Physical Activity and the Science of Successful Aging

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Successful aging encompasses more than just the prevention of disease and disability; the truly well-lived life is demonstrated by a sense of vitality and independence, freedom from bodily pain, and the continued involvement in meaningful activities. While physical inactivity and sedentary behaviors accelerate the aging process, deliberate exercise and other forms of activity delay and/or prevent the onset of age-related pathologies such as frailty, osteoporosis, sarcopenia, and cardiovascular disease. This review surveys the evidence that supports the position that physical activity is a necessary component for the development and maintenance of the physiological resources that are foundational to physical and cognitive functioning and ‘living well’ in one’s later years.

Keywords: Non-communicable chronic disease, health, frailty, osteoporosis, sarcopenia

Fellows of the National Academy of Kinesiology have known for decades that physical activity is a very important health habit, from both the individual and public health perspectives. It is encouraging that this position has become more widely accepted in recent years. The U.S. Department of Health and Human Services released the first official Physical Activity Guidelines in 2008 (PAGAC, 2009) and the first U.S. National Physical Activity Plan was released in 2010 (NPAP, 2012; Pate, 2009). An important series of papers on physical activity was published in The Lancet in July 2012, shortly before the London Olympic Games (Lancet, 2012), which to our knowledge is the first time that a medical journal of this standing has devoted an entire issue to physical activity. These papers illustrate the vast amount of information that has accumulated over the past 60 years on physical activity and health. There are many important findings in this series of papers, but one that will probably be surprising to many individuals is how physical inactivity compares with other well established risk factors in number of deaths caused world-wide. Professor I-Min Lee and colleagues (Lee, Shiroma, Lobела et al., 2012) obtained data from around the world on physical activity levels in numerous countries and estimated the number of deaths in the world each year that can be attributed to physical inactivity. At every stage of the analysis process, conservative approaches were taken in the calculations. The finding was that each year physical inactivity causes 5.3 million deaths in the world. For comparison, they report that the number of deaths caused each year by smoking is ~5 million. Given the sedentary nature of the US population (Blair, 2009; Matthews et al., 2008), this finding is a dramatic reminder of the significant amount of work that remains to be done.

This issue of The Academy Papers focuses on Physical Activity across the Lifespan. Our paper addresses issues related to physical activity and health outcomes later in life. To illustrate the relationship between PA and health, consider two women, both 80 years of age, Ms. X and Ms. Y (see Figure 1).

It is clear that Ms. Y has aged gracefully and successfully while Ms. X has not. None of us hope that we (nor any of our loved ones) develop the same morbidity and quality of life as Mrs. X if we reach 80 years of age. Therefore, the key questions are how can we age as successfully as Ms. Y? And how can we assist others in avoiding the accelerated aging from which Ms. X suffers?

Our position is that the best insurance you can obtain that will increase the likelihood that you will age like Ms. Y is to become and stay physically active. At a minimum, meeting the U.S. Physical Activity Guidelines and maintaining this level of activity throughout one’s lifespan is a productive first step in aging successfully. The Guidelines indicate that some activity is better than none, and that more is better, at least to a point. The principal recommendation is that individuals try to achieve 150 min/wk of moderate intensity activity, such as walking; or the same benefits can be obtained by accumulating 75 min/wk vigorous activity, such as jogging or doing strenuous sports. These minutes of activity should be accumulated in bouts of 10 min or more. The Guidelines also recommend that, for more health and functional benefits, individuals should achieve 300 min of moderate intensity activity/week or 150 min of vigorous activity/week. Finally, in addition to the aerobic activities described above, all adults should participate...
in muscle strengthening exercises that involve all major muscle groups on two or more days/week.

The purpose of the Physical Activity Guidelines is to forestall the functional decline and chronic noncommunicable diseases that so often accompany aging. In this report we will review the evidence supporting the necessity of physical activity for successful aging, physical function, health-related quality of life (HRQoL), and other health outcomes. Specifically, we examine the link between health and functional outcomes in the later years with participation in appropriate physical activity during earlier periods of life.

