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Western Washington University Honors College

The Three R's of Exercise: Review, Reframe, Recommend

Liam Arenas-Field

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Introduction

Exercise, or physical activity, is a vital element of survival for humankind. It can take many different forms, all with their own unique goals, intensities, and durations. Frequent exercise offers both mental and physiological benefits to promote longevity and health. The rise of physical inactivity worldwide because of environmental and social factors presents itself as a burden financially, psychologically, and physically on individual and societal scales (Carlson et al., 2014; Carlson et al., 2018; Costa-Santos et al., 2023). By examining our current understanding of exercise guidelines and combining this with our understanding of exercise physiology, we can reframe our perspective on exercise and provide a resource to those who may be limited in exercise participation due to a lack of knowledge. In doing so, we can prioritize specificity and unique considerations in exercise prescription because no one body is the same.

First, we must understand how exercise affects the body, and what the effects of different forms of- exercise are. From there we can review our current exercise guidelines and identify strengths and weaknesses. Then we can observe demographic differences that can be utilized to increase specificity of training to achieve certain goals. Finally, based on this reframing of exercise, we can recommend pathways forward and provide this content as a starting point for combatting inactivity.

Inactivity has been shown to increase the percentage of deaths in older adults (40+). Carlson et al (2018) examined the percentage of deaths in adults associated with physical inactivity, accounting for proportional hazards causing death. The results indicated significant percentages of deaths resulting from inactivity in age groups of both 40-69 years old and 70 years or older. The guidelines used to define adequate physical activity was 150mins/week of

moderate-intensity aerobic exercise, derived from the 2008 US department of health and human services (USDHHS) guidelines (Carlson et al., 2018).

In financial markets, inactivity creates a significant burden on the US economy on both individual and governmental levels. Carlson et al (2014) investigating health care expenditures associated with physical inactivity. The results indicated an 11.1% portion of healthcare expenditures being associated with physical inactivity, outlined by the same 2008 USDHHS guidelines. This percentage remained significant when adults who were inactive as a result of difficulty walking were removed from the data. These findings indicate that increasing physical activity in adults could help decrease aggregate healthcare expenditures in the US (Carlson et al., 2014). In addition, healthcare spending if inactivity is not improved could reach as high as \$47.6 billion per year worldwide by 2030. Despite the majority of health issues occurring in low-middle income countries, high-income countries, such as the United States, would bear the majority of the economic burden (Costa Santos et al., 2023).

On the world stage, inactivity can be linked to increases in major non-communicable diseases (NCDs), such as coronary heart disease, type II diabetes, as well as breast and colon cancers. A 2013 study by Min-Lee et al sought to quantify the extent of these impacts and found a lack of physical activity significantly responsible for these NCDs. Worldwide, inactivity was found to be responsible for 6% of coronary heart disease, 7% of type II diabetes, 10% of breast and colon cancer (Lee et al., 2013). On a broad scale, physical inactivity proves itself as a threat to health and mortality because of its correlation with NCD's, mortality rate of older adults, and healthcare expenditures. By delving into the causes of inactivity, we can find individualized solutions to promote positive mental and physical health outcomes worldwide.

There are many factors that contribute to an individual not participating in adequate levels of physical activity. Environmental factors include traffic, pollution, lack of outdoor spaces/pedestrian spaces, and lack of sporting facilities (WHO, 2020). Additionally, cell phone use in adults has been linked to increases in sedentary activity (Fennell et al., 2019). Another key component of inactivity is lack of understanding and access to health resources and guidelines. Additional studies found that a considerable number of participants in different populations have limited knowledge of physical activity guidelines and benefits, and the extent of their knowledge of guidelines is correlated with their activity level (Fredriksson et al., 2018; Vaara et al., 2019). This relationship is vital to understanding the purpose of reviewing, reframing, and recommending exercise guidelines. In doing so, we can negate confusion and provide a deeper understanding of exercise physiology, so that readers can apply specific guidelines to their own unique characteristics and maximize their potential, regardless of experience level.

To accomplish this, we will first review examples of current exercise guidelines in the US. Then we will give a brief explanation of exercise physiology to sharpen our understanding of the benefits and drawbacks for specific exercise types. By applying this understanding, in conjunction with the current guidelines, we can reframe our perspective to apply it to various population demographics. Finally, we will create unique recommendations for several different case studies, breaking down our decision-making process for the design of our guidelines.

Review

Several different sources were used to provide context and current guidelines for review. All sources were similar in their recommendations, albeit some more detailed than others. Both the USDHHS and the American College of Sport's Medicine (ACSM) provide a general adult exercise recommendation of 150+ minutes/week of moderate-intensity aerobic exercise or

75+minutes of high-intensity aerobic exercise/week. In addition, adults should perform strength/resistance training exercises at least 2 days per week. Both sources also stress that more movement and less sitting will benefit everyone (Garber et al., 2011; Piercy et al., 2018).

