, overweight adults (N = 40, 22 years)	RCT; 12 weeks; 3 sessions per week	<i>Block (RT)</i> Weeks –2–0: adaptation block Weeks 1–3: hypertrophy block Week 4: power block Weeks 5–6: circuit/recovery block Weeks 7–8: power block Week 9: recovery block Weeks 10–12: strength block <i>Control: Non-training</i>	Attrition: NR Compliance: 92% Adverse events: NR
de Macedo et al. (2012)	Sedentary, overweight adults (N = 25, 62 years) who had recently undergone myocardial revascularization	RCT; duration based on time of hospitalization in ICU and in room; 2 sessions per day	<i>Block (respiratory exercises + AT)</i> <i>ICU intensive block:</i> 3 sets of 10 40% maximal number of ventilation incursions (MNEI) <i>Hospital room readaptation block:</i> 3 sets of 10 at 60% MNEI One 6-min set of walking at 60–80% maximal speed <i>Non-periodized control</i> ACSM guidelines-based training 3 sets of 10 ventilation exercises with no added resistance One 6-min set of walking at random intensity	Attrition: 0% Compliance: NR Adverse events: NR
Botero et al. (2013)	Sedentary, overweight postmenopausal women (N = 23, 63 years)	UT; 48 weeks; 2 sessions per week	<i>Traditional (RT)</i> Weeks 1–4: 3 sets at 12–14RM Weeks 5–8: 3 sets at 10–12RM Weeks 9–12: 3 sets at 8–10RM Weeks 13–16: 3 sets at 6–8RM *16 week sequence repeated 3 times	Attrition: NR Compliance: Only analyzed those completing 95% of sessions Adverse events: NR
Ahmadizad et al. (2014)	Sedentary, overweight men (N = 32, 23 years)	RCT; 8 weeks; 3 sessions per week	<i>Traditional (RT)</i> Progression from 2 sets of 18 reps at 50% 1RM to 2 sets of 8 reps at 85% 1RM <i>Daily undulating (RT)</i>	Attrition: NR Compliance: NR Adverse events: NR

Table 1 (continued)

Author group (year)	Sample description	Study design, duration and training frequency	Training program overview	Attrition (%), compliance (%), & adverse events
Kemmler et al. (2013)	Inactive, obese postmenopausal women (N = 66, 52 years)	RTC; 12 months; 3 sessions per week	Day 1: 2 sets of 16 reps at 55% 1RM Day 2: 2 sets of 12 reps at 70% 1RM Day 3: 2 sets of 8 reps at 85% 1RM Non-periodized (RT) 2 sets of 12 reps at 70% 1RM Control: Non-training Block (AT + RT) Weeks 1–6: Initial conditioning Bone block (4–6 weeks) Session 1: high impact aerobics at 75–85% HRmax Sessions 2–3: high impact/high loading exercise + AT at 75–85% HRmax + plyometric jumps + isometric training + dynamic circuit training Endurance blocks (10–12 weeks) Session 1: 60 min AT at 65–75% HRmax Session 2: 45 min AT 75–85% HRmax Session 3: 20 min AT at 75–85% HRmax + 25 min RT *Endurance + bone block sequences repeated four times Wellness control Low frequency/intensity AT, RT, relaxation/coordination activities, flexibility Undulating (AT + RT) Cycling Daily/weekly/biweekly rotation of workloads ranging from 1 to 3 sets of 3–10 min at 50–60% maximal wattage to 6–10 sets of 1–2 min at 85–95% maximal wattage RT Daily/weekly/bi weekly rotation of workloads ranging from 1 to 2 sets of 20 reps at 30–40% 1RM to 4–5 sets of 1–3 reps at 85–95% 1RM Non-periodized control Standard progressive endurance training Cycling Progressing from 10 min at 30% maximum wattage to 24 min at 75% max wattage RT Increasing repetition volume paired with increasing intensity	Attrition: 16% in experimental. 29% in control Compliance: 67% in experimental. 70% in control Adverse events: None
Klijn et al. (2013)	Sedentary, overweight adults (N = 110, 61 years) with severe chronic obstructive pulmonary disease	RCT; 10 weeks; 3 times per week	Undulating (AT + RT) Cycling Daily/weekly/bi weekly rotation of workloads ranging from 1 to 2 sets of 20 reps at 30–40% 1RM to 4–5 sets of 1–3 reps at 85–95% 1RM Non-periodized control Standard progressive endurance training Cycling Progressing from 10 min at 30% maximum wattage to 24 min at 75% max wattage RT Increasing repetition volume paired with increasing intensity	Attrition: 0% Compliance: 81% in experimental. 82.7% in control Adverse events: None

