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Health-Related Physical Fitness Benefits of Exercise Prescriptions for Individuals with Down Syndrome

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Health-Related Physical Fitness Benefits of Exercise Prescriptions for Individuals with Down Syndrome

A Synthesis of the Research Literature

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Abstract

This literature review synthesizes the published articles that relate to adolescents and adults with Down syndrome and the benefits of exercise prescription on specific health-related fitness components. Individuals with Down syndrome typically have lower levels of health-related physical fitness in regard to most fitness components. Participating in regular exercise can improve each of these components. Depending on the desired outcome of the exercise regiment administered, variations in type, frequency, duration and intensity of exercise can be adjusted. The results found in the literature are similar to the guidelines provided by the American College of Sports Medicine with a few slight differences. In regard to cardiovascular fitness for individuals with Down syndrome, it appears that lower intensities and frequencies can still be effective. In order to improve muscular strength and endurance a program should have a frequency of two to three days per week and consist of eight to 20 reps and two to four sets. Body composition can be improved in individuals with Down syndrome, however it may take more than 16 weeks to see the resulting changes.

Introduction

Health-related physical fitness is a measure of a person's general physical well-being. It is comprised of five different components: cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition (Ayers & Sariscsany, 2011). All five of these components are directly related to one's health and quality of life. Every individual needs a minimum level of each component in order to perform regular daily living activities. A higher level of health-related fitness also decreases the risk for cardiovascular disease and other diseases and can promote physical, social, and emotional health (Ayers & Sariscsany, 2011).

In order to improve upon each of these five components, people typically participate in exercise or other forms of physical activity regularly. The specific exercise performed can have a range of effects; it may only affect one component or it may have an influence on each of the five components. Running, for instance, may not only improve cardiorespiratory endurance, but also may increase muscular endurance for specific muscle groups. Several other factors can affect the benefits obtained from exercise. These factors include the intensity, duration, and frequency of the exercise regiment. When altering any of these components, the results of the exercise regiment also will vary.

There are groups of people who are more likely to live sedentary lifestyles and have lower fitness levels than their peers. Studies have shown that individuals with disabilities, including those born with Down syndrome (DS), are less likely to live a physically active lifestyle (Balic, Mateos, Blasco, & Fernhall, 2000). DS is a genetic condition that is detected before or immediately after birth. It is the result of a chromosomal abnormality generally caused by an additional copy of chromosome 21, also called trisomy 21 (Chera-Ferrario, 2012). According to the National Down Syndrome Society there are about 400,000 people living in the United States who have this diagnosis and its rate of occurrence is about one in every 700 live births (Galli et al., 2010).

As with all human beings, each person with DS is an individual and has their own uniqueness, however, several common factors can be associated with the majority of people who have this condition. These individuals are more likely to have an intellectual disability, hypotonia (low muscle tone), muscle weakness, ligament laxity, congenital heart defects, hypothyroidism, and abnormal reflex development (Chera-Ferrario, 2012; Cowley et al., 2011; Galli et al., 2010). These physiological effects can have a dramatic negative impact on these individuals' ability to perform and participate in physical activities (Barr & Shields, 2011). Individuals with DS are frequently less active than their peers without DS; they also typically score lower in the majority of the five health-related fitness areas (Lewis & Fragala-Pinkham, 2005).

Multiple studies have been performed and reported about the effects of specific training regiments on individuals with DS. These studies typically look at one or two types of exercise to make comparisons or to determine the benefits, if any, of a particular regiment. While a number of these training studies have been published, no attempt to synthesize the findings of this research has been found in the literature. The purpose of this report, therefore, was to synthesize the scientific literature that has examined the effects of specific exercise training programs for individuals with DS in regard to the different health-related fitness components. A literature review of this type should help to answer several questions. What type of exercise methods and training methodologies work to improve each of the health-related fitness components for individuals with DS? Which ones do not? What type of exercises should be performed and how do frequency, intensity, and duration affect the results of the exercise programs? Are the recommendations for fitness development for people with DS different from those without DS?

Operational Definitions

For the purpose of this study the following definitions were adopted:

- 10 repetition maximum (10-RM) or 12 repetition maximum (12-RM): The maximal load lifted in a full range of motion for a total of 10 or 12 repetitions respectively (Mendonca, Pereira, & Fernhall, 2011).
- Body composition: A health-related fitness component that is used to describe the proportion of fat mass to fat-free mass in the body. Bone, muscle, connective tissue, blood, and organs make up the bulk of the fat-free mass (*Health and wellness for life*, 2010).
- Body mass index (BMI): A measure of a person's stockiness (body mass in kilograms divided by height in meters squared, BMI = Weight / Height^2) used to assess if a person is underweight, of healthy weight, overweight, or obese (Swain, 2014).
- Cardiovascular endurance: The ability to be active for a prolonged period of time at a moderate to high intensity level and is aerobic (needing oxygen) in nature (Ciccomascolo & Sullivan, 2013). It is also referred to as cardiorespiratory endurance or aerobic capacity.

- Down syndrome (DS): Is a genetic condition that is detected before or immediately after birth. It is the result of a chromosomal abnormality generally caused by an additional copy of chromosome 21, also called trisomy 21 (Chera-Ferrario, 2012).
- Exercise: Physical activity of a repetitive nature that is planned or structured to improve or maintain one or more of the health-related fitness components (Ayers & Sariscsany, 2011).
- FITT principle: A method of prescribing exercise that incorporates frequency, intensity, time (duration), and type (Swain, 2014).
- Flexibility: The maximum range of motion of a joint (Swain, 2014).
- Frequency: The number of exercise sessions per week, or in some cases, per day (Swain, 2014).
- Health-related physical fitness: Those specific components of physical fitness that have a relationship with good health. The components of health-related physical fitness are aerobic fitness, muscular strength, muscular endurance, flexibility, and body composition as they relate specifically to health enhancement (Kaminsky, 2014).
- Maximal oxygen consumption (VO2 max): The maximal volume of oxygen consumed per unit of time. It is generally established in an incremental exercise test using a large amount of muscle mass in which a plateau of VO2 is attained or signs of maximal effort are attained (Swain, 2014).
- Muscular endurance: The ability of a muscle or muscle group to perform repeated contractions against a resistance over a period of time. It also can be stated as the

number of repetitions to failure of a specific exercise performed using a certain resistance (Coulson & Archer, 2009).

