Musculoskeletal Fitness and Health

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Abstract/Résumé

The purpose is to examine the relationship between musculoskeletal fitness and health status. Muscular strength is positively associated with independence and overall quality of life, and negatively associated with morbidity and potentially premature mortality. Muscular endurance is positively related to overall quality of life. Elevated muscular endurance may reduce the incidence of falling and its associated injuries. Muscular power is predictive of functional capacity, resultant disability, and potentially premature mortality. Flexibility is positively associated with mobility and independence. Women and the aged may be susceptible to musculoskeletal impairments leading to reduced health status and thus may represent primary target groups for intervention programs. High levels of musculoskeletal fitness are associated with positive health status, and low levels of musculoskeletal fitness are associated with lower health status.

Le but de l'étude est d'analyser la relation entre la condition musculosquelettique et l'état de santé. La force musculaire est directement proportionnelle à l'autonomie, à la qualité de vie globale et inversement proportionnelle à la morbidité et à l'éventualité d'un mort prématurée. L'endurance musculaire est directement proportionnelle est la qualité de vie globale. L'amélioration de l'endurance musculaire peut contribuer à la réduction de

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l'incidence des chutes et des blessures causées par celles-ci. La puissance musculaire est un indicateur de la capacité fonctionnelle, de l'incapacité résultante et de l'éventualité d'une mort prématurée. La flexibilité est directement proportionnelle à la mobilité et à l'autonomie. Les femmes et les personnes âgées sont probablement plus sujets aux troubles musculosquelettiques associés à la diminution de l'état de santé ; les programmes d'intervention devraient d'abord s'adresser à ces populations. Des niveaux élevés de condition musculosquelettique sont associés à un bon état de santé et des niveaux inférieurs, à un moins bon état.

Introduction

For years, exercise scientists, fitness professionals, and physicians have intuitively expounded the health virtues of high levels of musculoskeletal fitness. In fact, many fitness appraisal protocols, such as the *Canadian Physical Activity, Fitness and Lifestyle Appraisal Manual* (*CPAFLA*; Canadian Society for Exercise Physiology, 1996), provide health-related interpretations to clients based on their musculoskeletal fitness scores. However, little experimental data exist regarding the impact of high levels of musculoskeletal fitness on indicators of health status. The limited knowledge that is available concerning the relationships between musculoskeletal fitness and indicators of health status has been drawn from longitudinal training investigations and/or cross-sectional investigations (Warburton et al., 2001).

Intervention programs designed specifically to enhance musculoskeletal fitness have been effective in improving several indicators of health status including glucose metabolism, obesity, bone health, independent living, incidence of falling plus associated injuries, and/or psychological well-being (Warburton et al., 2001). Therefore, it follows that higher levels of musculoskeletal fitness are likely associated with positive health status. However, prospective data are lacking to support this contention, and a detailed evaluation of the related literature is required. This knowledge is especially important for the health-related interpretation of musculoskeletal fitness appraisal results in fitness appraisal protocols such as the *CPAFLA*.

This review will critically evaluate the existing literature regarding the relationships of high and low levels of muscular strength, muscular endurance, muscular power, and flexibility, with high and low levels of health. It will specifically address the direct and indirect associations between the individual components of musculoskeletal fitness and indicators of health. The appropriateness of the health-related interpretation of musculoskeletal fitness and the establishment of "cut-off scores" in the *CPAFLA* will also be addressed. A summary of the important findings regarding what is known and not known about the relationship between musculoskeletal fitness and health will be provided and areas for future research will be identified.

Musculoskeletal Fitness and Risk Factors for Cardiovascular Disease

Improvements in muscular strength and/or muscular endurance from resistance training programs may result in several positive outcomes regarding the risk for cardiovascular disease (Warburton et al., 2001). Resistance training that improves muscular strength and/or muscular endurance has the potential for improving blood lipid profiles, decreasing resting/exercise blood pressure, improving glucose tolerance plus insulin sensitivity, and increasing energy expenditure potentially leading to a reduction in abdominal obesity (Warburton et al., 2001). Although this literature implies that high levels of musculoskeletal fitness are associated with positive health outcomes, the relationship is not well defined. In particular, there is very little prospective evidence regarding the relationship between musculoskeletal fitness and cardiovascular risk factors. Therefore, at this time the direct relationships between musculoskeletal fitness and risk factors for cardiovascular disease are difficult to quantify.