**The Necessity of Planned Physical Activity**

**Our Modern Environment**

The diminished quality of life and increased morbidity from which Ms. X suffers are relatively recent developments. For most of human history the demands of daily life required a remarkable amount of exertion. This physical effort, which usually began in childhood and continued past middle age, had salutary effects that forestalled noncommunicable diseases (NCDs). Not surprisingly, the dramatic decline in PA in all phases of daily life over the past five decades has lead to a concomitant increase in the morbidity and mortality from NCDs (Beaglehole et al., 2011). The transition from goods-producing jobs such as agricultural and manufacturing work to service jobs such as information technologies, health and education, and leisure/hospitality work has reduced the need for occupational PA and lead to a substantial decrease in occupational energy expenditure (EE). It has been estimated that workers in the US have experienced a decrease in occupational EE of > 100 kilocalories per day via reductions in both the number of hours spent working (Robinson & Martin, 2009) and the effort obligated by occupation (Church et al., 2011).

In addition to the decrements in transport and occupational EE, there have been substantial decreases in EE in other components of daily life. For example, labor and time-saving devices (e.g., washing machines, dishwashers, and microwaves) have dramatically changed how housework and cooking are performed (Lanningham-Foster, Nysse, & Levine, 2003). The physical effort required by domestic activity and housework has been on the decline since the middle of the 20th century and most estimates suggest that women are currently performing 10–15 hr less housework per week than in the 1960s (Bianchi, Robinson, & Milkie, 2006). As the time spent doing housework decreased, the amount of time in sedentary behaviors (e.g., TV viewing and computer use) has increased dramatically (Robinson, 2011). American adults now allocate > 2.5 hr per day watching television and additional time in front of their computers (Robinson, 2011). The estimated change in EE from active housework (e.g., washing the dishes and sweeping the floor) to sedentary pastimes (e.g., using a dishwasher while watching TV) is the equivalent of > 200kcals/day. The confluence of these results suggest that planned PA...
(i.e., deliberate exercise) is now a necessity to overcome the decrements in PA and EE engendered by the modern environment, and to avoid the decreased QoL and NCDs from which Ms. X suffers.

Ancient Wisdom

The necessity of PA for health has been recognized for millennia, and the detrimental effects of sedentary lifestyles were observed before the 21st century. Sushruta, an Indian surgeon who practiced ~600 BCE and is the father of Ayurvedic medicine (Dwivedi & Dwivedi, 2007; Guthrie, 1956), chronicled the discovery that inactive/sedentary people suffered from a number of "modern" NCDs, such as madhumeha (diabetes), vataraka (hypertension), and medoroga (obesity), in his ancient text *The Sushruta Samhita* (Guthrie, 1956; Tipton, 2008).

In the ancient Greco-Roman world, physicians were more concerned with the preservation of health than the treatment of disease. As such, PA played a vital role in the practice of medicine (Guthrie, 1945). Hippocrates of Kos (460BCE–370BCE), one of the most important figures in the development of modern medicine, wrote extensively on exercise and the maintenance of well-being (Hippocrates, 1868). In his text "Regimen in Health," he stated “exercise should be many and of all kinds” and “eating alone will not keep a man well” (Hippocrates, 1868). His perspective was based on simple observation and presaged the modern view that most chronic diseases are caused by inactive lifestyles.

Physical Function

To live independently and perform activities of daily living during the later parts of the lifespan, adults need to be able to maintain their physiologic resources (e.g., cardiorespiratory fitness, muscular strength and power, and cognitive function). Not surprisingly, the ability to carry out a range of activities, from self-care to vigorous exercise, is predictive of the development of chronic disease and mortality (Cesari et al., 2009; Guralnik, Ferrucci, Simonsick, Salive, & Wallace, 1995).

While age alone may diminish some of the physiologic resources necessary to meet the demands of daily living, it is important to note that sedentary behavior and inactivity have significant risks and severe consequences for all individuals independent of age, genetic endowment, body composition, and recent behavior (e.g., smoking; Archer & Blair, 2011; Blair, 2009; Blair et al., 1995; Lee, Sui, Hooker, Hebert, & Blair, 2011). Most importantly, the relative risks of physical inactivity increase with advancing age (Chodzko-Zajko et al., 2009; Shephard, 2009; Singh, 2004).