- Muscular strength: The maximum amount of force a muscle or muscle group can generate. Muscular strength is generally associated with resistance training programs that utilize high intensity and low repetitions (Coulson & Archer, 2009).
- Percent body fat: The percentage of an individual's mass that is fat. This can be estimated by dual-energy X-ray absorptiometry (DEXA), plethysmography, hydrostatic weighing, skinfold assessment, or other methods (Swain, 2014).
- Physical activity: Any bodily movement produced by contraction of skeletal muscle that increases energy expenditure above basal level (Swain, 2014).
- Physical fitness: An attained set of attributes that relates to the ability to perform physical activity (Swain, 2014).

Methods

The purpose of this report was to review all of the scientific literature that has been published which examines the effects of exercise training programs for individuals with DS in regard to the components of health-related physical fitness. This scientific literature was found using seven different search engines: SPORTDiscus, Academic Search Complete, Physical Education Index, ScienceDirect, MEDLINE, Google Scholar, and Academic Onefile.

The following terms were used to perform an exhaustive literature search: Down syndrome, trisomy 21, fitness, exercise, physical activity, health benefits, training, physical activity, muscular strength, muscular endurance, cardiorespiratory endurance, cardiovascular endurance, aerobic capacity, body composition, and flexibility. These terms were combined in a variety of ways in order to locate the maximum number of scholarly articles on the topic.

The combinations of terms that yielded the greatest results were:

- DS, exercise, benefits
- DS, muscular strength
- DS, cardiovascular endurance, exercise
- DS, body composition
- DS, physical activity, benefits

Using these search combinations, the seven different databases identified 409 potential articles. To narrow down these results and locate research specifically relating to this synthesis, inclusion criteria, as described below, were applied to each of the potential articles identified in the database searches.

Criteria for Inclusion

The following criteria were used to identify published research articles for inclusion in this literature review. Each of the studies selected had to:

- Be published in English
- Present original data
- Be published between 2000 and September 2016
- Appear in scholarly (peer reviewed) journals
- Focus on individuals with Down syndrome
- Center on adolescents and/or adults (10 years and older)
- Involve at least one form of exercise
- Be quantitative experimental research

- Provide data on at least one of the following four health-related fitness components
  - Cardiovascular endurance
  - Muscular strength
  - Muscular endurance
  - Body composition

Research studies were excluded if they did not fulfill the aforementioned criteria or the analysis of the experiment looked at the benefits of exercise regiments in regard to medical, social, or cognitive aspects. Others were disregarded because they pertained specifically to skill-related physical fitness; their focus was on balance, coordination, and/or agility instead of the five health-related fitness components. Individuals with DS, however, characteristically have ligament laxity and hypotonia, which generally results in hyper flexibility (Galli, Rigoldi, Brunner, Virji-Babul, & Giorgio, 2008). Since increasing flexibility is typically not a goal for individuals with DS, and no research was found that attempted to improve flexibility for people with DS, flexibility was not examined in this synthesis.

Procedures for Coding

After narrowing the search via the inclusion criteria, a total of 18 articles were selected for the synthesis. Scientific literature was found and analyzed from a number of different countries including the United States, Australia, Spain, Greece, Brazil, Portugal, India, and Taiwan. Although the research came from a variety of countries, all articles used for this synthesis had to be written in or translated to English. These articles were published in a number of different scholarly journals such as *Journal of Intellectual Disability Research, Disability and Rehabilitation, Clinical Rehabilitation, Journal of*

Physiotherapy, Journal of Strength and Conditioning Research, International Medical Review on Down's Syndrome and *Research in Developmental Disabilities.*

All 18 of these articles were coded for analysis. The following information was abstracted from each of the articles and recorded on the coding sheet: authors, publication date, title, source, health-related fitness components measured, frequency, duration (in weeks), intensity of regiment, type of exercise, and experimental findings. Some of the research articles used provided data for more than one health-related fitness component. This information was noted in the coding sheet, but the study was still coded as one individual study. The coding sheets can be found in the appendix.

Each of the health related fitness components found in the literature was measured differently. Cardiovascular endurance typically was measured by a change in maximal oxygen consumption (VO2 max), whereas body composition was measured by body mass index (BMI) or percent body fat. The data on muscular strength was obtained in the form of estimating a one-repetition maximum (1RM) or by using an instrument that can measure the magnitude of force. Muscular endurance was calculated by performing an exercise using a submaximal force and measuring the time or number of repetitions until exhaustion. Whether the study showed an increase, decrease, or no change in one of these measurements, it was recorded on the coding sheet under experimental findings.

The mode of exercise performed, such as aerobic or resistance training, was recorded as the type of exercise for the experiment. The frequency was measured by number of days per week for the regiment and the duration was recorded as the number of weeks. The intensity was not always provided, however when it was, it came in different forms. For strength and resistive exercises it was calculated using either a percentage of 1RM or by using a 10 or 12 repetition maximum (10-RM; 12-RM). For cardiovascular or aerobic exercises intensity was supplied as either a percentage of VO2 max or as a percentage of maximal heart rate (HR max). In order to compare the two measurements the equation below was obtained from the National Council on Strength and Fitness. It was used to convert the percentage of HR max to a percentage of VO2 max.

$$\%\text{HR max} = .6463 \times \%\text{VO2 max} + 37.182$$

Plan for Analysis

After all articles were read and all data were extracted an analysis was performed by examining the similarities and differences among each of the studies. Each study was first grouped by the health-related physical fitness component(s) for which it provided experimental findings. Once grouped by component, the studies were then separated by whether or not an improvement was found. Finally, similarities and differences in the frequency, intensity, duration, and type of exercise were noted.

