Uncomplicated Resistance Training and Health-Related Outcomes: Evidence for a Public Health Mandate

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PHILLIPS, S.M. and R.A. WINETT. Uncomplicated Resistance Training and Health-Related Outcomes: Evidence for a Public Health Mandate. *Curr. Sports Med. Rep.*, Vol. 9, No. 4, pp. 208–213, 2010. *Compared to aerobic training (AT), resistance training (RT) has received far less attention as a prescription for general health. However, RT is as effective as AT in lowering risk for cardiovascular disease, diabetes, and other diseases. There is a clear ability of RT, in contrast to AT, to promote gains, maintenance, or slow loss of skeletal muscle mass/strength. Thus, as an antisarcopenic exercise treatment, RT is of greater benefit than AT; given the aging of our population, this is of primary importance. In our view, a substantial barrier to greater adoption of RT is the incorrectly perceived importance of variables such as external load, intensity, and volume, leading to complex, difficult-to-follow regimes. We propose a more feasible and easier-to-adhere-to paradigm for RT that could affect how RT is viewed and adopted as a prescription for public health.*

INTRODUCTION

In this review, we define resistance training (RT) as a form of periodic exercise whereby external weights provide progressive overload to skeletal muscles in order to make them stronger and often result in hypertrophy. The external load lifted classically is expressed as a percentage of the individual's one "repetition" maximum (1 RM, the maximum load that can be lifted once through a complete range of motion). However, we propose that for the general public the use of external load may not be the best way to define RT. The volume (dose) of resistance training is described by the load lifted, the number of repetitions, and the number of sets of repetitions. There are numerous other variables that can be manipulated within the design of RT programs, such as inter-set rest intervals, time under tension, number of sets/repetitions, and order of exercises. In our view, these variables largely are redundant in achieving a phenotype of improved strength and even more so in gaining favorable health benefits.

CURRENT DOGMA

It is typically believed that at least three sets using high loads (mostly ≥80% 1 RM) and low repetitions (5–9) per set are best to increase muscle strength (32,48), whereas lower loads (50%–70%) and higher repetitions (9–19) are best to increase muscular endurance. On close scrutiny, evidence to support these contentions largely is lacking (9–11). Some of the earliest reports of what is the basis of formal RT are from De Lorme (19). These reports showed that heavy RT restored muscular strength and power in war veterans with physical disabilities. Regrettably, De Lorme's conclusions still guide the canonized belief of the previously mentioned strength-endurance continuum. At the other end of the exercise continuum, books such as Kenneth Cooper's 1968 *Aerobics* (14) denigrated muscle building as essentially useless for health benefits. This led to a revolution in cardio-centric research and a large volume of publications on the health and fitness benefits of activities such as running. Conversely, RT received little attention for its value in disease-risk reduction until more recently. In 2010, few would argue that some form of RT should not be part of a complete exercise program; however, the bulk of literature on the cardio-protective effects of aerobic exercise has continued to make this form of exercise preeminent and the central focus of many physical activity guidelines in Canada, the United States, and many other countries.

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AIMS OF THE REVIEW

A central tenet of this review is that the dogmatic dichotomy of RT as being muscle and strength building with little or no value in promoting cardiometabolic health and aerobic training (AT) as endurance promoting and cardioprotective, respectively, largely is incorrect. In fact, RT has been shown to be equal, and in some cases superior, to AT in reducing cardiometabolic health risk. The separation that does exist, however, is that RT fundamentally is anabolic for skeletal muscle and thus is able to stimulate new muscle growth or to slow muscle loss; by contrast AT only is mildly, if at all, anabolic. Viewed in the context of North America's burgeoning aged population and the prevalence and associated cost (30) in that population of sarcopenia (29), we view RT as a form of exercise that should be promoted for overall public health. As a decidedly potent countermeasure to muscle and strength loss, ultimately, we hypothesize that prescription and practice of RT would lead to improved physical function (36), lower risks for physical disability (28,29), falls (7), and potentially reduced risk for mortality (49,50). If these hypotheses are correct, then it would be compelling that RT assume a position of primary or at least equal importance to AT in public health guidelines. Beyond disease prevention, however, there also is a wealth of other positive health effects of RT for elderly individuals (43).