Cardiovascular Health and Cardiorespiratory Fitness (CRF)

While the general term ‘physical function’ represents a comprehensive assessment of multiple systems (Studenski et al., 2011), a closer examination sheds light on the essential role of the cardiorespiratory system in health and well-being. In 2007, our group analyzed medical records of over 4,000 men and women age 60 or older who completed a clinical examination and were enrolled in the Aerobics Center Longitudinal Study (ACLS; Sui, Laditka, Hardin, & Blair, 2007). As part of the examination occurring between 1971–2001, these participants completed maximal treadmill tests to examine their cardiorespiratory fitness (CRF), and were then followed until their death or 2003. After adjustments for potential confounders such as age, sex, smoking, baseline medical conditions (hypertension, type II diabetes, etc.), we found progressively lower risks for individuals who were moderately or highly fit versus those who were low fit for both all-cause and cardiovascular disease (CVD) mortality (41% and 43% reductions, respectively). This pattern existed both overall and within each category of aging. For example, among those between the ages of 70–79 years old, low fit individuals had > 3.0 times higher rate of total mortality than those in the highest fitness group. We also have published data from the ACLS that show that higher levels of fitness are associated with a 70% lower risk of functional limitations (Huang et al., 1998).

Since it may not be practical for all adults to complete a maximal treadmill test, a simpler method to quantify physical function in older adults is measurement of walking speed. Walking is an ideal representation of function since it requires energy, mobility, and places demands on multiple systems including the heart, lungs, circulatory, nervous, and musculoskeletal systems (Studenski et al., 2011). The relationships between walking speed and physical functioning (Vermeulen, Neyens, van Rossum, Spreeuwenberg, & de Witte, 2011) as well as mortality are well-known (Batty, Shipley, Kivimaki, Marmot, & Davey Smith, 2010; Studenski et al., 2011) For example, in both men and women walking speed had a strong influence on independence in later years. Individuals that maintained their independence from the ages of 70–76 yrs had significantly greater maximal walking speed (and leg strength) at 70 yrs than those who became dependent or were dependent at baseline and/or follow-up (Sonn, 1996). A recent meta-analysis including nine studies and nearly 35,000 participants found reductions in risk of death with increased walking speed across all studies and within each age category, regardless of gender (Studenski et al., 2011).

Now that we understand walking gait speed is an important objective measure of physical function and ultimately mortality risk, is there a speed that indicates a threshold for improved odds of survival? Recently, 1,705 men age 70 or older completed a timed walking test at their normal pace, and were subsequently followed for an average of 59.3 months (Stanaway et al., 2011). Men who walked > 2.0 miles per hour were 1.23 times less likely to die compared with those who walked more slowly. This finding prompted the authors to note that this value represented the preferred walking speed of the Grim Reaper himself. Extending the findings further, the maximum speed of the Grim Reaper appeared to be 3 miles per hour, as none of the men who walked at this speed...
or greater died during the follow-up period. However, if you feel this level of precision is too finite, a much simpler comparison is available. Participants in the seminal Whitehall study were asked in 1967–70 to self-report their walking speed using the question: ‘Compared with men your same age, do you tend to walk slower, faster, or about the same pace?’ (Batty et al., 2010). After nearly 40 years of follow-up including 5294 men, those who walked ‘slower’ had a 71% increased risk for all-cause mortality compared with those who walked ‘faster.’ This research suggests that we should aim to walk faster than the Grim Reaper, or at a minimum, faster than our peers and our hypothetical Ms. X.

Nevertheless, all is not lost for those who find themselves with limited physical function. In the Dose Response to Exercise in postmenopausal Women (DREW) study, we recently randomly assigned 427 sedentary, overweight or obese, hypertensive older women into one of four groups: control, or one of three levels of progressively increasing volumes of exercise for six months (Church, Earnest, Skinner, & Blair, 2007). As expected, as the volume of exercise increased, there was a dose-dependent increase in functional capacity as defined by CRF. Importantly, the lowest volume of exercise was approximately 72 min/wk, or just over 10 min/day, and resulted in significant increases in fitness. A separate analysis among adults over age 65 followed for eight years found that improvements in gait speed in the first year resulted in a 58% reduction in relative risk of death (Hardy, Perera, Roumani, Chandler, & Studenski, 2007). In other words, becoming more active is possible at any age, and the positive influences on health are clear.