This is where the first point of reframing can be assessed. These guidelines are broad and offer no specificity for different demographics. The issue of inactivity can also be attributed to a lack of knowledge of where to start, and being told these guidelines would not help that, as potential followers would not know what kind of exercises to do for both aerobic and resistance training. To begin this process, it is necessary to lay a brief foundation of basic exercise physiology, so the intricacies of each exercise form can be effectively practiced by the reader.

Reframe

Bioenergetic Pathways of Exercise

There are three primary systems of energy production active during exercise. The phosphocreatine (PCr) system, glycolytic system, and aerobic system.

The PCr system utilizes carbohydrates to perform fast, explosive movements using immediately available stored ATP, as well as ATP produced by the reaction of phosphocreatine with free energy in the body catalyzed by creatine kinase. In this reaction, the body stores phosphocreatine, and then when exposed to a creatine kinase catalyst, is broken into creatine and inorganic phosphate. This inorganic phosphate then combines with free energy and ADP to produce ATP. This reaction can be performed aerobically or anaerobically, meaning with or without oxygen present, but is performed anaerobically. The drawback to utilizing the PCr system is that it is available in short supply and is effective for only the first 10-20s of exercise (Haff & Triplett 2015).

Glycolysis involves the breakdown of blood glucose or muscle glycogen through several enzyme catalyzed reactions. This causes glycolysis to synthesize ATP at a slower rate than the PCr system but have a much higher capacity for production due to the larger supply of substrates (glycogen/glucose). The end product produced is known as pyruvate, which can subsequently be turned into lactate (known as “fast” glycolysis) or shuttled to the mitochondria to undergo the citric acid cycle if under oxidative conditions. The Glycolytic system is primarily active during the first 2-3 minutes of exercise (Haff & Triplett 2015).

The oxidative/aerobic system is most active at rest or during low intensity exercise. Under conditions where oxygen is present in sufficient quantities, the pyruvate produced via glycolysis will be converted to Acetyl-CoA and enter the citric acid cycle. In the citric acid cycle, various amounts of ATP will be produced via electron carriers NADH and FADH, and phosphorylation of GTP. The final production of ATP starting from glycolysis and ending after the electron transport chain varies within literature, but generally ranges at a net of 30-39 ATP. If the original glucose substrate is muscle glycogen rather than blood glucose, this net yield will be higher by 1 ATP, since it takes one less ATP to break down muscle glycogen to enter glycolysis (Haff & Triplett 2015).

With a brief discussion on the three main bioenergetic sources, we can begin to see patterns of influence for each system. The duration and intensity of exercise are directly influential on what system will be utilized as the primary energy production source. A key pattern is that in order from phosphagen-glycolysis-aerobic, we see an increase in capacity for energy production, and a decrease in rate of energy production. Another key point is that none of these sources is acting independently at any point. All three systems are always active during

exercise, certain systems just dominate the energy production based on duration and intensity (Brooks et al., 2005). This relationship is illustrated within *Figure 1*.

Figure 1

Energy System	ATP Production*	Rate of ATP Production*	Time Active	Intensities Active
Phosphocreatine (PCr)	4	1	<20 s	High
Anaerobic Glycolysis	3	2	2-3 min	High/Moderate
Aerobic Glycolysis	2	3	2-3 min	Moderate
Aerobic System	1	4	>3 min	Moderate/Low

*ranked 1=Highest, 4=Lowest

Figure 1. Relative rates of ATP production, Relative Capacity of ATP production, associated time of activity, and associated intensities active of the main bioenergetic systems.

Exercise Types and Subcategories

A large part of confusion when it comes to exercise guidelines and the process of applying them to individuals arises from the variety of exercise types and what benefits they offer in achieving specific goals. There are many ways to differentiate exercise types, but for this paper's purpose, it will be split into cardiovascular, resistance, and neuromotor exercise.

Cardiovascular exercise involves two different forms of training. First, aerobic cardiovascular exercise is what is considered steady state or “cardio”, where the aerobic system is primarily used; things like jogging, cycling, walking, etc. that are performed at submaximal intensities for longer durations. In comparison, interval (anaerobic) training primarily utilizes the glycolytic system, and is performed on shorter intervals at high intensity, with allocated recovery

periods to renew substrates used. Both formats offer significant benefits to cardiac and respiratory health since they help the body adapt to longer durations and higher intensities of sympathetic stimulation of the heart and lungs.