Given the relative lack of promotion of RT compared with AT as a mainstream form of exercise for health and fitness and as a viable means for reducing the incidence and/or burden of chronic illnesses, it is not surprising that only 10%–15% of middle-aged to older adults practice RT (25). This is much lower than the percentage (approximately 35%) engaging in AT (59) or physical activity to meet minimal guidelines (25). Our assertion is that one of the biggest barriers to greater adoption of RT as a *bona fide* exercise intervention for health is the purported complexity of RT as certainly suggested by the complicated current guidelines for resistance exercise (32,48). In contrast to published guidelines that emphasize complex, time-consuming protocols (32,48), we propose RT protocols that are *brief*, *simple*, and *feasible*. Such protocols may be more likely to be adopted in the long run and are effective in promoting strength gains and health benefits. In addition, these RT programs can be performed twice weekly and still can induce marked positive changes in health and quality of life. From a public health perspective, our thesis is critical because it suggests that translational research can focus on strategies for wide adoption of RT in various settings by different population segments. The subsequent goal then would be the maintenance of RT training for disease prevention or management (58). The simple protocols and research findings are in stark contrast, as noted, to the perception that RT is complicated, time-consuming, and difficult and also are dissimilar to current RT recommendations (48).

RT AND CARDIOVASCULAR HEALTH

The constellation of factors that defines cardiovascular health usually includes body composition, blood lipids, blood pressure (BP), and vascular variables such as vascular reactivity and compliance. There are a multitude of studies showing the benefit of AT on these variables. However, it has been assumed that given the lower energy cost/energy expenditure, lower cardiovascular effort, and possibly shorter duration of the exercise itself, RT would not bring about comparable benefits. However, there is now convincing evidence showing the benefits of RT for cardiovascular health.

Lowering blood lipid concentrations via exercise is thought to be mediated through the oxidation of lipid as a fuel both during and after the exercise bout that subsequently depletes the body's pools of triglycerides (TG). Indirectly, the impact is to also lower low-density lipoprotein-cholesterol (LDL-c) and raise high-density lipoprotein-cholesterol (HDL-c). A review conducted by Tambalis *et al.* (53) showed that RT had a positive effect on lowering LDL-c and a tendency to raise HDL-c. Because of the heterogeneity of the trials, the changes observed with RT could not be shown to be different from those induced by AT but were of a comparable magnitude. The combination of RT and AT has been proposed to be more effective in lowering lipids than either exercise alone (45); however, this conclusion requires further trials.

The effects of AT on resting BP easily are summarized by the general findings that BP, both systolic BP (SBP) and diastolic BP (DBP), generally are lower in fitter individuals and that longitudinal findings show that AT lowers resting BP and does so more in those with initial hypertension (16). From the few studies in this area, it does appear that, with RT, reductions in SBP are comparable with AT (SBP = −6 mm Hg and DBP = −4.7 mm Hg) (15). Thus the available data on RT show comparable changes to AT, and importantly, changes that are about the same magnitude as those induced pharmacologically.

Related to BP are the changes in vascular reactivity and compliance. An initial cross-sectional comparison of aged control and RT persons showed a greater age-related reduction in arterial compliance (40). Subsequent longitudinal studies appear to have corroborated the cross-sectional data (17,41). However, other studies report no changes in arterial compliance following RT (46,47). In addition, one report documents no changes in central artery compliance (and increased nitric oxide bioavailability) in older men following RT (38). In another study, it was reported that basal femoral blood flow and vascular conductance increased by 55%–60% after RT (1). It also appears that a blend of RT and AT appears to prevent any training-induced reduction in compliance or increase in arterial stiffness (13). Clearly, more work is required to ascertain the relevance of any arterial stiffening or reduced compliance brought about by RT.