Results

A critical mass of 18 articles was examined to provide information on health-related physical fitness components in relation to exercise programs for individuals with DS. Each of the health-related fitness components was analyzed separately and this section of the literature review is organized into sections for each of these components: cardiovascular endurance, muscular endurance, muscular strength, and body composition. A table is provided for each individual component which provides a summary of each of the articles that pertained to that health-related fitness component being analyzed. The results column provides information about if and how the specific component being addressed was changed after the intervention.

Cardiovascular Endurance

Cardiovascular endurance is the ability to be active for a prolonged period of time at a moderate to high intensity level and is aerobic in nature (Ciccomascolo & Sullivan, 2013). It is also referred to as cardiorespiratory endurance or aerobic capacity. This component is generally evaluated using peak VO2 or VO2 max. This measurement quantifies the body's ability to circulate oxygen and utilize oxygen during moderate to vigorous exercise. Out of the 18 research articles reviewed, nine of them produced results directly related to cardiovascular endurance and are summarized in Table 1. Seven of the nine of these training studies showed increases in aerobic capacity while two did not show any improvement.

Table 1

Cardiovascular Endurance

Author(s)	Type	Frequency	Duration	Intensity	Result
Boer & Moss (2016)	Continuous Aerobic Training vs. Interval Training (running & cycling)	3 days/ week	12 weeks	70-85% VO2max for aerobic group, all out sprints for the interval group	Increase
Cowley et al. (2011)	Progressive Resistance Training	2 days/ week	10 weeks	10-RM increasing when exceeded	No change
González-Agüero (2014)	Circuit Training	2 days/ week	21 weeks	Not provided	Increase
Lewis & Fragala-Pinkham (2005)	Aerobic Conditioning & Strength Training	4-6 days/ week	6 weeks	60-80% HRmax (35-66% VO2max)	Increase
Mendonca & Pereira (2009)	Ergometer Conditioning	2 days/ week	28 weeks	60-85% VO2max	Increase

	(treadmill, stepper, cycling, etc)				
Mendonca et al. (2011)	Aerobic & Resistance Training	3 days/ week	12 weeks	65-85% VO2max, 12-RM increasing by 10%	Increase
Rimmer et al. (2004)	Cardio & Strength Training	3 days/ week	12 weeks	50-70% VO2max	Increase
Tsimaras et al. (2003)	Jogging & Walking Training	3 days/ week	12 weeks	65-75% HRmax (43-60% VO2max)	Increase
Varela et al. (2001)	Rowing	3 days/ week	16 weeks	55-70% VO2max	No change

The type of exercise employed by the studies summarized in Table 1 varied among the experiments. Most of these exercise regiments included a mixture of aerobic and strength training. Aerobic exercises such as running, walking, and/or cycling were part of the exercise training for six out of the seven articles that showed improvement (Boer & Moss, 2016; Lewis & Fragala-Pinkham, 2005; Mendonca & Pereira, 2009; Mendonca, Pereira, & Fernhall, 2011; Rimmer, Heller, Wang, & Valerio, 2004; Tsimaras, Giagazoglou, Fotiadou, Christoulas, & Angelopoulou, 2003). The two that showed no improvement focused on progressive resistance training and rowing (Cowley et al., 2011; Varela, Sardinha, & Pitetti, 2001). These two types of exercises may not be useful in improving cardiovascular endurance among subjects with DS.

The frequency of these exercise programs ranged from two days per week up to six days per week, with an average of three days per week. The duration of these programs ranged from six weeks to 28 weeks long. The frequency and duration did not appear to be a factor in whether cardiovascular endurance was improved. Two of the articles did not provide information on the intensity of the exercises being performed, however the seven that did ranged from 35% to 85% of VO2 max. Even at the lower levels of VO2 max, participants were able to increase their level of cardiovascular endurance.

One article was different from the rest because it explored the differences in two types of exercise programs. Boer & Moss (2016) compared two types of training in regard to aerobic fitness, which allowed for a direct comparison between these two types. One of the experimental groups participated in continuous aerobic training, running and cycling at 70-85% of VO2 max. The other experimental group completed an interval training program in which they performed shorter sprints at 100% effort with breaks in between. Both of the experimental groups showed significant improvement in cardiovascular endurance in comparison to the control group. The interval training program, however, showed greater improvement in aerobic capacity than the continuous aerobic training group.

Muscular Endurance

Muscular endurance is the ability of a muscle or muscle group to perform repeated contractions against a resistance over a period of time. It also can be stated as the number of repetitions to failure of a specific exercise performed using a certain resistance (Coulson & Archer, 2009). Four of the 18 studies provided results in the area of muscular endurance. Table 2 lists the details for each of these four articles. Each of these training regiments showed at least some improvement in muscular endurance, however, Shields, Taylor, & Dodd (2008), only found improvement in upper body muscular endurance and no change in lower body muscular endurance.