BMI = body mass index, RCT = randomized controlled trial, UT = uncontrolled trial, RT = resistance training, RM = repetition maximum, AT = aerobic training, HRR = heart rate reserve, NR = not reported, ACSM = American College of Sports Medicine.

et al., 2003; Vanni et al., 2010) or using blocks containing both strength and aerobic training (Bebenek et al., 2010; Kemmler et al., 2013). Block periodized exercise training had no significant effect on total body (Rosario et al., 2003), lumbar or neck BMD (Vanni et al., 2010). However, when compared to a non-training control, it was found that periodized training maintained lumbar BMD compared to decreases seen in control participants and was associated with reduced menopausal complaints (Bebenek et al., 2010; Kemmler et al., 2013). Prescribing muscular endurance, strength, and hypertrophy blocks had no effect on total body or fat mass (Vanni et al., 2010), whereas the inclusion of power, plyometric and circuit training blocks was able to induce reductions in percent body fat by 4% and 6% in early and advanced postmenopausal women, respectively (Rosario et al., 2003). The combination of “bone” and “endurance” blocks was able to reduce waist circumference (5%), with no significant impact on fat mass (Kemmler et al., 2013).

Pain

Traditional periodization

Three of the studies determined the effects of traditional periodized resistance training on pain and disability related to low back pain (Kell and Asmundson, 2009; Kell et al., 2011; Marshall and Murphy, 2006), with one study assessing the effects of periodized aerobic training as well (Kell and Asmundson, 2009). All resistance-training interventions were successful in improving self-reported disability, pain intensity and health-related quality of life (both physical and mental). Aerobic training led to improvements in perceived disability and mental health (Kell and Asmundson, 2009), albeit significantly lower than those

experienced by the resistance-training group. Two studies reported favorable changes in body composition with resistance training, such that %BF was reduced when training three to four days per week for 16 weeks (Kell and Asmundson, 2009; Kell et al., 2011). Unsurprisingly, 16 weeks of periodized aerobic training also resulted in substantial reductions both in %BF and body mass (Kell and Asmundson, 2009). Only the earliest study (Marshall and Murphy, 2006), conducted a follow-up analysis and found that by three months post-intervention, only disability score and pain intensity remained reduced below baseline values.

Block

One study assessed early effects of a block periodized, 12-week post-operative exercise program (USC Spine Exercise Program) vs. education controls to improve functional performance in lumbar microdiscectomy patients (Kulig et al., 2009). Compared to an education-only group, the training group significantly reduced disability score and improved during a 5-min walk test. Interestingly, over 50% of individuals assigned to the education-only group were non-compliant and attended usual physical therapy. In a separate analysis, periodized training still yielded enhanced results over both the physical therapy and education-only groups.

Combination

One study combined more than one periodized approach in prescribing both traditional and undulation periodized exercise training to improve neck and shoulder pain in untrained adults (Zebis et al., 2011). Intensity of neck pain was reduced by 49% in the training group and 17% in the control group for those who indicated pain. Similarly, intensity of right and left shoulder pain was also decreased by a

greater magnitude with training (71% and 80%) compared to controls (47% and 56%). For individuals without pain at baseline, training reduced the odds of developing pain after the intervention.

Disease severity

Undulating periodization

One study (Klijn et al., 2013) compared the effects of nonlinear periodized cycling/resistance exercise to traditional endurance and progressive cycling/resistance exercise over 12 weeks in patients with severe COPD. Post-intervention performance on a constant work rate cycle test demonstrated that nonlinear training resulted in significantly lower peak dyspnea (5.5) and fatigue (4.7) scores relative to non-periodized training (6.4 and 6.5, respectively). While both groups experienced improvements in all Chronic Respiratory Questionnaire domains, improvements were significantly greater following nonlinear periodized training regarding dyspnea (1.90 point improvement vs. 0.94 points in non-periodized), fatigue (1.64 vs. 0.90 points), emotion (1.32 vs. 0.83 points), and mastery (1.39 vs. 0.87 points). Nonlinear training also resulted in and small, but significant increases in fat-free mass (0.29 kg/m² improvement vs. 0.03 kg/m² in non-periodized condition).

Block

One study (de Macedo et al., 2012) assessed the impact of block periodized training on the intra-hospital evolution of patients following myocardial revascularization. Participants were randomized to receive respiratory and motor exercise prescriptions during time within the intensive care unit (ICU) and during hospitalization in room based on recommendations from the American College of Sports Medicine (ACSM) or based on block periodization. Although both groups experienced the expected decrease in a 6 minute walking test distance following the revascularization procedure, the periodized group showed smaller decreases (−7%) compared to ACSM (−15%). Similarly, the periodized group showed smaller decreases compared to the ACSM group in both partial pressure of oxygen (−8% vs. −22%) and arterial oxygen saturation (−1% vs. −3%). In short, those in the periodized group left the hospital in better condition than those in the ACSM group.

