GOOD HEALTH: The POWER of POWER

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POWER is a word with multiple meanings. It is a word that can be used to describe one of the many components of physical fitness, to refer to the possession of influence or control (political power) or to a source of energy (electric or solar power; Corbin & Le Masurier, 2014). Power, when used to define a fitness component, is commonly described as explosive strength or the ability to exert strength quickly (strength × speed; U.S. Department of Health and Human Services [USDHHS], 1996; Corbin, Pangrazi, & Franks, 2000; Corbin, Welk, Corbin, & Welk, 2016). This article will focus on power, the component of physical fitness, and how it relates to good health, primarily in youth. Methods of assessing power in field settings such as physical education classes, athletic programs, and community sports will also be discussed.

A Brief History of Power

Power is not new as a component of physical fitness. Nearly 100 years ago, Superman was born and celebrated in post-Depression comic books. Superman was "faster than a speeding bullet, more powerful than a locomotive, and able to leap buildings in a single bound" (Superman Home Page, www.supermanhomepage.com). Superman exhibited power that enabled him to have a high level of performance (e.g., sprinting, jumping, throwing). And although he popularized the concept of power, he was years behind physical educators in understanding its importance for health.

In the late 1880s physical educators identified muscle fitness, including power, as important for health. These early leaders were medical doctors (Institute of Medicine [IOM], 2012, p. 24), and their medical background no doubt led them to focus on health as a primary reason for being fit. In the early 1900s, for example, Dudley Sargent developed a vertical jump test he considered to be a general measure of fitness and health. The vertical jump test, or "Sargent jump," is still used today as a measure of muscle power. The Sargent jump was championed as a health-fitness test in Sargent's books, *Universal Test for Strength, Speed and Endurance of the Human Body* (Sargent, 1902) and *Health, Strength and Power* (Sargent, 1904/1914).

The focus on fitness began to shift from health to performance with the entry of the United States into World War I. Fitness was promoted primarily for men to help them perform well in fighting the "Great War" and subsequent wars. Wonder Woman made

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her debut just after the beginning of World War II, illustrating the importance of fitness for women as well as men (DC Comics, n.d.). Wonder Woman had the strength and power of Superman and demonstrated her ability to perform important tasks just as women of the World War II era demonstrated their ability to perform tasks that required fitness (e.g., Rosie the Riviter).

The emphasis on fitness for war continued well into the 1950s. However, the 1950s also saw a rise in collegiate and professional sports programs and brought attention to fitness for performance in different settings. Influenced by Jesse Feiring Williams (1927), Rosalind Cassidy (1954), and others who promoted the "new physical education," sports became central to the physical education curriculum. It is not surprising that the first national fitness test battery, the Youth Fitness Test (American Alliance for Health, Physical Education and Recreation [AAHPER], 1958), featured primarily skill-related fitness or performance-based test items. Power was included but as a skill-related component of fitness, not because of its association with health.

During the 1960s fitness education programs — commonly called conceptual physical education programs — began to distinguish between health-related fitness and skill-related fitness components (Johnson, Updyke, Stolberg, & Schaefer, 1966; Corbin, Dowell, & Landiss, 1968). Health-related components were considered to be cardiorespiratory endurance, strength, muscular endurance, flexibility and body composition, while skill-related components were considered to be agility, balance, coordination, power, reaction time and speed. In 1980 the American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD) developed the first health-related fitness test featuring the same health-related fitness components listed earlier (AAHPERD, 1980). A test of power was not included as a health-related fitness component because at that time the link between muscle power and health had not been firmly established. Health-related fitness gradually became the focus in physical education programs, as the public-health approach to physical education emerged in the 1980s (Pate, Corbin, Simons-Morton, & Ross, 1987; Sallis & McKenzie, 1991). The change in emphasis from performance (skill-related fitness) to health (health-related fitness) reflects a return to the emphasis of the early founders of physical education.

The health emphasis led to the development of FITNESSGRAM®, a health-related fitness test battery (Cooper Institute for Aerobics Research, 1987) that has since emerged as the national fitness test of SHAPE America and the Presidential Youth Fitness Program (www.presidentialyouthfitnessprogram.org). While a test of power is not currently included in the Fitnessgram test battery (Meredith & Welk, 2013), as evidence of the relationship between power and good health continues to grow (Baptista, Mil-Homens, Carita, Janz, & Sardinha, 2016; Janz, Letuchy, Burns, Francis, & Levy, 2015; Hardcastle et al., 2014), it is likely that a test of power will be included in the future.