Table 2

Muscular Endurance

Author(s)	Type	Frequency	Duration	Intensity	Result

Lewis & Fragala-Pinkham (2005)	Aerobic & Strength Training	4-6 days/ week	6 weeks	Not provided	Increase lower body muscular endurance
Rimmer et al. (2004)	Aerobic & Strength Training	3 days/week	12 weeks	70% of 1RM, increasing by 10% when exceeded, 1-2 sets, 10-20 reps	Increase lower body muscular endurance
Shields et al. (2008)	Progressive Resistance Training	2 days/week	10 weeks	12-RM, 2 sets, 10-12 reps	Increase upper body muscular endurance, no change in lower body muscular endurance
Tsimaras & Fotiadou (2004)	Muscular Strength (plyometrics) & Balance Exercises	3 days/week	12 weeks	Not provided	Increase lower body muscular endurance

All four studies summarized in Table 2 included strength training exercises. Two of the training regiments included aerobic exercise training and a third incorporated balance training. Types of exercises included plyometrics, body weight exercises (such as push-ups, squats, and sit-ups), free weights, and progressive resistance training. Only two of the studies provided the intensity for these exercise regiments which were 70% of 1RM (Rimmer et al., 2004) and two sets at 12-RM (Shields, Taylor, & Dodd, 2008). The training sessions also varied in time from 30 to 60 minutes, and the programs lasted from six weeks to 12 weeks. Because the type, intensity, and duration vary so widely for these four studies, it is impossible to determine which ones had a greater effect on muscular endurance, but regardless of the regiment used, each provided some positive gains in muscular endurance.

The frequency of these programs varied from two days per week to six days per week, with an average of 3.25 sessions per week. Shields, Taylor, & Dodd (2008) conducted the only study that had a frequency of less than three days per week. This also was the only study that did not show improvement in lower body muscular endurance. Increasing the frequency of the exercise regiment may have resulted in an increase in the improvement of lower body muscular endurance.

Muscular Strength

Muscular strength is the maximum amount of force a muscle or muscle group can generate (Coulson & Archer, 2009). This is commonly measured by performing a one-repetition maximum for a specified exercise. It also can be estimated by performing an exercise with heavy resistance until failure, or by used of dynamometers. This health-related fitness component is vitally important for all individuals, but especially those with intellectual disabilities (Shields & Taylor, 2010). It can have a direct effect on a person's ability to perform regular daily activities and work-related tasks.

Table 3

Muscular Strength

Author(s)	Type	Frequency	Duration	Intensity	Result
Boer & Moss (2011)	Continuous Aerobic vs. Interval Training (running & cycling)	3 days/ week	12 weeks	70-85% VO2max for aerobic group, all out sprints for the interval group	Increase lower body strength for both groups, greater for aerobic
Cowley et al. (2011)	Progressive Resistance Training	2 days/ week	10 weeks	10-RM increasing when exceeded, 3 sets, 8-10 reps	Increase lower body strength
Gupta et al. (2011)	Progressive Resistive, Strength & Balance Exercises	3 days/ week	6 weeks	50% 1RM, 2 sets, 10 reps	Increase lower body strength

Lewis & Fragala-Pinkham (2005)	Aerobic & Strength Training	4-6 days/ week	6 weeks	60-80% HRmax for aerobic, not specified for strength training	Increase lower body strength
Lin & Wuang (2012)	Virtual Reality with Treadmill Warm-up	3 days/ week	6 weeks	Not provided	Increase lower body strength
Mendonca et al. (2011)	Aerobic & Resistance Training	3 days/ week	12 weeks	65-85% VO2max, 12-RM increasing by 10% when exceeded	Increase upper & lower body strength
Rimmer et al. (2004)	Aerobic & Strength Training	3 days/ week	12 weeks	70% of 1RM, increasing by 10% when exceeded, 1-2 sets, 10-20 reps	Increase lower body strength
Shields & Taylor (2010)	Progressive Resistance Training	2 days/ week	10 weeks	10-RM increasing when exceeded, 3 sets, 12 reps	Increase lower body strength, no change in upper body strength.
Shields et al. (2008)	Progressive Resistance Training	2 days/ week	10 weeks	12-RM, 2 sets, 10-12 reps	Increase upper body strength, no change in lower body strength
Shields et al. (2013)	Strength Training, Pin Loaded Weight Machines	2 days/ week	10 weeks	60-80% of 1RM, 3 sets, 12 reps	Increase upper & lower body strength
Tsimaras & Fotiadou (2004)	Muscular Strength & Balance Exercises	3 days/ week	12 weeks	Not provided	Increase lower body strength

Out of the 18 research articles examined, muscular strength was addressed in the 11 summarized in Table 3. The majority of the research was focused on lower body muscular strength as this is vital for walking, running, climbing stairs, and other daily movements. All 11 of these articles showed at least some improvement in muscular strength as a result of training. Shields & Taylor (2010) found an increase in lower limb muscular strength and no significant change in upper body muscular strength. Shields, Taylor, & Dodd (2008), however, found just the opposite; there was a trend toward increasing upper limb muscular strength and no change in lower body muscular strength.

The type of exercise training varied among the 11 studies, although, nine of the 11 included some form of resistance training. This involved body weight exercises, pin-loaded weight machines, fitness band exercises, and free weights. Four of these studies also incorporated aerobic exercises into the regiment and two others included balance activities within their programs. The resistive exercises were typically performed for a specified number of repetitions and sets. The repetitions varied between eight and 12, whereas the number of sets only varied between one and three. The number of exercises for each of these studies ranged from six to 11, with an average of 7.5 exercises. It appeared as if the number of repetitions, sets, and exercises did not vary substantially throughout the research.

There were only two studies that did not focus specifically on resistance training. Boer & Moss (2016) compared continuous aerobic training to interval training. Both of these programs showed an increase in muscular strength, however, the improvement was larger for the continuous aerobic training group. The other study that did not involve resistance training examined the effects of a virtual reality exercise program (Lin & Wuang, 2012). This program involved a warm-up period followed by 20 minutes of game-like exercises provided by the Nintendo Wii gaming technology. This innovative and unique form of exercise also showed increases in lower body muscular strength.