Like cardiovascular training, resistance training can be broken into three main categories that utilize different primary bioenergetic systems: resistance, power, and strength. Resistance training blends elements of all three energetic systems, with a focus on higher repetitions and shorter rest intervals. Power training primarily uses the PCr system, executing explosive movements of high force at high velocity for extremely short duration followed by longer rest intervals (3-5min). Common examples of power training include Olympic weightlifting, the vertical jump, and sprinting. Strength training shifts into use of fast/anaerobic glycolysis along with the PCr system because of a longer duration. In strength training, more repetitions and shorter rest periods (1-3min) are employed, with a focus on hypertrophy and maximal strength, rather than velocity of the movement (Haff & Triplett 2015).

Neuromotor training involves elements of balance, agility, coordination, and proprioception, and is often referred to as “functional” training. One of the most common and heavily researched methods of neuromotor training is Tai Ji. Neuromotor training has been largely studied in older populations as a method of decreasing fall risk but has limited study in younger populations (Garber et al., 2011). In recent years, more research has been done on healthy populations to provide insight into the benefits offered to all populations. Improvements in body composition and measures of health have been found in groups such as untrained middle-aged women, older adults, and children with neural deficiencies (Bortone et al., 2018; Brustio et al., 2015; De Oliveira et al., 2019). Through exploration of available literature, a pattern emerges of immense content availability regarding older/disabled populations and elite

athletic populations, but only recently are benefits to middle aged or active individuals being explored and quantified. Benefits of neuromotor training in individuals in the middle of the spectrum of neuromotor capability still exist, they are just often less observed in research because of the absence of clinical or athletic applications.

Since all bioenergetic systems are active during exercise, each method of exercise is really a combination of all the different methods explored, just contributing to varying degrees. In some cases, combinations can prove to offer greater benefits to at risk populations like overweight or obese individuals. Regarding the impact of combination training, one study found greater improvements in body fat percentage in a combination (aerobic and resistance) training group compared to a control group of only resistance training (Ho et al., 2012). When exploring exercise guidelines, it's important to specify which training methods should be prioritized, if any, to promote the best positive health outcomes.

Now that we have a groundwork of exercise physiology and exercise types, the more challenging part happens when we seek to apply this knowledge in a more specific manner. No human body is the same, so it is easy to see why exercise guidelines are so broad. In addition, the complexity of exercise types and the benefits of prioritization of one or another is extensive, along with the unique bioenergetic considerations. For the purposes of simplicity, this paper will distinguish characteristics of age, gender, and disabilities as avenues of deeper inquiry.

Age-Related Considerations

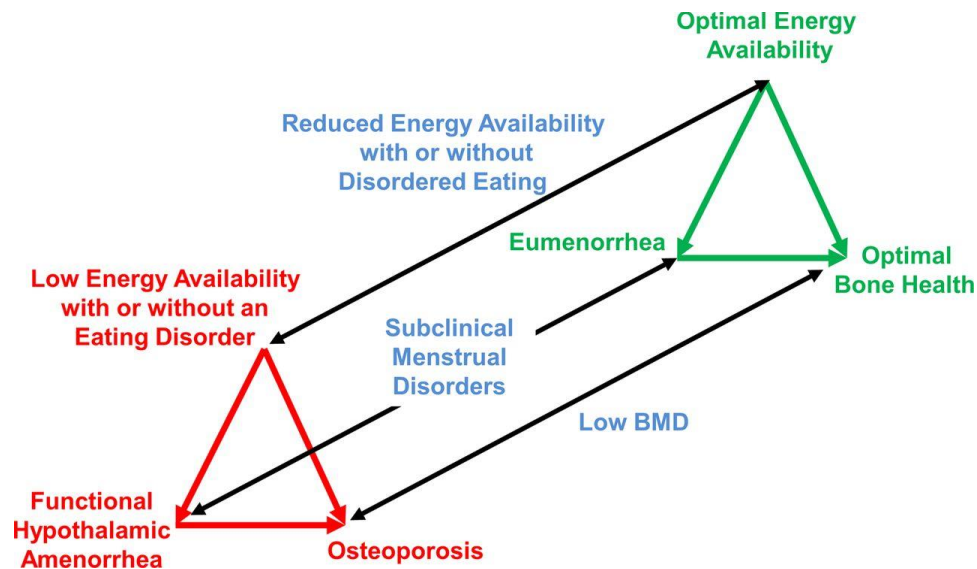
Age can often produce misconceptions in an individual's capabilities to perform exercise. So long as measures of perceived exertion are considered, the methods behind training youth and older adults can be extremely alike to those used for general populations (Haff & Triplett 2015).