As much as regular physical activity improves physical function, physical inactivity, even for short spans of time can have the opposite effect. In 1966, five healthy young men underwent extensive clinical measurements, and then spent three weeks in voluntary bed rest before repeating the measurements (Saltin et al., 1968). These same men had these same clinical measurements repeated 30 years later (McGuire et al., 2001a, 2001b) and again 10 years later, for a total of 40 years of follow-up (McGavock et al., 2009). Amazingly, the declines in CRF during the three weeks of bed rest at age 20 were greater than 40 years of normal aging. Declines in fitness were accelerated after age 50, but were highly individualized. For example, the poorest health outcomes (fitness and its various components) at age 60 were observed in one participant who was a collegiate football player in 1966, but had become extremely sedentary in the intervening 40 years. While some may question whether three weeks of bed rest in the context of a research study translates to the real-world, it is easy to imagine Ms. X’s dramatic decline beginning with an illness or injury requiring inpatient hospital care followed by weeks of recovery and rehabilitation, all the while confined to a bed or restricted in her PA.

Muscular Strength

Physical fitness is comprised of a number of components in addition to cardiovascular health (as measured by CRF). Muscular strength, muscular power and coordination are important components that are as essential to successful aging as CRF (Reid, Naumova, Carabello, Phillips, & Fielding, 2008). In fact, research suggests that strength-related factors may be more important in the later years than CRF for the performance of the activities of daily living (ADL; Reid & Fielding, 2012). Interestingly, in trained masters athletes muscular power was affected to a greater extent than aerobic power with the passage of time (Gent & Norton, 2012). This suggests that efforts directed at maintaining muscular strength and power are as necessary as aerobic training and CRF as one ages.

Wilcox et al. (2006) analyzed data from over 40 years on 5820 Japanese-American men in the Honolulu Heart Program study. The men were classified into four groups: 1) nonsurvivors, 2) ‘usual’ survivors but disabled, 3) ‘usual’ survivor with major chronic condition but not disabled, and 4) ‘exceptional’ survivors (i.e., men w/no major chronic condition, or cognitive/physical impairment). ‘Exceptional’ survivors had significantly stronger grip strength at baseline than the ‘usual’ survivors, with an odds ratio of 1.24 for ‘usual’ vs. ‘exceptional’ survivors (Wilcox et al., 2006). These results suggest that higher physical fitness as evidenced via muscular strength at midlife may be predictive of successful aging. Given this evidence, there is little doubt that Ms. Y’s weight lifting has maintained her muscular strength, power, and physical function, and by doing so has allowed her to age successfully.

Cognitive Function

Advancing age is predictive of decrements in performance on numerous cognitive tasks from reaction time to memory tasks. In addition, aging is one of the strongest predictors of Alzheimer’s disease and other forms of dementia (Salthouse, 2003). Nevertheless, while the relationship between aging and cognition is well-established (Angevaren, Auffdenakme, Verhaar, Aleman, & Vanhees, 2008a), there is strong and growing evidence from longitudinal and experimental studies that environmental influences such as PA lead to the maintenance of cognitive function and more successful aging (Christensen et al., 2003; McMorriss, Tomoprowski, & Audriffen, 2009). The seminal work of Spirduso and colleagues (Spirduso, 1975; Spirduso & Cronin, 2001) demonstrated that PA ameliorates (and in many cases eliminates) the age-related decrements in reaction-time tasks. Older active individuals have faster reaction times than inactive older adults and are potentially the functional equivalent of younger individuals on a number of cognitive tasks.
In 2003, Christensen et al. found that active older individuals were not only leaner and had lower body weights, but had significantly greater psychomotor performance on an extensive battery of cognitive tests (e.g., simple reaction, and coincidence-anticipation timing tasks). Also in 2003, a Cochrane review examined PA, aging and cognitive functioning and found that there is valid evidence that aerobic PA that improves CRF is beneficial for cognitive functioning in older adults. These positive effects were observed for general motor functioning, cognitive processing speed, memory, and auditory and visual attention (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008b).