The frequency of these 11 studies ranged from two to six days per week, with an average of three days per week. The duration ranged from six to 12 weeks with an average of 9.8 weeks. The two studies that did not report increases in both lower and upper muscular strength (Shields et al., 2008; Shields & Taylor, 2010) were similar in that the frequency was twice per week and the duration was 10 weeks. Gupta, Rao, & SD (2011) and Lewis & Fragala-Pinkham (2005) both reported increases in muscular strength for programs that had a duration of six weeks. Both studies involved a frequency of at least three days per week.

Body Composition

Body composition is the health-related fitness component that is used to describe the proportion of fat mass to fat-free mass in the body. Bone, muscle, connective tissue, blood, and organs make up the bulk of the fat-free mass (*Health and wellness for life*, 2010). There are several ways to measure body composition, but the two main methods are body mass index (BMI) and percent body fat. From the 18 articles examined, nine studies investigated body composition, and each summarized below in Table 4.

Table 4

Body Composition

Author(s)	Type	Frequency	Duration	Intensity	Result
Boer & Moss (2016)	Continuous Aerobic Training vs. Interval Training (running & cycling)	3 days/ week	12 weeks	70-85% VO2max for aerobic group, all out sprints for the interval group	Decrease in weight & BMI for both groups, greater decrease for interval group, no change in fat mass for either group
González-Agüero et al. (2011)	Aerobic & Plyometric Exercises	2 days/ week	21 weeks	Not provided	Increase in lean mass, no change in fat mass
Lewis & Fragala-Pinkham (2005)	Aerobic & Strength Training	4-6 days/ week	6 weeks	60-80% HRmax (35-66% VO2max)	No change in BMI, no change in weight

Mendonca & Pereira (2009)	Ergometer Conditioning (treadmill, stepper, cycling, etc)	2 days/ week	28 weeks	60-85% VO2max	Decrease in fat mass, increase in lean mass, no change in weight or BMI
Mendonca et al. (2011)	Aerobic & Resistance Training	3 days/ week	12 weeks	65-85% VO2max, 12-RM increasing by 10%	No change in body mass or BMI, no change in fat mass
Ordonez et al. (2006)	Aerobic Exercises (on land in water)	3 days/ week	12 weeks	Not provided	Decrease in fat mass, decrease in weight
Rimmer et al. (2004)	Aerobic & Strength Training	3 days/ week	12 weeks	50-70% VO2max, 70% 1RM	Decrease in body weight, no change in body fat %
Seron et al. (2014)	Aerobic Training vs. Resistance Training	2-3 days/ week	12 weeks	50-70% HRmax, (20-50% VO2max) 12 Rep Max	No change body fat % for either group, decrease in BMI for the aerobic group
Varela et al. (2001)	Rowing	3 days/ week	16 weeks	55-70% VO2max	No change in body weight, no change in body fat %

Of the nine articles summarized in Table 4, eight of them evaluated their participants using BMI. Four of these experiments ascertained a decrease in either weight or BMI, whereas the other four did not exhibit a change in these areas.

Although BMI is widely accepted as an estimated measure of body composition, there are other methods that can be used which have been shown to have greater accuracy (Duren et al, 2008). Of the eight articles that assessed body composition, five different methods were used. Varela et al. (2001) used the Kelly & Rimmer equation which involved measuring height, weight, and specific body circumferences. Other methods included skinfold calipers (Ordonez, Rosety, & Rosety-Rodriguez, 2006; Rimmer et al., 2004), dual-energy X-ray absorptiometry (González-Agüero et al., 2011), airdisplacement plethysmography (Seron, Silva, & Greguol, 2014), and bioelectrical impedance (Boer & Moss, 2016; Mendonca & Pereira, 2009; Mendonca, Pereira, & Fernhall, 2011). Of these eight articles only three saw a positive change in fat mass or body fat percentage.

The frequency of training was very consistent for each of these training regiments; it ranged from 2 to 3 days per week. Intensity, however, was wide ranging from 20% to 85% of VO2 max. Two of the studies (González-Agüero et al., 2011; Ordonez, Rosety, & Rosety-Rodriguez, 2006) did not provide a statistic for intensity, although both reported an improvement in body fat percentage. Neither frequency nor intensity appeared to have an effect on whether there was a change in body fat percentage.

The duration of these studies ranged from six to 28 weeks. Only two of them had a duration greater than 16 weeks. González-Agüero et al. (2011) conducted their study for 21 weeks while Mendonca & Pereira (2009) researched for 28 weeks. Both of these studies showed improvement in body fat percentage. The only study that was shorter than 16 weeks in duration and still showed improvement in percent body fat percentage was conducted by Ordonez, Rosety, & Rosety-Rodriguez in 2006. This study was based on aerobic exercise which was a common attribute throughout all eight of these studies. Each of these exercise regiments included some sort of aerobic training and five of them included strength and/or resistance training. The one uniqueness in Ordonez, Rosety, and Rosety-Rodriguez's study was that their regiment included both aerobic activities on land and in the water.

Discussion

The results of the examination of the primary literature showed trends in exercise regiments that have led to an improvement in at least one of the health-related fitness components for individuals with DS. These trends were analyzed in relation to type, frequency, duration, and intensity of the exercises being performed. The results varied depending on the specific health-related fitness component(s) being examined. The American College of Sports Medicine (ACSM) lists guidelines for exercise prescription for adults without disabilities (Pescatello, 2014). This section will compare each of the four fitness components examined to the guidelines published by the ACSM. Recommendations for educators and future research will be provided at the end of this section.

Cardiovascular Endurance

The results of the literature review showed that the frequency and duration of the exercise regiments examined to improve cardiovascular endurance varied widely. The frequency ranged from two to five days and the duration of the program ranged from six to 28 days. Even though there was considerable variation in these aspects of the program, aerobic capacity improved for individuals with DS. This may imply that it is not the frequency or duration that is the main contributing factor to improving fitness in this area.