In older populations, one distinct benefit of resistance training is the improvements to bone health, and mitigation of risk for osteoporosis. Specifically, to achieve the bone growth and maintenance benefits provided, it is essential that older populations place themselves under higher forces than those they would experience in everyday life (Hong & Kim 2018). Combinations of resistance/strength training with aerobic exercise offer even greater benefits than just aerobic or just resistance training, such as increases in flexibility, strength, balance, and self-reported performance (Bai et al., 2022). Older adults who do not participate in physical activity experience greater decreases in physical performance measures and increase their own risk of debilitating injury (Park et al., 2014). Finally, neuromotor training can improve several factors of physical health, such as mobility function, fear of falling, and activities of daily living (Brustio et al., 2015).

In youth, resistance training can promote injury prevention, anatomical and psychosocial parameters, as well as improving motor skills and sport performance (Myers et al., 2017). Aerobic, resistance, and combination training in obese youth has also been shown to improve health measures including waist circumference and total body fat (Sigal et al., 2014). More recently, research has shown that implementing strength specific training prior to power training in youth can offer the most benefits to overall physical health. Implementation of power exercise without an adequate base of musculoskeletal strength provides little benefit (Behm et al., 2017). Other considerations when implementing exercise guidelines for youth are quality of instruction and rate of progression, both of which need to be managed to achieve the best results and promote future exercise adherence (Haff & Triplett 2015).

Sex-Related Considerations

When assessing considerations regarding sex-related differences in exercise, our stance will be analyzing considerations necessary for females, since large amounts of research and past study has surrounded males, so the information is swayed in a male-centric lens. One such consideration is regarding what is known as the “Female Athlete Triad” (FAT). The FAT is a set of interrelated conditions found in female athletes. It is presented as a sliding scale of several different conditions, which we see in the image below.



(De Souza et al., 2014)

On the green or “good” end of this scale, we see athletes that have optimal energy availability, which leads to eumenorrhea, or a normal menstrual cycle, as well as optimal bone health. As female athletes may begin to overtrain, and/or recover improperly, this scale begins to slide toward the red or “bad” end. This end is indicated by low energy availability, with or without an eating disorder, which promotes functional hypothalamic amenorrhea. This is a condition in which the stress experienced by the body results in upregulation of homeostatic controls within the hypothalamus, shutting off the menstrual cycle. Another consequence of low

energy availability is osteoporosis, or decreased bone mineral density that can increase risks of breaks and injury (De Souza et al., 2014).

In promoting activity for female participants, it is important to be educated in potential risks associated with FAT. This allows for better prescription of exercise to female groups and subsequent consistency of adherence to physical activity.

Individuals with Disabilities

For individuals with physical or intellectual disabilities, a lack of physical activity is common, and can produce related health co morbidities. For people with intellectual disabilities, weight-related comorbidities are particularly common, increasing subsequent risk for cardiovascular and pulmonary diseases. In individuals with physical disabilities, a potential decrease in movement capabilities poses significant risk of secondary chronic conditions. An important observation regarding our current guidelines is that the major epidemiological studies that were performed to create these guidelines did not include individuals with disabilities (Carter & Swank 2014).

To promote activity for people with disabilities, we can keep the concepts (duration, intensity, frequency, and type) of exercise prescription the same. Application of these concepts just must be relative to each individual's specific physiological parameters. For example, individuals with down syndrome experience a lower resting heart rate and reduced cardiac response after light-exercise (Vis et al., 2012). In creating programs for promotion of physical activity in people with disabilities, being methodical and observational in program prescription is vital to reaching ideal outcomes.

Recommend

To effectively promote physical activity, we must be capable of identifying themes that arise in exercise adherence. In many different populations, three themes result in continuation of physical activity: variety, enjoyment, and social support. Promoting a variety of exercise types results in increased adherence in both short and long-term (Sylvester et al., 2016). Enjoyment of a given exercise, whether facilitated by the participant or the practitioner, results in increased adherence to a given physical activity program (Jekauc 2015). Finally, social support during exercise, or surrounding participants outside of exercise, promotes increased exercise adherence (Tian & Shi, 2022).

Given these factors, a psychosocial perspective of exercise comes into play. Promoting enjoyment of exercise is key to ensure the changes in physical activity needed are maintained. However, without some effort to address the environmental factors of inactivity we identified, barriers will continue to be built, rather than broken down. Major changes must be made legislatively so individuals have access to try a variety of activities, eventually finding something they enjoy and want to partake in long-term.

Within this work, we have gone over the risks and causes of physical inactivity. Our reframing sought to close some of the gap in educational factors by providing brief context to exercise science and methods. The complicated nature of exercise science is because it is several different scientific avenues combined and applied to the human body. We explored the biochemical aspects of exercise, but very little about biomechanics or psychological influences. Even a brief education like this work can still make a difference. Seeking to promote activity must include the “human” in the human body, or else the intricacies of each person will be lost, like we see in major exercise guideline publications.

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