Aerobic and muscular fitness outcomes

Out of the 21 included studies, 13 included traditional fitness outcomes in addition to health-related variables (Table 2).

Discussion

Periodization advocates the strategic use of variable workloads over time. Although periodized methods are purported to be superior to non-periodized methods in trained populations (Fry et al., 1992a,b; Rhea and Alderman, 2004), only two (de Macedo et al., 2012; Klijn et al., 2013) of the 21 included studies compared periodized and equivalent non-periodized training in sedentary populations, highlighting a substantial limitation in this body of research. While both studies found that periodized training yielded greater health and fitness effects, it is premature to determine superiority over non-periodized exercise prescriptions in untrained adults. Nonetheless, periodization of exercise training showed significant improvements in various risk factors for cardiovascular disease, pain, disease severity and quality of life compared to baseline values and/or non-training controls, with mixed results in improving bone mineral density. Additionally, all studies that measured training-related variables, such as aerobic and muscular fitness, found significant improvements regardless of periodization method utilized.

An additional rationale underlying the widespread use of periodization is that variable workloads allow for adequate physical and mental recovery, making long-term adherence to intensive training more likely. However, a primary limitation of included studies was that factors such as attrition, compliance and adverse events were specifically discussed

in only 13, 9 and 6 of the included studies, respectively. Average attrition was $14 \pm 7\%$ (range 5%–22%) within the 6 traditional periodized programs, and $14 \pm 11\%$ (range 0%–34%) within the 6 block periodized programs. These results were similar to the 12% attrition seen in the study combining traditional with undulating periodization (Zebis et al., 2011). While the one study using undulation periodization reported 0% attrition, this study was conducted in a clinical setting where all participants were required to complete the rehabilitation exercises (Klijn et al., 2013). Attrition rates for most studies were acceptable, based on the research suggesting that attrition rates greater than 20% may pose significant threats to validity (Sackett, 2000; Schulz and Grimes, 2002). Average compliance across all periodized studies was $84 \pm 12\%$ (range 65–100%). While compliance was fairly good across studies reporting this variable, as evidenced by significant fitness improvement, measuring adherence is perhaps more important *after* an intervention has ended, when supervision and support ceases. Unfortunately, none of the included studies assessed adherence to the prescribed exercise at any follow-up intervals. Combined with the lack of non-periodized controls, lack of follow-up assessments further precludes any statement of *superiority* over exercise prescribed in a non-periodized fashion. Despite these limitations, the results of this review indicate that, at minimum, various methods of periodization are feasible within supervised exercise interventions for untrained adults and elicit significant improvements in health and fitness. Thus, future research is warranted in order to optimize periodized approaches for untrained populations.

Future directions

Periodization of aerobic exercise

Few of the included studies assessed periodized aerobic training. In addition to low exercise levels, the majority of U.S. adults are categorized as overweight or obese (Flegal et al., 2012). In order to promote weight loss and weight loss maintenance, aerobic exercise (particularly walking) is highly promoted in conjunction with a low fat, low calorie diet (Catenacci et al., 2008; Douketis et al., 2005; Wing, 1999). Specifically, research suggests that 200–300 min of moderate-intensity aerobic activity per week is necessary for weight loss maintenance (Jakicic et al., 2001). Considering that many behavioral programs aim for weight losses within 10% of initial body weight, many individuals, while clinically healthier, may still be overweight or obese. Unfortunately, a relatively low percentage of individuals are able to maintain requisite volume of exercise once the intervention ends (Tate et al., 2007). Jeffery and colleagues noted that prescribing this high volume of exercise was associated with higher injury rates and diminished weight loss results despite maintaining a higher physical activity level, suggesting a deterioration of intervention effects over time (Jeffery et al., 2003). Considering that periodization of training purportedly reduces injury risk and promotes continued physiological improvements, periodization of aerobic exercise may ease the burden of achieving this relatively high volume of exercise, making long-term adherence and continued benefits of aerobic exercise more likely.