There is emerging evidence that enhancing physical fitness at any point across the lifespan is positively associated with cognitive and physical functioning (Angevaren et al., 2008a; Davenport, Hogan, Eskes, Longman, & Poulin, 2012; Hillman, Erickson, & Kramer, 2008). In a 2001 review, Spiriduso and Cronin found that there is a dose-dependent effect of long-term physical activity for the prevention of both cognitive and physical disability as well as an increase in the odds for independent living. This effect was demonstrated in the oldest-old subjects as well as individuals with chronic conditions. Another recent Cochrane review noted that physical activity interventions were safe, effective and reduced disability in individuals residing in long-term care facilities (Forster et al., 2009). These results suggest that even in a state of reduced function, all individuals such as Ms. X would benefit cognitively from increased levels of PA.

**PA, Quality of Life, and Aging: From Young Adulthood to Older Adults**

Successful aging entails much more than a lack of chronic conditions and survival. The truly well-lived life is demonstrated by a sense of vitality, freedom from bodily pain, and a positive perception of one’s physical condition and health (i.e., health-related quality of life; HRQoL). Research has demonstrated that greater levels of PA in early adulthood are predictive of successful aging, inclusive of greater HRQoL in later years. This section reviews the epidemiological evidence that PA is a necessary component for maintaining a high HRQoL and ‘living well’ in one’s later years.

**Successful Aging and Quality of Life**

Ms. Y has been physically active her entire life, and her early activity levels have helped her age gracefully. Her experience is supported by research that suggests being more active as a young adult lays the foundation for continued PA and successful aging later on. For example, Lachman and Agrigoroaei (2010) found that, after a 10 year follow-up, self-reported regular vigorous exercise at baseline was significantly associated with functional health in later life after controlling for important covariates such as sociodemographic, previous health status, and other factors. In addition, Sun et al. (2010) examined the longitudinal association of PA and successful survival in 13,535 women in the Nurses’ Health Study. Successful survival was defined as individuals who experienced no history of major chronic diseases, no cognitive or physical impairment and no mental health limitations. After a 15 year follow-up, they found significant trends for successful survival, across quintiles for total PA metabolic equivalents (METs; 1.00, 0.98, 1.37, 1.34, and 1.99; \( p < .0001 \)) and walking METs (1.00, 0.99, 1.17, 1.47, 1.45; \( p < .0001 \); Sun et al., 2010). Intensity played a significant role in that participants who walked at a moderate vs. easy pace experienced a 90% increase in odds for successful survival and for those who walked brisk/very brisk vs. easy, had an odds ratio of 2.68 (Sun et al., 2010).

In the Whitehall II study, Britton, Shipley, Singh-Manoux, and Margot (2008) conducted a longitudinal examination of successful aging after a 17-year follow-up in London civil servants (4,140 men and 1,823 women, ages 35–55). Successful aging was defined as being free of major chronic diseases and in the top third of physical and cognitive function. They found that self-reported moderate PA (MPA) and vigorous PA (VPA) were positively associated with successful aging after adjustment for age and socioeconomic position. For men, the odds ratio was 1.94 for VPA and 1.48 for MPA and for women, the 1.66 and 1.41 for VPA and MPA, respectively. These results suggest that even with the attenuation of activity-health relationships via self-reports, PA is associated with successful aging and that ‘more’ (and more intense) activity is better, at least to a point.

**Health-Related Quality of Life (HRQoL)**

As individuals age and begin to lose physical function, health increasingly becomes a priority. Numerous qualitative studies have demonstrated that the motivation to achieve a greater HRQoL often leads to increased PA. Aaltonen et al. (2012) demonstrated that among twins \( (n = 16) \), one of the strongest motivators for long-term adherence to PA over a 30-year period was increased health. The primary difference between active vs. inactive twins was a focus on how PA would improve their physical fitness and mental health (i.e., HRQoL). Similarly, Laditka et al. (2009) asked 396 older adults across 42 focus groups to describe “someone who you think is aging well.” Themes related to HRQoL were predominant as words such as “positive mental outlook,” “good physical health,” and “good memory” were used to describe successful aging.