To our knowledge, the investigation by Kohl and colleagues (1992) is the only epidemiological investigation that evaluated the impact of musculoskeletal fitness levels on risk factors for cardiovascular disease. Kohl and colleagues (1992) examined the relationship between muscular strength and lipid-lipoprotein profiles in 1,193 women and 5,460 men. All participants had evaluations of upper and lower body strength (one repetition maximum bench and leg press), fasting serum total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), triglycerides (TG), and high-density lipoprotein cholesterol (HDL-C). After adjusting for the covariates of age, body composition, and cardiovascular fitness, the authors reported that there was no relationship between upper and lower body strength and TC or LDL-C. However, there was a direct relationship between muscular strength and TG in men, but not women. Also, there was an inverse relationship between muscular strength and HDL-C in men. These authors concluded that improved muscular strength is not associated with a concomitant improvement in lipid-lipoprotein profiles and may actually be associated with an adverse effect on lipid-lipoprotein status. This conclusion is contrary to the findings of another epidemiological investigation by Tucker and Silvester (1996), which evaluated the relationship between participation in strength exercises (self-reported) and lipid-lipoprotein profiles in 8,499 men. They reported that regular participation in strength exercises (4 to 7 hours per week) reduced the risk for hypercholesterolemia. Although no measures of muscular strength were taken, these data suggest that high levels of muscular strength are not associated with a poorer lipid-lipoprotein profile in men as reported in the investigation by Kohl and colleagues (1992).

Clearly, evidence on this topic is lacking, and further epidemiological investigations are needed to evaluate the impact of the individual components of musculoskeletal fitness on the risk factors for cardiovascular disease. At present, therefore, our knowledge regarding the relationship between musculoskeletal fitness and risk factors for cardiovascular disease is limited to the extrapolation of information from training programs that are known to improve musculoskeletal fitness.

Musculoskeletal Fitness and the Determinants of Quality of Life

The majority of literature regarding the relationship between musculoskeletal fitness and health status relates to indicators of quality of life (QOL). Quality of life encompasses the physiological, psychological, emotional, and spiritual well-being of an individual (Warburton et al., 2001). An assessment of the effect of high levels of musculoskeletal fitness on indicators of QOL is important because of the impact of QOL in the prevention of chronic disease (Hennessy et al., 1994). This review will address several indicators of QOL, including measures of functional status, psychological well-being, morbidity, and mortality.

Functional Status

Functional status refers to the ability to carry out the activities of daily living (ADLs). As functional capacity decreases, disability and the need for institutionalization and/or hospitalization increases, along with the rate of premature mortality (Ensrud et al., 1994). With the aging population, improving functional status will increasingly become a greater concern for the North American society. Many elderly persons currently live near or below the functional threshold of musculoskeletal fitness for daily living, such that a slight ailment may cause them to lose their independence (Astrand, 1992). This review will specifically address several determinants of functional status including bone health, independent living and disability, and fall and fracture prevention.

Musculoskeletal Fitness and Bone Mineral Density

Osteopenia (reduced bone mineral density) and osteoporosis (reduced bone mineral density and bone porosity) are indicators of poor bone health and are associated with several negative health outcomes (American College of Sports Medicine, 1998; Ensrud et al., 1994; Heinonen et al., 1996). Aging is associated with a significant decline in bone mineral density, and postmenopausal women are particularly at risk for reductions in bone health (Hurley and Hagberg, 1998). Longitudinal investigations have revealed that bone health may be improved after high intensity strength training. The positive effect of strength training on bone health seems to be particularly evident in older individuals, especially postmenopausal women (Warburton et al., 2001).