Assessment of psychological factors

Although periodization reportedly helps prevent negative mood states associated with burn out and reduces boredom associated with monotonous training (Bompa and Haff, 2009), none of the included studies assessed changes in psychological constructs related to exercise behavior. Psychological assessment is warranted as it may help promote long-term adherence. First, psychological responses to training are likely more important than baseline characteristics in affecting performance factors (Morgan, 1985). Second, previous research has shown that higher ratings in constructs such as self-efficacy (McAuley and Blissmer, 2000), enjoyment of exercise (Dishman et al., 1985) and affective valence (feelings of pleasure/displeasure) during exercise (Williams et al., 2008, 2012) are predictive of higher activity levels in the future. These findings led to the suggestion that exercise be prescribed in a tripartite model, such that prescriptions should aim to prevent negative psychological

Table 2

Performance-based outcome measures. Selected performance-based outcome measures include percent change in muscular strength, muscular endurance, and aerobic fitness measures over the course of the intervention. All studies were identified between January and February 2014.

Author group (year)	Muscular fitness outcome measures		Aerobic fitness outcome measures
	Upper body	Lower body	
Rosario et al. (2003)	10-RM BP Block + 140%	10-RM S Block + 250%	N/A
Kraemer et al. (2007)	1-RM BP RT men + 12% RT women + 2% Control men + 3.6% Control women – 1%	1-RM S ^a RT men + 26% RT women + 45% Control men + 3% Control women + 2%	MSFR ^a RT men + 45% RT women + 65% Control men – 5% Control women + 2%
Prestes et al. (2009)	1-RM BP RT + 21%	1-RM LP RT + 30%	N/A
Kell and Asmundson (2009)	1-RM BP RT + 28% AT + 4% Control + 3%	Peak power–Leg Ext. RT + 13% AT + 4% Control + 2% Peak power–Leg Flex. RT + 18% AT + 9% Control – 4%	N/A
Vanni et al. (2010)	1-RM BP Traditional + 27% Block + 46%	1-RM LP Traditional + 48% Block + 52%	N/A
Schaun et al. (2011)	1-RM BP Traditional + 19% Control + 5%	1-RM KE Traditional + 15% Control + 4%	VO _{2max} Traditional + 11% Control + 7%
Kell et al. (2011)	5-RM BP Traditional + 37% Control + 2%	5-RM LP Traditional + 51% Control + 5%	N/A
Augusto Libardi et al. (2012)	1-RM BP RT men + 21% RT women + 29% Control men – 4% Control women + 4%	1-RM LP RT men + 38% RT women + 40% Control men – 1% Control women + 7%	N/A
de Lima et al. (2012)	1-RM BP Traditional + 17% Undulating + 19% Control – 1% Max reps–BP Traditional + 62% Undulating + 127% Control + 2%	1-RM LP Traditional + 32% Undulating + 38% Control – 2% Max reps–LP Traditional + 90% Undulating + 198% Control – 1%	VO _{2max} Traditional + 4% Undulating + 4% Control – 1%
Landaeta-Diaz et al. (2013)	N/A	N/A	VO _{2max} Traditional + 45% Control + 12%
Botero et al. (2013)	1-RM BP RT + 31%	1-RM LP RT + 101%	N/A
Ahmadzad et al. (2014)	1-RM BP Traditional + 12% Undulating + 15% Not periodized + 7%	1-RM LP Traditional + 7% Undulating + 10% Not periodized + 4%	N/A
Klijn et al. (2013)	N/A	1-RM LP Intervention + 29% Control + 24%	N/A

N/A = not applicable, BP = bench press, LP = leg press, KE = knee extension, S = squat, MSFR = multistage fitness run, Ext. = extension, Flex. = flexion, VO_{2max} = maximal oxygen uptake.

^a Data estimated based on bar graph.

effects *in addition to* maximizing physiological outcomes and minimizing risk, to promote long-term adherence (Ekkekakis et al., 2011). Third, fluctuations in mood state are associated with relevant physiological factors (O'Connor et al., 1989; Raglin et al., 1996), which are often too expensive to measure on a large number of individuals at multiple intervals during an intervention. Thus, periodical assessment of psychological states during training may allow researchers and practitioners to identify periods of boredom or distress, previously demonstrated in athletes (Kentta et al., 2006; Morgan et al., 1987), and subsequently modify the prescription before adherence is negatively impacted. Such findings would help to further support and refine periodization methods to be used in untrained populations.

Another relatively unexplored, but potentially important construct is self-expansion. Self-expanding activities are characterized by novelty, excitement, and interest or challenge (Aron et al., 2001,

2013). Self-expansion positively influences perceptions of and motivation to engage in behaviors (Aron et al., 2001; Mattingly and Lewandowski, 2013), and has been shown to be beneficial to health behaviors, such as smoking cessation (Xu et al., 2010). Furthermore, self-expansion has been shown to lead to increased effort and persistence in subsequent tasks (Mattingly and Lewandowski, 2013), which has health implications as adherence and effort are important in behavioral change and maintenance. While self-expansion occurs naturally, it is possible that an exercise prescription itself could promote expansion effects. Given that methods of periodization implement short- and long-term goals, incorporate variety, and promote continued progression of physiological factors and skill-acquisition, periodized methods have a strong potential to promote self-expansion (and thus, better adherence) to a greater degree than non-periodized programs.