Intensity was also wide-ranging for these regiments: 35-85% of VO2 max. Each of these studies fell within the scope of moderate to vigorous physical activity according to the ACSM (Pescatello, 2014). Tsimaras et al. (2003) examined the effects of a jogging and walking program for individuals with DS. The intensity was monitored and remained at approximately 43-62% of VO2 max. This is considered moderate physical activity and does not quite meet the level of vigorous activity, yet improvement resulted for the individuals under this protocol. This may be the result of low initial fitness levels for these specific participants. It is known that people with DS typically have lower levels of physical fitness and therefore improvement in these levels may occur at lower intensities. The ACSM notes that light to moderate exercise can be advantageous in deconditioned individuals (Pescatello, 2014). These individuals may see the benefits of lower intensity exercise at the moment, but once they reach a higher level of fitness, greater intensities may be required to achieve physical fitness improvements.

Although the frequency, intensity, and duration of the programs differed greatly, the studies that indicated improvement in cardiovascular endurance did not differ considerably in relation to type of exercise. Walking, jogging, and cycling all resulted in an increase in aerobic capacity for individuals with DS, whereas rowing and progressive resistance training alone did not provide improvements to cardiovascular endurance. According to the principle of specificity, physiological changes to exercise are specifically related to the type of exercise being performed (Garber et al., 2011). When designing an exercise regiment that attempts to improve cardiovascular endurance in deconditioned people with DS light aerobic activities such as walking, jogging, or cycling should be included.

Muscular Strength & Muscular Endurance

Although muscular strength and muscular endurance were examined separately, the findings were similar and are therefore combined in this section. The type of exercise was extremely wide-ranging for these studies. Some studies merely included walking and running or participating in a virtual reality exercise session. Others, however, involved a conglomeration of different activities including progressive resistance training, balance training, plyometric exercises, and many more. It appears that muscular strength and muscular endurance can be improved by a multitude of ways and therefore the exact type of exercises that should be included in muscular strength and endurance training regiments for people with DS may be more specific to the individual and their personal preferences.

The intensity of exercise was provided in several different ways including 1RM, 10-RM, 12-RM, and %VO2 max, therefore a comparison between the intensities of each study was unfeasible. Most of these articles did, however, provide information on the number of sets and repetitions that were performed for each exercise. The range between these numbers was minimal. The repetitions fluctuated between eight and 12, whereas the sets ranged between one and three. The ACSM suggests eight to 12 repetitions to improve strength and 15-20 repetitions to improve endurance. They also recommend two to four sets to improve strength and one to two sets to improve endurance (Pescatello, 2014). The majority of these studies appeared to be aimed more at improving muscular strength than endurance, however, residual improvements in endurance were found after completion of these regiments.

The frequency of these regiments varied between two to six days per week and lasted anywhere from six to 12 weeks. The studies that did not report increases in both lower and upper muscular strength or endurance (Shields, Taylor, & Dodd, 2008; Shields & Taylor, 2010) were similar in that the frequency was twice per week and the duration was 10 weeks. Shields, Taylor, & Dodd (2008) reported that increasing the frequency and/or duration may help to find greater gains in muscular strength and/or lower body muscular endurance. Gupta, Rao, & SD (2011) and Lewis & Fragala-Pinkham (2005) both reported increases in muscular strength for programs that had a duration of six weeks. Both studies involved a frequency of at least three days per week. It appears as if increasing the frequency of these training programs to at least three days per week may have a greater effect than increasing the duration of the regiment.

Body Composition

The research that examined changes in body composition for individuals with DS in relation to training regiments included a wide variety of exercise types. Walking, running, resistance training, aerobic conditioning, strength training, swimming, plyometrics, and rowing were just some of the forms of exercise involved in this research. Although the types were different, each of these studies included at least some form of aerobic training. No trends were identified between the type of exercise and the outcome of the regiment in regard to change in body composition for individuals with DS.

The intensities of the regiments varied between 20% and 85% of VO2 max. Only three of the studies showed an improvement in body composition and two of these did not provide a statistic for intensity. Since these values were not provided, no conclusion on what level of intensity is necessary to show improvements in body composition was drawn. The frequencies of these training programs varied minimally: two to three days. This low variability did not allow for differences to be observed.

Only two programs had a duration longer than 16 weeks. Both of these indicated improvement in body composition. This may imply that a duration longer than 16 weeks may be necessary to improve body composition among individuals with DS. This component of health-related physical fitness can take longer to exhibit changes. Only one study that was 12 weeks long saw a positive change in body composition. The main difference between this study and the remainder was that it included both land and water aerobic activities. The water exercises may have been the reason for the improvement in body fat percentage. Including the pool or other aquatic activities in an exercise regiment may promote changes in body composition at a quicker rate than those that only incorporate land exercises.

Exercise Prescription For Individuals with DS

The ACSM guidelines for improving muscular strength and endurance appear to be very similar to the results found in this research review. Individuals with DS should perform resistance exercises two to three times per week for two to four sets and eight to 20 repetitions depending on the intended out come.

The ACSM guidelines for cardiovascular endurance differ slightly from the results in the research review. ACSM recommends at least three days of vigorous physical activity each week or greater than five days for moderate activity. Many of the studies in this review have shown that cardiovascular endurance has been improved by just performing exercise at a moderate level for three days per week. Individuals with DS typically have a lower level of physical fitness and therefore a lower intensity and lower frequency can still provide positive results. It is important to note that none of these studies listed dropouts due to difficulty or injury. Individuals with DS can participate safely in regular physical activity when provided with proper instructions, equipment, and guidelines.

Although ACSM does not provide guidelines to improve body composition, the results in this review indicate that this health-related fitness component may take longer to change. Body composition did not display improvement until after 16 weeks and therefore a longer duration program should be implemented when attempting to improve this specific component. A summary of the comparison between the ACSM guidelines and the findings in this literature review is provided in Table 5.