Very little is known about the relationship between muscular endurance, muscular power or flexibility, and bone health. More data exist regarding the relationship between muscular strength and bone health; however, the exact nature of this association remains unclear. Some investigators have reported a linear relationship between muscular strength and bone mineral density in men and women (Bevier et al., 1989; Rhodes et al., 2000; Sinaki et al., 1986). However, differences in muscular strength only accounted for a small portion of the difference in bone mineral density (Bevier et al., 1989).

Others have observed no relationship between muscular strength and bone mineral density (Alfredson et al., 1999; Block et al., 1989). Evans (1999) reported that in elderly nursing home residents, leg strength only accounted for 29% of the variance in whole body potassium. As well, Block and colleagues (1989) reported that the strongest predictor of bone mineral density in the spine and hip was muscle cross-sectional area. The effects of muscle pull and increased gravitational stress on the bone also appear to be important factors in bone formation (Chilibeck et al., 1995). Thus, although muscular strength may play an important role in bone health, it is not the only factor (Evans, 1999).

Musculoskeletal Fitness and Independent Living/Disability

Functional status, the maintenance of independence, and the prevention of disability are largely related to an individual's capacity to perform ADLs. High levels of musculoskeletal fitness should enhance one's capacity to meet the demands of everyday life thereby allowing an individual to maintain functional independence for a greater period of time. The majority of information on this topic concerns the relationships between muscular strength and/or muscular power and functional outcomes. Less is known about the impact of muscular endurance or flexibility on independent living.

Muscular Strength and Independent Living/Disability

High levels of muscular strength are likely to be accompanied with a greater capacity to perform ADLs. For instance, strength training has been shown to offset the loss in muscle strength and mass (sarcopenia) associated with aging, which may increase the ability to perform ADLs, improve bone health, and reduce the risk of falling (Warburton et al., 2001). Also, high levels of muscular strength may allow an individual to engage in more recreational activities, which will help offset sarcopenia and disuse-related diseases. Therefore, achieving high levels of muscular strength may be an effective means of maintaining functional status, especially in older populations.

The prevalence of disability increases with aging and is thought to be due in part to the age-related reduction in muscular strength. There seems to be a curvilinear relationship between muscular strength and age, with muscular strength reaching its peak value at 20 to 30 years of age then declining at approximately 45 to 50 years of age (Aoyagi and Shephard, 1992; Hurley, 1995; Kallman et al., 1990). The rate of decline has been estimated to approximate 12 to 15% per decade (Hurley, 1995) such that the loss of muscular strength approximates 25 to 40% by the sixth and seventh decades (Aoyagi and Shephard, 1992; Young et al., 1984). The rate of decline remains relatively constant until the eighth decade when there is an accelerated loss of muscular strength (Hurley, 1995; Kallman et al., 1990). The rate of decline between the age of 65 and the eighth decade has been estimated at 1.5 to 2.0% per year (Bassey and Harries, 1993; Young and Skelton, 1994). The loss of strength appears to occur earlier and at a faster rate in the lower body than in the upper body (Bemben et al., 1991).

Women have approximately 56% of the strength of men (Bassey and Harries, 1993; Hyatt et al., 1990; Rantanen et al., 1994), and this gender difference remains even after skeletal size is accounted for (Bassey and Harries, 1993). In absolute terms, the rate of decline in muscular strength may be greater for men than women, but percentage losses in strength may be slightly greater in women, which lead Bassey and Harries (1993) to postulate that "women will become progressively more disadvantaged as they grow older compared with men."

The loss of muscular strength with aging has been associated with several factors, including decreased muscle mass (Danneskiold-Samsoe et al., 1984; Grimby et al., 1982; Kallman et al., 1990; Larsson et al., 1979) reflected by a decrease in the number and/or size of muscle fibers (Grimby et al., 1982; Lexell et al., 1988; Sato et al., 1984), changes in muscle fibre composition including selective atrophy (Aniansson et al., 1986; Grimby et al., 1984; Grimby et al., 1982; Larsson et al., 1979) and/or selective loss of fast twitch (Type II) muscle fibers (Larsson et al., 1979; although this finding remains controversial; Lexell et al., 1988), and loss of alpha-motoneurons and/or motor units (Ansved and Larsson, 1990; Brown, 1972; Tomlinson and Irving, 1977; Booth et al., 1994, beginning at approximately 60 years of age). The age-associated decline in muscular strength and mass may also be related to prolonged disuse (Bassey and Harries, 1993; Tseng et al., 1995) and/or chronic disease (Kallman et al., 1990), such that a vicious cycle is created wherein inactivity leads to sarcopenia, which further worsens the ability to perform ADLs.