It should be noted that power has been included for a number of years in the ALPHA Health-related Fitness Test Battery (ALPHA-FIT, 2009) widely used in Europe.

Empowering Good Health

As noted previously, power has traditionally been considered a skill-related component of fitness; however, it has also been referred to as a "combined" component (strength × speed) because of its association with strength (health-related) and speed (skill-related). In an article in *JOPERD* in 2014, authors from multiple organizations argued for the reclassification of power as a health-related fitness component (Corbin et al., 2014). They cited a report of the IOM indicating that

> musculoskeletal fitness is a multidimensional construct that encompasses three related components: muscle strength (the ability of skeletal muscle to produce force under controlled conditions), muscle endurance (the ability of skeletal muscle to perform repeated contractions against a load), and muscle power (the peak force of a skeletal muscle multiplied by the velocity of the muscle contraction). (IOM, 2012, p. S-7)

The IOM concluded that "adequate experimental and prospective longitudinal evidence supports the relationship between the multidimensional construct of musculoskeletal fitness and health" (see Table 1).

Powering the Bones. One of the primary health benefits of power-related physical activities is optimal skeletal development. The principle of overload states that appropriate amounts of physical activity result in improved fitness. While the principle is most often associated with muscles, it applies to bones as well. For over a century it has been known that bone strength (resistance to loading forces) increases in response to the mechanical loads to which it is exposed. In the medical literature this understanding is commonly referred to as Wolff's law (Wolff, 1892/1986). More recently, Frost (1987) suggested that there is an overload threshold for building bone. Specifically, when the bone is exposed to forces that produce higher than normal mechanical loads (see left side of Figure 1), new bone is formed and bones become stronger (see "Overload" in Figure 1). Examples of these forces are compression, tension, torsion and bending. Conversely, if mechanical loads remain below a certain threshold (e.g., sitting), bone is resorbed, and bones become weaker (see "Disuse" in Figure 1). In the extreme, too little stress on the bones contributes to osteoporosis, a metabolic bone disease characterized by low bone strength and increased risk of fractures, especially in the hip, spine and wrist. Osteoporosis is a global public health problem with an estimated prevalence of 200 million cases worldwide and 10 million cases in the United States.

Just as physical activites of high metabolic intensity improve cardiovascular health, physical activities of high mechanical intensity, applied quickly, cause bone adaptation. The force produced when the weight of the body hits the ground after a jump (impact forces), for example, contributes to bone strength. However, the largest loads placed on bone come from muscle during physical activity, such as lifting the body during a jump. This is because of a leverage disadvantage during most forms of skeletal muscle exercise. There is solid evidence that jumping and similar explosive activities improve bone strength (Tan et al., 2014; Weaver et al., 2016). The U.S. Physical Activity Guidelines for Americans (USDHHS, 2008) explicitly recommend bone-enhancing (also called weight-bearing or weight-loading) physical activities for children and adolescents. In addition, bone-healthy physical activity has been shown to optimize bone gains in youth (Weaver et al., 2016), minimize bone loss in adulthood (Borer, 2005; Nilsson et al., 2014; USDHHS, 2004), and therefore prevent or delay osteoporosis.

Bone mass (or absolute amount) is relatively low in children compared to adults. Bone mass increases during the teen years, and "peak bone mass" typically occurs in the late teens or early adult years. Peak bone mass refers to an individual's bone mass at the highest level during life. In later years bone mass decreases. Results from cross-sectional, longitudinal and randomized intervention studies unmistakably indicate that physical activity results in increased bone mass and strength in both children and adults, although the magnitude of the response is greatest prior to skeletal maturity (Bailey, McKay, Mirwald, Crocker, & Faulkner, 1999; Howe et al., 2011; Janz et al., 2006; Scerpella, Dowthwaite, & Rosenbaum, 2011; Bolam, van Uffelen, & Taaffe, 2013).

In addition to building strong bones to prevent or delay osteoporosis, bone-healthy physical activity has an immediate effect on youth (Janz et al., 2006). Among healthy children, approximately one half of boys and one third of girls will sustain a fracture by age 18 (Weaver et al., 2016). Most of these fractures occur to the forearm and result from falling on an outstretched arm. Youth fracture rates are, in fact, higher among the most active children. This is due to the inherent risks in sports and vigorous physical activities, as well as the risk-taking nature of youth. However, among children with similar forearm trauma, the fracture rate is lower for those children with greater bone strength (Kalkwarf, Laor, & Bean, 2011).