CHANGES IN BODY COMPOSITION

Collectively viewed, changes (or maintenance) of skeletal muscle favoring the retention of an important source of metabolically active tissue would be beneficial (3). This is the largest site of postprandial glucose disposal and storage (26). At the same time, loss (or maintenance) of fat mass, which is now recognized to be a source of inflammatory cytokines (42), also would be a substantial health benefit. While AT may be beneficial for aiding in fat mass loss or the prevention of addition fat mass gain, it is, at least as practiced by most people in its current form (*i.e.*, walking), of limited benefit in preventing sarcopenia. In comparison, a noted benefit of RT is the natural tendency to promote gains in muscle mass or at least a better retention or slowed loss of muscle. An increase in muscle mass is the most conspicuous change in body composition that one would predict to occur with RT, and this is an outcome achievable in young (44) and the elderly (31), even into the 10th decade of life (21). However, an often underappreciated observation is a reduction in body fat mass (54), particularly visceral fat mass (54), that can occur with RT. The loss of fat, particularly visceral fat, tends to be greater in those who initially have greater visceral fat. Thus, RT presents, as discussed later in this article, an attractive primary or adjunct therapy for those who are obese or overweight or have type 2 diabetes (T2D) (54). In addition, RT acts to preserve muscle mass during weight loss and in doing so may eliminate or at least may attenuate the weight loss-induced decline in resting metabolic rate due to the effect of RT in promoting lean mass retention, which is a primary determinant of resting metabolic rate.

RT AND T2D

Several years ago, a seminal review by Eves and Plotnicoff (20) summarized evidence suggesting that RT should be an important treatment component for T2D (39). Brief RT two to three times weekly currently is recommended by the American Diabetes Association (ADA).

Substantial improvements in blood glucose and insulin homeostasis with RT have been reported among individuals with diabetes (20,39). RT-induced improvements in glucose and insulin homeostasis are attributed to several factors, including increases in muscle cross-sectional area, increases in lean body mass, and qualitative improvements in muscle metabolic properties (*i.e.*, increases in GLUT-4 transporter density, glycogen synthase content/activity, and insulin-mediated glucose clearance). Importantly, these beneficial effects of RT have been noted without changes in body weight, fat mass, or cardiorespiratory fitness (20), and RT even may be superior to AT for improving insulin sensitivity (6,20). Since reductions in lean body mass and worsening of glucose tolerance both are observed commonly with advancing age, RT regimens that maintain or increase lean body mass may prevent declines in functional ability and prevent/delay the development of impairments in glucose homeostasis (20).

Eves and Plotnicoff (20) noted that the optimal intensity, frequency, and volume of RT that produces improvements in blood glucose and insulin homeostasis were unknown. While ACSM and the ADA recommend protocols using one set per exercise in whole body routines using 8–10 exercises, recent studies with RT and T2D have not followed these guidelines. While these more recent studies have been ambitious and show promising results, their potential for advancing the field may be reduced because the RT protocols that have been used can be described as "idiosyncratic." RT protocols have included a whole body protocol, with heavier resistance and apparently training to fatigue (51), whole body training with moderate non-fatiguing resistance (39) or to fatigue (37,60), and heavier resistance to fatigue with some sets using moderate resistance but with explosive repetitions (27). RT was performed two to three times weekly with different degrees of supervision. All RT protocols used multiple sets, with some protocols using as many as 4–5 sets per exercise. It is not clear why the briefer one-set protocols recommended by the ACSM and ADA were not used as a starting point to assess what may be a minimal dose requirement that may be more readily feasible for the large population segments with T2D.

One important step for finding an optimal dose of RT for positively affecting insulin sensitivity was taken in a study by Black and colleagues (2). They investigated the acute effects of a single bout of whole body RT with a small sample of male and female identified as prediabetic (impaired fasting glucose, 100–125 mg·dL^{-1} [5.5–6.9 mM]). The study used four protocols, all with the same exercises: a single set at 65% of 1 RM, 4 sets at 65% of 1 RM, a single set at 85% of 1 RM, and 4 sets at 85% of 1 RM. While all protocols resulted in significant and positive changes in insulin sensitivity, it was shown that multiple sets were superior to single-set RT, and that the multiple set RT at 85% of 1 RM produced the largest effect size for change in insulin sensitivity. From the protocol description by Black *et al.* (2), it was not indicated whether there was a difference in the degree of effort required with any of the 4 sets between training with 65% or 85% of 1 RM, that is, training to fatigue or concentric failure. Given the comparison between one and four sets, it also is not clear if just 2 or 3 sets would produce comparable effects to 4 sets; this study clearly needs to be replicated given the small sample size (*i.e.*, potential for a type 1 error).