The increased disability seen with aging has been shown to be related to decreases in neuromuscular performance, including decreased muscular strength, impaired balance, and reduced walking speed (Ensrud et al., 1994). The decreased walking speed in elderly men and women in particular is associated with disability. In fact, several investigators have revealed that walking speed, balance, the capacity to rise from a chair, and muscular strength are all strong predictors of resultant disability in older men and women (Guralnik et al., 1995; Rantanen et al., 1994; Rantanen et al., 1996; Rantanen, Guralnik, et al., 1998; Rantanen, Guralnik, Ferrucci, et al., 1999; Rantanen, Guralnik, Foley, et al., 1999; Rantanen, Guralnik, Sakari-Rantala, et al., 1999). The age-related decline in muscular strength may also be associated with the age-related decline in $\dot{V}O_2max$ (Booth et al., 1994; Fleg and Lakatta, 1988). Thus, an individual's aerobic endurance may be reduced in part due to limitations in muscular performance, which may further limit the ability to perform ADLs.

Several investigators have examined the associations between muscular strength and functional capacity (as it relates to ADLs). Jette and colleagues (1990) reported that a reduction in hand function is a significant contributor to the impairment in performing basic ADLs (e.g., eating, bathing, moving from bed to chair, dressing, and walking across the room) in the elderly. A further decrease in the capacity to perform instrumental ADLs (e.g., housekeeping, food preparation, grocery shopping, transportation, and handling personal affairs) was also observed with progressive decreases in lower body function (Jette et al., 1990). Other investigators have also revealed that grip strength is an independent predictor of impaired function relating to functional status and/or the capacity to perform ADLs in older men and/or women (Ensrud et al., 1994; Giampaoli et al., 1999; Hyatt et al., 1990). Decreased muscular strength of the lower body has likewise been associated with impaired functional status (Hyatt et al., 1990; Ringsberg et al., 1999; Skelton et al., 1994).

A series of investigations by Rantanen and coworkers (1994, 1996; Rantanen, Guralnik, et al., 1998; Rantanen, Guralnik, Ferrucci, et al., 1999; Rantanen, Guralnik, Foley, et al., 1999; Rantanen, Guralnik, Sakari-Rantala, et al., 1999) evaluated the relationship of reduced strength scores with functional disability. They reported several important findings:

1. Maximal isometric strength of the upper limbs (i.e., hands and arms), and/or the lower limbs (i.e., knees and hips) is positively associated with mobility,

including measures of maximal walking speed and stair climbing ability (Rantanen et al., 1994; Rantanen, Guralnik, et al., 1998).

2. Muscular strength is a strong predictor of functional limitations and disability 25 to 27 years later in men (Rantanen, Masaki, et al., 1998; Rantanen, Guralnik, Foley, et al., 1999).
3. Muscular strength tests may be useful in the detection of those individuals at or near their threshold for functional limitations (Rantanen, Guralnik, et al., 1998).
4. Strength and balance are independent predictors of severe walking disability in older women, with the combined effects of impairments in strength and balance being greater than the individual summed effects (Rantanen, Guralnik, Ferrucci, et al., 1999).
5. A vicious cycle may occur in older persons wherein difficulties in performing the ADLs lead to a decline in physical activity promoting an additional reduction in strength and a greater disability (Rantanen, Guralnik, Sakari-Rantala, et al., 1999).