The American College of Sports Medicine (ACSM) has noted that among adults, "the health benefits of enhancing muscular fitness (i.e., the functional parameters of muscle strength, endurance and power) are well established" (ACSM, 2013, p. 190). Furthermore, insufficient power has been associated with health risks among older adults (ACSM, 2013). Research suggests that muscle

Table 1.
Health Benefits of Activities That Build Power

Age	Benefits
Children	Improves bone mass and architecture Reduces risk of bone fractures Enhances muscle development
Adolescents	Promotes greater peak bone mass Reduces risk of bone fractures Enhances muscle development
Adults	Improves functional fitness and quality of life Reduces fall risk Reduces risk of osteoporosis (bone mineral loss) Reduces risk of bone fractures Prevents sarcopenia (muscle mass loss)

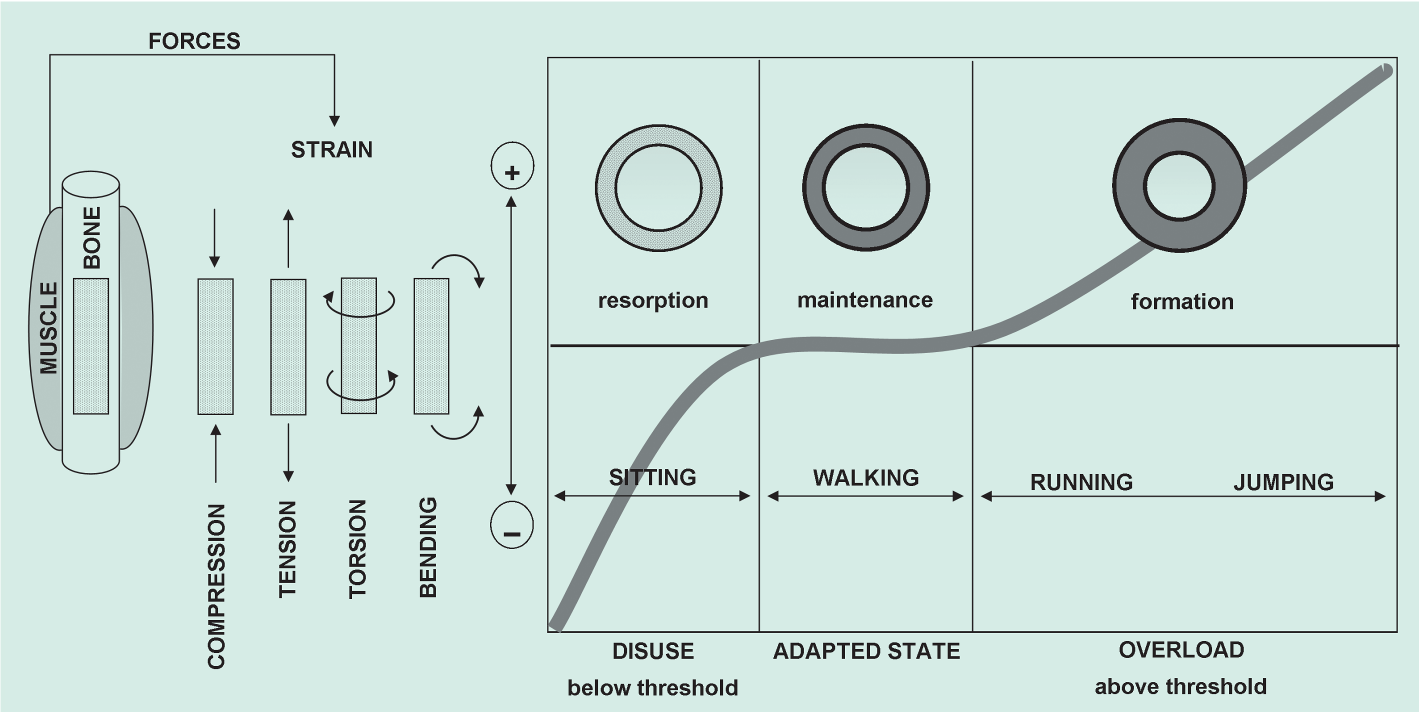

Figure 1.
Powering the bones

Muscle forces (far left) result in mechanical loading (compression, tension, torsion, and/or bending forces). Lack of mechanical loading (e.g., sitting) results in resorption of bone. Activities such as running and jumping produce above threshold overload (far right) that results in bone formation. Moderate activity helps in bone maintenance.

power is related to bone health (Gunter, Almsteadt, & Janz, 2012) and may be a useful surrogate for bone mass (Robling, 2009). Janz and Francis (2015, p. 1) reported "strong and consistent associations as well as direct and indirect pathways" between measures of power and fit muscles and bones.