Table 5

ACSM Guidelines vs. Synthesis Findings

Health-Related Fitness Component	ACSM Guidelines	Synthesis Findings
Cardiovascular Endurance	At least five days of moderate physical activity or at least three days of vigorous physical activity.	Improvement was found using moderate activity for just three days per week.
Muscular Endurance	2-3 days/week 1-2 sets 15-20 repetitions	Regiments were based on strength guidelines, however residual improvements were found for muscular endurance.
Muscular Strength	2-3 days/week 2-4 sets 15-20 repetitions	2-3 days/week 2-4 sets 15-20 repetitions (same as the ACSM guidelines)
Body Composition	No set guidelines	Regiments that were 16 weeks or longer showed improvement.

As shown in Table 5, the findings from this literature review are very similar to the ACSM guidelines with minor differences. Cardiovascular endurance can be improved with just three days of moderate activity and residual improvements can occur in muscular endurance when following the guidelines for muscular strength.

Recommendations for Teachers

Individuals with DS are often integrated into an inclusive setting with their typically developing peers. Teachers will need to make adjustments in order to accommodate these learners, including adjustments in exercise prescription. According to the results of this synthesis, however, only minor changes will need to be made. The type, frequency, duration, and intensities of the exercise regiments examined can be used to create a well-rounded exercise program that promotes benefits for individuals with DS to improve their cardiovascular fitness, muscular endurance, muscular strength, and body composition.

The research showed that adolescents with DS were able to participate in a wide range of activities that are already being taught in the physical education setting. The results also show that the frequency (two to three days per week) of training is similar to a typical physical education schedule in many schools. When creating a program to improve these four components of physical fitness for adolescents with DS it should include two to three days of muscular strength and muscular endurance exercises; it should also incorporate at least three days of cardiovascular endurance exercises. Individuals with DS also have the ability to work at an intensity that corresponds with the recommended guidelines for their typically developing peers. It is important, however, to remember that individuals with DS may have a lower level of initial fitness, especially in the muscular strength and cardiovascular endurance areas and therefore their personal intensity level for these activities should be adjusted to fit their needs. In order to improve body composition, the program should minimally be 16 weeks in duration.

Recommendation for Future Research

A recommendation for future research is warranted based on the analysis of this research. The majority of the studies reviewed involved individuals who had previously lived a sedentary lifestyle. Initial testing with these participants showed that they were below average in almost all aspects in comparison to their peers without DS. Research should be conducted on individuals with DS who are physically active and determine whether the differences found from the ACSM guidelines are a result of deconditioning or are related specifically to DS. Future research also should be conducted to see the long-term effects of these programs. The majority of studies had a duration of only 12 weeks. It is unknown what changes should be implemented once the participants are actively involved in a program for a greater duration.

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Appendix
Coding Sheets

Author/Date	**Title**	**Source**	**Health-Related Component(s)**	**Frequency**	**Duration**	**Intensity**	**Type of Exercise**	**Findings**
Boer, P., & Moss, S. J., (2016)	Effect of continuous aerobic vs. interval training on selected anthropometrical, physiological and functional parameters of adults with Down syndrome	*Journal Of Intellectual Disability Research*	Body Composition, Muscular Strength, & Cardiovascular Endurance	3 days /week	12 weeks	70-85% VO2max for aerobic group, all out sprints for the interval group	Interval training, continuous aerobic training (running & cycling), control group	Increase in aerobic capacity for both experimental groups. Increase in lower body muscular strength for both groups but higher in CAT group. Decrease in weight & BMI for both groups, greater decrease for interval group, no change in fat mass for either group
Cowley, P. M., Ploutz-Snyder, L. L., Baynard, T., Heffernan, K. S., Young Jae, S., Hsu, S., Miyoung, L., . . . Fernhall, B., (2011)	The effect of progressive resistance training on leg strength, aerobic capacity and functional tasks of daily living in persons with Down syndrome	*Disability & Rehabilitation*	Muscular Strength, Cardiovascular Endurance	2 days /week	10 weeks	10-RM increasing when exceeded, 3 sets, 8-10 reps	Progressive resistance training	Increase lower body muscle strength. No change in aerobic capacity.

González-Agüero, A., Gómez-Cabello, A., Matute-Llorente, A., Gómez-Bruton, A.,Vicente-Rodríguez, G., & Casajús, J. A., (2014)	Effects of a circuit training including plyometric jumps on cardiorespiratory fitness of children and adolescents with Down syndrome	*International Medical Review on Down's Syndrome*	Cardiovascular endurance	2 days /week	21 weeks	Not provided	Circuit training & plyometrics	Increase cardiovascular endurance; increase vo2 max.
González-Agüero, A., Vicente-Rodríguez, G., Gómez-Cabello, A., Ara, I.,	A combined training intervention programme increases lean mass in youths	*Research In Developmental Disabilities*	Body Composition	2 days /week	21 weeks	Not provided	Aerobic and plyometric exercises	Increase lean mass, no change in fat mass.

Moreno, L. A., & Casajús, J. A., (2011)	with Down syndrome							
Gupta, S., Rao, B. K., & SD, K., (2011)	Effect of strength and balance training in children with down's syndrome: A randomized controlled trial	*Clinical Rehabilitation*	Muscular Strength	3 days /week	6 weeks	50% 1RM, 2 sets, 10 reps	Strength & Balance, Progressive Resistive Exercises	Increase in lower body muscular strength.
Lewis, C. L., & Fragala-Pinkham, M. A., (2005)	Effects of aerobic conditioning and strength training on a child with Down syndrome: A case study.	*Pediatric Physical Therapy: The Official Publication Of The Section On Pediatrics Of The American Physical Therapy Association*	All 5 Components	4-6 days /week	6 weeks	60-80% HRmax (35-66% VO2max) for aerobic, not specified for strength training	Aerobic conditionin g & strength training	Increase aerobic capacity. Increase in lower body muscular strength. Increase in lower body muscular endurance. No change in body weight; no change in BMI.
Lin, H. C., & Wuang, Y. P., (2012)	Strength and agility training in adolescents with Down syndrome: A randomized controlled trial.	*Research In Development al Disabilities*	Muscular Strength	3 days /week	6 weeks	Not provided	Virtual reality with treadmill warm-up	Increase in lower body muscular strength.