There also are studies assessing RT, AT, and combined RT-AT. In these studies, AT was performed on the same or alternate day, most often for 30–45 min at a mean of about 75%–80% of HR_{max}. These studies have demonstrated the efficacy of these protocols, and preliminary data suggest that RT may be superior to AT for lowering HbA1c (6). However, consistent with our prior and central point, the required time commitment, especially for combining RT and AT, may limit potential public health impacts (3). More attention needs to be focused, as is true of other areas of RT and risk reduction, on translational research that uses time-efficient but efficacious protocols combined with theory-based behavioral strategies to increase long-term maintenance of RT in minimally supervised settings (58).

WHAT MORE CAN RT DO?

Beyond the effects of RT on chronic health conditions as discussed previously, there are multitudinous other pathological conditions that are affected beneficially by RT. Randomized trials of RT in rheumatoid arthritis have shown the capacity to induce strength gains and hypertrophy, as well as reversing the cachexic phenotype associated with this condition (34). A recent meta-analysis of high-quality trials of women with osteopenia and osteoporosis also concluded that RT resulted in significant improvements in the domains of physical function, pain, and vitality (35). Recent analyses of RT interventions in knee (22) and hip osteoarthritis (24) also reached similar conclusions regarding the use of RT as an effective intervention for lessening pain and often improving health-related quality of life.

There is a small but growing body of literature that is showing highly beneficial effects of RT in cancer rehabilitation for a variety of cancer types (12,18,23,52). Of relevance to the points made in this review, some of the salient changes seen in these patients include improvements in estimates of aerobic capacity, fatigue, and body composition (12,23). Namely, patients see gains in lean mass while still on treatments with drugs that would normally result in marked reductions in muscle mass and increased fat mass. For example, this has been the case for men receiving androgen suppression therapy for prostate cancer treatment (23). Given that cancer appears poised to overtake cardiovascular disease as a leading killer in many developed countries, these observations are of great importance. A critical observation is that despite oncologists' often-heard plea that cancer patients are unable to withstand an exercise intervention because of their disease- or treatment-induced fatigue, this is not the case. In fact, contrary to this suggestion, there are data indicating that cancer patients have a greater resistance to fatigue even when performing intense RT protocols and report enhanced quality of life (12,23).

A PARADIGM SHIFT TO AN INTRINSIC MODEL OF RT

One impetus for compiling this review is to urge much greater focus in subsequent position stands and clinical trials on compelling public health concerns addressed with relatively simple, feasible, and efficacious RT protocols (4,55,56). Moving towards greater public health relevance, we believe, also will require a different way of conceptualizing RT, which then directly will impact its presentation to the public, the accessibility of RT, and possibly effectiveness at a population level. These broad conceptual changes are a true paradigm shift.

RT largely has developed and more recently been diversely applied to risk reduction and health promotion based on an extrinsic weightlifting paradigm. That is, the focus often is placed on the amount of resistance, number of repetitions, sets, and myriad other *seemingly* critical variables (48). The assumption also has been that at least for increasing strength, heavier resistance produced superior outcomes compared with moderate resistance. Critical analyses of such suppositions (10,11) indicate that numerous different combinations of resistance, repetitions, and sets produce astonishingly similar, rather than disparate, strength outcomes, and most importantly, heavier was not shown to be better (10,11). Even if such a conclusion was in dispute, we still would propose that at a population level, subtle differences in strength gains that *may* be achieved with complex weightlifting protocols are far less relevant to public health. At best, complex training is reserved for elite population segments. However, if as we propose, different combinations of resistance, repetitions, and sets produce similar outcomes (10,11), one explanation is that there are common processes and mechanisms that are activated by seemingly disparate RT protocols. An obvious candidate is the degree of motor unit activation, a proxy for which is the degree of effort involved in the RT stimulus; such a thesis has been put forward previously in recent reviews (8–10). The *degree of effort* such as required to complete a set of repetitions, rather than the amount of resistance as traditionally defined as percent of 1 RM, constitutes a true measure of *intensity*. A higher intensity stimulus, that is a stimulus requiring a high degree of effort, may be a common process underlying efficacious protocols.

We propose for consideration and further research a more intrinsic RT model (note that Dr. Ralph Carpinelli originally defined extrinsic and intrinsic RT models). Instead of arduous, time-consuming, complicated RT protocols crafted primarily with the extrinsic "heavier is better" mantra in mind, one can prescribe more intrinsic protocols with a person's own effort as a guide. Such a program could use only a moderate amount of resistance (weight), but with excellent form (including attention to range of motion and controlled repetitions to reduce momentum), with performance of the last repetition in a set representing a fatiguing or near fatiguing effort. Such intrinsic RT would not be "easy" to perform. In fact, high *effort* is central to this RT model. However, heavier resistance would not be required and neither would consideration of the multitude of other "important" variables inherent in other prescriptive RT models (48). Such a model of RT is not complicated and moves beyond the extrinsically dictated weightlifting models that dominate much of the research in this area.