One of the greatest predictors of HRQoL is PA in early adulthood. Many studies have demonstrated that PA patterns established early in life carry forward throughout the lifespan. For example, Hamer et al. (2012) examined longitudinal changes in PA with an average follow-up of
13 years in 394 men and women from the Whitehall II cohort (Hamer, Kivimaki, & Steptoe, 2012). The participants in the highest quartile at baseline had on average almost 30 min per day more total activity at follow-up than those in the lowest quartile of activity; this is the equivalent of meeting or exceeding the PA Guidelines (Hamer et al., 2012; PAGAC, 2009). These results suggest that those who are active during younger adulthood are more likely to stay active during the aging process.

There is empirical evidence that a dose-response exists between HRQoL and PA. Martin et al. (2009) examined the effect of varying volumes of exercise in the previously mentioned DREW study (Martin, Church, Thompson, Earnest, & Blair, 2009). They found a significant dose response relation between the amount of exercise and improvements in both physical and mental health, as demonstrated by SF-36 health survey scales. It is interesting to note that significant improvements in HRQoL occurred at modest volumes (74 min/wk) and modest intensities (50% VO2max) when compared with the control/no exercise group.

Sawatzky, Liu-Ambrose, Miller, and Marra (2007) used cross-sectional data from the Canadian Community Health Survey (n = 22,432) to demonstrate that even for older adults burdened with chronic conditions, PA mediates the relationship between the health condition and HRQoL. These results suggest that the negative costs of chronic conditions such as limited mobility, pain, decrements in emotional wellbeing, and cognitive decline can be partially mediated by PA, with the degree of mediation varying from 18% for mobility limitations, 5% for pain, and 13% for emotional well-being.

Finally, in the Study of Women’s Health Across the Nation (SWAN), Dugan et al. (2009) studied more than 2,400 middle-aged women. PA was measured by self-report, and physical and bodily pain indices via the SF-36 health survey at three annual follow-up visits. Being active was significantly associated with positive reports of ability to fulfill functional roles and pain level: “Each 1-point increase on the physical activity score was associated with a 7% greater likelihood of a high role-physical score (95% CI = 1.02–1.13) and a 10% greater likelihood of a low bodily pain score (95% CI = 1.04–1.17) after adjusting for age, race, menopausal status, educational level, body mass index, depressive symptoms, smoking, and chronic medical conditions.” (Dugan et al., 2009, p. 33).

In addition to being active, it is necessary to avoid sedentary behavior if one wishes to age successfully. Dogra and Stathokostas (2012) examined sedentary behavior (independent of PA) in 20,000 middle and older adults from the Healthy Aging cycle of the Canadian Community Health Survey, and found that individuals who were least sedentary (self reported duration sitting per day < 2 hr) were 43% more likely to age successfully compared with the adults who most sedentary (> 4 hr).

The research reviewed to this point demonstrates that inactive and sedentary lifestyles are independent and strong predictors of successful aging and clearly suggest that PA improves and/or maintains physical functioning and HRQoL. The vast differences between Ms. X and Ms. Y are the result of PA patterns established early in life and carried forward into their later years. It our next section we briefly review the mechanisms by which PA facilitates successful aging.

**Physiology of a Well-Lived Life**

The failure to initiate and maintain activity across one’s lifespan leads to decrements in numerous physiologic and metabolic systems. This is clearly demonstrated by the fact that the major inactivity-induced NCDs, such as type II diabetes and CVD, are often comorbid with other pathologies associated with sedentary lifestyles: sarcopenia, osteoporosis, obesity (Bouchard, Dionne, & Brochu, 2009; Gunter, Almstedt, & Janz, 2012; Villareal, Apovian, Kushner, & Klein, 2005). The co-occurrence of these conditions denotes the accelerated aging so clearly exhibited by Ms. X (Booth, Laye, & Roberts, 2011; Charansonna, 2011).