Powering the Muscles. The muscles and bones work together to allow human movement, and, as noted earlier, it is the action of the muscles that provides the force that builds the bones. The action of the muscles builds bone but also results in an increase in muscle mass (overload principle). So activities that build power enhance both bones and muscles.

Powering Healthy Body Composition. According to the IOM report on *Fitness Outcomes and Health Measures in Youth*,

> Six high-quality studies provide direct evidence of a link between changes in muscle strength and power and favorable changes in health markers, including percent body fat, lean or fat-free mass, waist circumference, and body mass index…and lower-body (i.e., leg press, squat, and vertical jump) musculoskeletal measures are most consistently related to these body composition outcomes. (IOM, 2012, p. 172)

Power and other musculoskeletal measures are associated with both muscle and bone development. This accounts for a relatively high lean body mass, and thus a relatively lower percent body fat, among those with good scores on tests of musculoskeletal fitness (including power).

Assessing Power

Physical educators interested in helping their students build power through activities that promote it will ultimately want to help students assess it. Fitness assessments are generally of two types: laboratory (lab) and field tests. Lab tests are valid and reliable but often require expensive equipment and expertise. Lab tests typically use force plates, accelerometers, video and other specialized techniques. Measurements using force platforms are considered the gold standard. Force platforms can measure vertical jump height using both "take-off velocity" and "time in the air" methods. While "take-off velocity" is considered the most accurate method for measuring vertical jump height, the "time in the air" method has been found to be highly valid and reliable as well, and most researchers currently calculate jump height by measuring the flight time of the jump.

Field tests are commonly used in school physical education and youth sport settings. A variety of field assessments exist. A summary of the most commonly used and most effective field tests is provided here.

Vertical Jumping. There are several types of vertical jump tests. The most common is the bilateral (two leg) vertical jump with a countermovement where an eccentric contraction (leg flexion) precedes the concentric contraction (leg extension). To perform the test, the participant stands away from the wall and leaps vertically as high as possible using both legs and a downward arm swing,

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followed by an upward arm swing to assist in projecting the body upward. The participant tries to touch the wall at the highest point of the jump. The score is the difference of the distance between the standing reach height and the jump reach height. Markings on the wall or use of a special piece of equipment (Vertec) are most often used to assess jump height. The use of the arms increases variability in performance associated with technique and coordination. For this reason some have proposed the use of a vertical jump with no arm movement. One hand is placed on the hip, and the other is raised above the head. This procedure isolates the leg muscles and reduces the effect of different levels of coordination in the arm movements. New advancements in technology may provide yet another field assessment tool. The newly available iPhone app called My Jump (Apple, Inc.) may soon be practical for mea-

suring vertical jump height: a high-speed camera is used to record the jump, and special software calculates jump height (Stanton, Kean, & Scanlan, 2015).

Horizontal Jumping. The standing long jump (SLJ), also called the broad jump, is a measure of horizontal jumping. The SLJ is the only power test currently included in fitness test batteries to evaluate the physical fitness of school-age children and young people. The SLJ is used in the ALPHA-Fitness and EUROFIT (Ruiz et al., 2011; Gulias-Gonzalez, Sánchez-López, Olivas-Bravo, Solera-Martínez, & Martínez-Vizcaíno, 2014), developed and used in Europe. It is also used in BOUGE, a French fitness test battery (Vanhelst, Béghin, Czaplicki, & Ulmer, 2014).

In the SLJ the participant stands behind a line marked on the ground, with feet apart. A two-foot takeoff is used with swinging of the arms and bending of the knees to provide forward drive. The participant attempts to jump as far as possible, landing on both feet without falling backward. The measurement is taken from the takeoff line to the nearest point of contact on the landing (most often, the back of the heels). Research indicates that horizontal jump distance may be equally or more effective at predicting sporting movements than vertical jump measures, particularly in sprinting (Dobbs, Gill, Smart, & Mcguigan, 2015). However, it is difficult to separate kinetic and kinematic aspects that contribute to jump performance — forces that cause movement and aspects that describe the movement (jump distance), respectively. Jumping distance is influenced by takeoff angles, body dimensions, and jumping technique. For example, too high of a projection angle will result in a reduction of forward jumping distance; too low of a projection angle will result in insufficient time in the air. In either case, using an optimal projection angle is critical for maximizing the distance that can be achieved. For example, the horizontal jump in children includes more vertical movement than what is needed to achieve the greatest possible distance (Cadenas-Sanchez et al., 2016).