Flexible non-linear periodized training

Prescribing exercise using FNLP is an attractive avenue for future research in untrained populations. Although none of the included studies used this method, initial studies have shown FNLP to be more effective in improving strength than undulating periodization in untrained participants in several studies (McNamara and Stearne, 2010, 2013), which was previously shown to be superior to traditional periodization (Peterson et al., 2008; Rhea and Alderman, 2004). Furthermore, the flexibility inherent to FNLP is more likely to reduce overtraining and promote long-term adherence by accommodating changes in schedules and acute changes in physical and/or mental readiness to exercise (Kraemer and Fleck, 2007). FNLP supports the Mental Health Model, which suggests that athletes with 'better than average' mental health during training should be capable of tolerating, and in theory, should benefit from even harder training regimens (Raglin, 2001). Further, by adjusting workloads based on readiness to exercise, it may be possible to avoid provoking feelings of displeasure during exercise and promote feelings of enjoyment, which could then improve adherence. The more frequent manipulation of training components (mode, intensity, duration) inherent in FNLP may also be beneficial for adherence. Research has demonstrated a positive correlation between variety in exercise mode and minutes of physical activity (Bond et al., 2012) and shown that individuals reporting more exercise variety exhibit greater energy expenditure through physical activity following weight loss (Raynor et al., 2014). To date, it is currently unknown if variety in intensity or volume is as salient as variety in mode in promoting higher levels of activity, but future research is warranted in order to optimize the exercise prescription for long-term adherence.

Effectiveness of unsupervised, periodized exercise programs

Determining the scalability and sustainability of a behavioral intervention is important for assessing program effectiveness (i.e. degree of beneficial outcomes in "real world" settings). Given that all included studies implemented a supervised exercise program, positive results are only indicative of efficacy (i.e. outcomes under ideal conditions). Considering that many non-periodized exercise interventions (particularly aerobic) are implemented in an unsupervised manner, it is critical that future studies aim to adapt periodized programming for free-living populations, wherein data regarding scaling, sustainability, and cost-effectiveness can be compared to standard approaches. Because prescribing periodized prescriptions are inherently more complex than prescribing uniform workloads (e.g. brisk walking for 30 min per day), it may seem that supervised training is the most feasible approach, where a professional can monitor progress and prescribe workloads appropriately. However, smartphone technology, including stand alone applications and those that can be synced with wearable devices, is rapidly expanding to promote physical activity (Bort-Roig et al., 2014). Further, the majority of adults in the U.S. now own smartphones (Smith, 2015). Technology-based approaches would allow more complex exercise prescriptions to be prescribed to untrained individuals without the need for supervision, which may substantially improve scalability, sustainability, and cost-effectiveness of periodized training in free-living adults. Thus, future research in this area is highly suggested in order to further understand the benefits of periodized vs. non-periodized exercise in sedentary populations.

Conclusions

This systematic review identified 21 research studies that tested the impact of periodized exercise programs on health outcomes in sedentary adults. The majority of studies assessed overweight and obese adults, with traditional periodization being the most prevalent method. Results indicate that various periodization strategies can be used to organize exercise training for sedentary adults in order to improve health and fitness compared to baseline values or non-training controls, with no reports of adverse events. However, research in this area lacks the

use of non-periodized control groups, assessment of post-intervention adherence, and adaptations for free-living populations. Thus, it is not yet possible to draw conclusions regarding the benefits of periodized exercise extending beyond standard, non-periodized programs. Future research should aim to understand the psychological benefits of periodized exercise in inactive populations. Further, the impact of prescribing exercise according to FNLP to untrained adults warrants further investigation given the call towards preventing negative exercise experiences and the importance of promoting variety within exercise interventions. To date, long-term adherence to regular exercise is a substantial problem in all areas of behavioral research, including physical activity interventions (Middleton et al., 2013). Because periodization is a favored method of organizing exercise training in athletes, further study of the usefulness of periodized exercise for untrained adults is necessary as this population is arguably in substantial need of effective, yet sustainable exercise programming in an effort to reduce disease burden and improve quality of life.

Conflict of interest

The authors have no conflict of interest to disclose.

Acknowledgments

No external funding was received by any of the authors to conduct this review.

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