Mendonca, G. V., & Pereira, F. D., (2009)	Influence of long-term exercise training on submaximal and peak aerobic capacity and locomotor economy in adult males with Down's syndrome	*Medical Science Monitor: International Medical Journal Of Experimental And Clinical Research*	Body Composition & Cardiovascular Endurance	2 days /week	28 weeks	60-85% VO2max	Ergometer conditioning (treadmill, stepper, cycling, etc)	Increase in cardiovascular endurance. Decrease in fat mass, increase in lean mass, no change in weight or BMI.
Mendonca, G. V., Pereira, F. D., & Fernhall, B., (2011)	Effects of combined aerobic and resistance exercise training in adults with and without Down syndrome	*Archives Of Physical Medicine & Rehabilitation*	Body Composition, Muscular Strength, & Cardiovascular Endurance	5 days /week	12 weeks	65-85% VO2max, 12-RM increasing by 10% when exceeded	Combined aerobic & resistance training	Significant improvement in VO2 peak. Generalized improvement in both lower body and upper body muscular strength. No change in body mass or BMI, no change in fat mass
Ordonez, F. J., Rosety, M., & Rosety-Rodriguez, M., (2006)	Influence of 12-week exercise training on fat mass percentage in adolescents with Down syndrome	*Medical Science Monitor: International Medical Journal Of Experimental*	Body Composition	3 days /week	12 weeks	Not provided	Aerobic exercises on land & in water	Decrease in fat mass, no change in weight.

		And Clinical Research						
Rimmer, J. H., Heller, T., Wang, E., & Valerio, I., (2004)	Improvements in physical fitness in adults with Down syndrome.	*American Journal Of Mental Retardation: AJMR*	Muscular Strength, Muscular Endurance, Cardiovascular Endurance, Body Composition	3 days /week	12 weeks	50-70% VO2max, 70% of 1RM, increasing by 10% when exceeded, 1-2 sets, 10-20 reps	Cardiovascular exercises & strength training	Increase in lower body muscular strength. Increase in lower body muscular endurance. Increase in cardiovascular endurance. Decrease in body weight, no change in body fat percentage.
Seron, B. B., Silva, R. C., & Greguol, M., (2014)	Effects of two programs of exercise on body composition of adolescents with Down syndrome.	*Revista Paulista De Pediatria: Orgão Oficial Da Sociedade De Pediatria De São Paulo*	Body Composition	2-3 days /week	12 weeks	50-70% HRmax, (20-50% VO2max) 12 Rep Max	Aerobic training vs resistance training	No change body fat % for either group, decrease in BMI for the aerobic group.
Shields, N., & Taylor, N. F., (2010)	A student-led progressive resistance training program increases lower limb muscle strength in adolescents with Down syndrome: A	*Journal Of Physiotherapy*	Muscular Strength	2 days /week	10 weeks	10-RM increasing when exceeded, 3 sets, 12 reps	Progressive resistance training	Increase in lower body muscular strength. No change in upper body muscular strength.

	randomised controlled trial.							
Shields, N., Taylor, N. F., & Dodd, K. J., (2008)	Effects of a community-based progressive resistance training program on muscle performance and physical function in adults with Down syndrome: A randomized controlled trial	*Archives Of Physical Medicine & Rehabilitation*	Muscular Strength, Muscular Endurance	2 days /week	10 weeks	12-RM, 2 sets, 10-12 reps	Progressive resistance training	Increase in upper body muscular endurance. Trend toward upper body muscular strength improvement. No change in lower body muscular strength or muscular endurance.
Shields, N., Taylor, N. F., Wee, E., Wollersheim, D., O'Shea, S. D., & Fernhall, B., (2013)	A community-based strength training programme increases muscle strength and physical activity in young people with Down syndrome: A randomised controlled trial.	*Research In Developmental Disabilities*	Muscular Strength	2 days /week	10 weeks	60-80% of 1RM, 3 sets, 12 reps	Strength training, pin-loaded weight machines	Increase upper and lower body muscular strength.

Tsimaras, V. K., & Fotiadou, E. G., (2004)	Effect of training on the muscle strength and balance ability of adults with Down syndrome.	*Journal Of Strength & Conditioning Research*	Muscular Strength, Muscular Endurance	3 days /week	12 weeks	Not provided	Muscular strength (plyometrics) and balance exercises	Increase lower body muscular strength and lower body muscular endurance.
Tsimaras, V., Giagazoglou, P., Fotiadou, E., Christoulas, K., & Angelopoulou, N., (2003)	Jog-walk training in cardiorespiratory fitness of adults with Down syndrome	*Perceptual & Motor Skills*	Cardiovascular Endurance	3 days /week	12 weeks	65-75% HRmax (43-60% VO2max)	Jogging and walking training	Increase in aerobic capacity.
Varela, A. M., Sardinha, L. B., & Pitetti, K. H., (2001)	Effects of an aerobic rowing training regimen in young adults with Down syndrome.	*American Journal on Mental Retardation*	Body Composition & Cardiovascular Endurance	3 days /week	16 weeks	55-70% VO2max	Rowing	No change in body weight or %body fat. No change in peak VO2/cardiovascular endurance.