The IOM has recommended the standing long-jump for use in national youth fitness surveys based largely on evidence from Europe (IOM, 2012). However, because of the large contribution of technique when performing the SLJ, this test may not produce the most valid results (Veligekas, Tsoukos, & Bogdanis, 2012). In this sense, the vertical jump seems to be better for assessing health-related outcomes such as bone strength because it does not necessitate extensive training and has no significant learning effect (Rittweger, Schiessl, Felsenberg, & Runge, 2004).

Upper-body Assessments. Like other components of health-related fitness, power is specific for different areas of the body. The most common test of upper-body power is the medicine ball throw (Corbin & Le Masurier, 2014). Research is less prevalent for upper-body measures than for horizontal and vertical jumping.

Clinical Field Tests. As noted earlier, the ACSM indicated that power is important for older adults. Power is important for maintaining bone health (preventing osteoporosis), preventing falls and fractures, and maintaining the ability to function effectively in daily living. Clinicians such as physical therapists use measurements such as chair rising, timed up and go, and other similar tests with older adults (Buehring et al., 2015).

Health Standards for Power. Clear evidence has been presented that power is a health-related component of fitness that can be enhanced by physical activity that places a significant load on muscles and bones. Age- and sex-appropriate health-related standards exist for American field tests of strength and muscular endurance (90-degree push-up and curl-up) in Fitnessgram (Plowman & Meredith, 2013), but not for power. The European batteries EUROFIT (6–12 years old) and ALPHA-FIT (13–17 years old) have standards for the SLJ as well as for other health-related tests (Gulías-González et al., 2014; Ortega et al., 2011). Standards for both the medicine ball throw and the SLJ are available as self-assessments in *Fitness for Life* (Corbin & Le Masurier, 2014). Preliminary evidence is available for vertical jumping standards (19 and 22 cm standard for 8-year-olds; Baptista et al., 2016). Standards for muscle fitness or musculoskeletal fitness (strength, muscular endurance, and power) are less available than for assessments of cardiorespiratory endurance and body composition. Additional research is necessary.

Implications for Physical Education

SHAPE America's National Standards for K–12 Physical Education (SHAPE America – Society of Health and Physical Educators, 2014), as well as the national fitness education framework (National Association for Sport and Physical Education [NASPE], 2012), emphasize health-related fitness as an important outcome of physical education programs. Accordingly, providing youth with multiple everyday opportunities to engage in activities that promote health-related fitness, including power, is important. Specifically, including activities such as those in jumping sports (e.g., volleyball and basketball) and activities such as jump rope, hopscotch and skipping games should be considered when developing physical education and school or community sport programs. In addition to the activities mentioned, plyomterics (plyometric exercises) are effective in building muscle power and can be included as appropriate activities for youth when conducted by qualified instructors using age-appropriate guidelines (see Faigenbaum et al., 2009, pp. S68–S69).

Appropriately administered fitness tests are also an important part of a quality physical education program. Because the link between power and good health is now well established, it is appropriate that assessments of power be included in future educational fitness testing in physical education.

Summary

While it has not always been recognized for its health benefits, power has been included in fitness tests batteries for more than a century. Recent research shows that power is an important component of health-related physical fitness. Muscle power is positively associated with bone strength, muscle development, and healthy body composition, and it has the potential to identify people with suboptimal bone health (Baptista et al., 2016; Janz, Letuchy et al., 2015; Hardcastle et al., 2014). Based on solid evidence that power-related physical activity improves bone strength (Tan et al., 2014; Weaver et al., 2016) and muscle development, it is important to provide youth with multiple opportunities to be engaged in muscle-power activities.

The 2008 Physical Activity Guidelines for Americans specifically recommended "age-appropriate muscle- and bone-strengthening activities" on at least three days a week for youth and twice a week for adults (USDHHS, 2008). Building muscle power through physical activity should be a priority in physical education, public health interventions, and community-based health promotion programming. While additional research is necessary concerning appropriate age and sex standards, the evidence supports the inclusion of an assessment of power in youth fitness test batteries used in schools and in national fitness assessment programs.

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