As illustrated earlier, physical inactivity and sedentary behavior induce a myriad of pathologic conditions from musculoskeletal dysfunction, to diabetes and CVD. As activity levels decrease, there is a dose-dependent loss of contraction-stimulated growth factors in skeletal muscle (e.g., IGF-1, BDNF). This loss induces decrements in physical function via the loss of muscle quality, volume, force and power development, as well as mitochondrial mass (Pillard et al., 2011). In addition to the loss of skeletal muscle mass and function, there is a progressive loss of bone mass as inactivity and sedentary behaviors reduce the mechanical stress on the skeletal system. Without daily mechanical stress (e.g., activity of moderate or greater intensity), osteoblast activity progressively decreases and leads to accelerated bone mineral loss and reduced bone formation. The end-result is a progression from osteopenia to osteoporosis and an increased risk of falls and fractures (WHO, 2003).

Moreover, sedentary behavior and inactivity cause dramatic declines in energy metabolism (Poehlman et al., 1993; Poehlman, Melby, & Badyak, 1991). Decreased activity levels lead to diminished glucose disposal, insulin resistance, and altered lipid metabolism that results in hyperlipidemia and an increased risk of type II diabetes (Bergouignan et al., 2006; Gaster, 2011; Hallsworth et al., 2011; LaMonte, Blair, & Church, 2005; Ryan, 2000; Szendroedi & Roden, 2008).

Not surprisingly, given the relationship between PA and CRF, inactivity increases CVD risk (Archer & Blair, 2011). There are a number of physiologic mechanisms responsible for this increase in risk. For example, inactivity and sedentary behavior reduce the endogenous antioxidant production that protects against oxidative injury (Corbi et al., 2012). Inactivity reduces the fluid shear stresses necessary to maintain proper endothelial function and induce vascular remodeling of the major arteries (Faria Tde et al., 2010; Golbidi & Laher, 2012).
Importantly, decrements in CRF from reduced activity are indicative of reduced vascular health and are predictive of increased morbidity and mortality (Jackson, Sui, Hebert, Church, & Blair, 2009).

Nevertheless, the loss of physiologic resources, diminished HRQoL and increments in metabolic impediments (e.g., increased fat mass, insulin resistance) concomitant with sedentary lifestyles and aging are not inevitable (Sundell, 2011). Data from observational studies and randomized trials suggest that general PA (Archer & Blair, 2011; Blair et al., 1995) and lifestyle (i.e., nutritional and exercise) interventions (Church et al., 2007, 2010; Wadden et al., 2006) are both efficacious and cost-effective in the prevention age and inactivity-induced morbidity and mortality (DPPRG, 2003; Garrett et al., 2011). For example, while low skeletal muscle mass is linked with insulin resistance and diabetes risk (Ferrucci & Studenski, 2009; Srikanthan & Karlamangla, 2011), progressive resistance training leads to greater muscle volume, mass, quality and function (Pedersen & Febbraio, 2012). Endurance training combined with resistance training leads to reductions in biomarkers of insulin resistance, induces increments in insulin sensitivity, enhances glycemic control, and reduces diabetes risk (Church et al., 2010; LaMonte et al., 2005; Treserras & Balady, 2009). In addition, while inactivity reduces bone mineral density, progressive resistance training augments bone mass by increasing the mechanical stress on the skeletal system, increasing osteoblast activity and thereby preventing osteopenia, osteoporosis and reducing the risk of falls (Rolland, Dupuy, Abellan van Kan, Gillette, & Vellas, 2011; WHO, 2003). These results demonstrate that lifestyle interventions not only enhance the physiologic and metabolic resources necessary to perform ADL, but halt the progression along the continuum from inactivity to disability and death.

Summary

Many healthy, young and middle-aged individuals appear to follow the axiom “if it (i.e., health) ain’t broke don’t fix it.” Unfortunately, what may not appear “broke” today may become so tomorrow as the ravages of poor lifestyle choices take their toll over time. It is essential to note that successful aging is the result of the development and maintenance of the physiological resources that are foundational to physical and cognitive functioning. Being healthy at age 30 or even 50 years of age is not a guarantee of being healthy in one’s later years. Ms. Y has aged gracefully because she developed productive PA habits early in life and continued them throughout her lifespan. Her activity maintained her physical and mental health, and improved her quality of life as the years passed. Nevertheless, this is not to suggest that an older individual who failed to achieve a productive level of fitness early in life will not benefit from PA in their later years—quite the contrary. As with many things in life, PA is better late than never and even a little PA is better than none.

References


Archer et al.