Work from one of the author's groups recently has demonstrated that when subjects lift loads equivalent to 90% of their 1 RM versus lifting a load that represents only 30% of 1 RM, but both 90% and 30% perform to voluntary fatigue, similar increments in the synthesis of new muscle proteins are shown (5). These data indicate that external load is not the absolute stimulus that dictates the muscle cellular response to resistance exercise. Rather, the data suggest that given these widely different loads, effort is a key component of the RT stimulus because both loads were lifted to voluntary fatigue. Note, however, that effort is internal to the person, can be created with a variety of protocols, and is not dependent upon a specific amount of external force. Defining intensity as a degree of effort, and not as percent of 1 RM, is a pivotal part of moving RT out from under a weightlifting paradigm. If effort dictates the phenotypic change in muscle (*i.e.*, hypertrophy) and, we hypothesize, strength gains, then the paradigm becomes one of having people exert a hard effort to achieve benefit rather than lifting heavy weights, much less heavy weights in complex programs. In intrinsic RT, the focus and goal are to target and fatigue muscle groups. A wide range of repetitions and time under tension can be used to achieve such a goal. Resistance simply is a vehicle to produce fatigue and only is adjusted when fatigue is not reached within the designated number of repetitions and time under tension. Subsequent studies assessing whether the acute finding of effort-dependent and load-independent response equivalency (5) translates into longer-term adaptations are forthcoming. If this type of training is efficacious, translational research can assess the broad acceptability of more intrinsic RT, including the necessity for precision and effort and its effectiveness and longer-term maintenance among healthy and at-risk population segments.

We also favor a different perspective on descriptions of RT in that expressions such as "sets per exercise" may not be the best measure of volume. Rather, "sets per muscle group" may be a better measure of workload. Multi-joint exercises affect multiple muscle groups, so if a sufficient workload is required, a relatively simple protocol with select exercises may provide a sufficient stimulus. Research should be directed to ascertaining a "volume threshold," the minimum volume from a public health perspective that results in a meaningful change in, for example, insulin sensitivity, blood lipids, body fat, or some combination of these. While protocols with higher volume may produce large strength gains in younger athletic populations, such protocols may result in lower adherence rates in clinical populations, negating their potentially positive impacts. Thus, the large volume of exercises and time spent in the gym derived from the "more is better" archetype also is not necessary for improved health outcomes (57). It also is unclear whether more volume unequivocally results in greater strength gains (10,33,57). However, a pertinent question is whether the ostensibly superior gains in muscle strength that *may* occur with greater volume would be offset by greater injury incidence and poor adherence (whether due to time commitment or low self-efficacy) outside of the lab in the general population. Our thesis is that an intrinsically-oriented (*i.e.*, guided by a high degree of effort intrinsic to each subject) program with at minimum of one set with 10–15 multiple muscle group exercises (*e.g.*, leg press, chest press, pulldown, overhead press) executed with good form would be highly effective from a public health perspective. The relatively uncomplicated nature and low time required to complete such an intrinsic model of training would allow greater self-efficacy for performance, maintenance, and continued adherence beyond the initial supervised training phase (58). We also propose that such training models could be time efficient and would result in equivalent strength gains when compared with the heavier, extrinsically-oriented RT protocols, and importantly, equivalent or greater health benefits.

CONCLUSION

Our review shows that RT has positive effects on many health-related mechanisms. RT can become a central component in disease prevention and public health policies and programs. However, the pivotal change needed for wide-scale adoption of RT likely is a paradigm shift from a complex, time-consuming, extrinsic model to a more time-efficient, yet efficacious, intrinsic model of training. We fully acknowledge that such an idea may seem a radical departure from numerous recommendations in which complex programs of RT with manipulation of multiple variables are proposed as being maximally effective, at least in terms of promoting strength gains. However, we view such recommendations as largely unsupported and mostly redundant and unimportant in designing RT protocols that are far more likely to be adhered to by the general public in numbers sufficient enough to have an effect on public health.

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