Other investigators have, however, revealed that there may be only weak relationships between muscular strength and functional measures in both healthy and moderately frail elderly persons (Brown et al., 1995; Danneskiold-Samsoe et al., 1984). A recent investigation by Salem and colleagues (2000) revealed that these discrepancies may be explained by the use of low-intensity functional tests (e.g., normal pace walking) versus high-intensity tests (e.g., brisk walking). They reported that an elevated knee strength was associated with increased functional performance in healthy mobile seniors. The relationships between muscular strength and functional outcomes were stronger for the higher intensity functional tasks (e.g., brisk walking, stair climbing, and chair standing) than for the lower intensity functional tasks (e.g., 8-ft normal walk, 50-ft normal walk, and standing reach).

These data collectively indicate that those with the lowest strength measures tend to have the lowest functional status, and this relationship seems to be the strongest when high-intensity functional tasks are performed. There may also be a minimal threshold for the capacity to perform ADLs. Future prospective investigations using various ADLs are required to establish these thresholds.

Muscular Endurance and Independent Living/Disability

From a QOL point of view it is important for an individual to be able to carry objects (e.g., groceries, small children) and perform repeated contractions (e.g., gardening, raking leaves, shoveling) for extended periods of time without fatiguing. Many tasks of everyday living do not require a large muscular strength, although having increased muscular strength will make everyday activities easier to complete. Most everyday tasks require good muscular endurance (Canadian Society for Exercise Physiology, 1996). Intuitively, the performance of ADLs will be largely influenced by an individual's level of muscular endurance. Preliminary data indicate that muscular endurance is directly related to functional independence. For instance, Suni and colleagues (1998) reported that trunk muscular endurance was a strong predictor of mobility and perceived health, respectively, in men and women. Salem and colleagues (2000) also reported that muscular endurance was directly associated with several functional outcomes. Similar to their findings regarding muscular strength, the relationships between muscular endurance and functional tests were the strongest with high-intensity tasks. Therefore, it would appear that muscular endurance is directly related with functional independence. Further investigation concerning the impact of muscular endurance on independent living is still required.

Muscular Power and Independent Living/Disability

Muscular power involves a combination of muscular strength and speed (i.e., explosiveness). Generally, muscular power is thought to be more important for optimal sport performance than personal health status. Very little information exists regarding the impact of muscular power on body composition, aerobic power, and risk factors for cardiovascular disease. However, many ADLs require the capacity to apply a force quickly (i.e., shoveling, hammering, avoiding a collision, etc.). Thus, muscular power may be associated with functional capacity and the potential to perform ADLs. As Buchner (1997) wrote, "Muscle power is more logically related to functional limitations in older adults than the peak force of a muscle."

There appears to be a greater loss in muscular power than muscular strength as a function of aging (Rantanen and Avela, 1997; Young and Skelton, 1994) approximating 3.5% per year between the ages of 65 to 84 (Young and Skelton, 1994). Bosco and Komi (1980) revealed that 71- to 73-year-old men and women had approximately 30 and 25%, respectively, of the power found in their 18 to 28 year old counterparts. Therefore, older individuals may be limited in daily tasks that require the application of rapid forces (Harries and Bassey, 1990).

The accelerated rate of decline in power may be related to the dependence of the speed component of power on fast twitch fibers (Bassey et al., 1992). The age-related decrements in muscular power are especially seen during actions requiring higher velocities (Harries and Bassey, 1990), whereas at lower velocities the age-related difference in muscular power is similar to that observed for maximal isometric force (Danneskiold-Samsoe et al., 1984; Hurley, 1995; Larsson et al., 1979). These findings may be related to selective atrophy of Type II fibers (Larsson et al., 1979), especially the fast glycolytic Type IIb fibers (Grimby et al., 1982), and/or a reduced proportion of type II fibers (Aniansson et al., 1986; Larsson et al., 1979).

Women have significantly lower leg extensor power than men (Bosco and Komi, 1980; Payne, Gledhill, Katzmarzyk, Jamnik, and Keir, 2000; Rantanen and Avela, 1997), and Rantanen and Avela (1997) postulated that reduced leg extensor power may be associated with the increased prevalence of disability in older women. The gender differences in leg power begin in the teenage years and continue throughout life (Payne, Gledhill, Katzmarzyk, Jamnik, and Keir, et al., 2000), even after normalization for differences in body mass (Bosco and Komi, 1980). At the age of 71 to 73 years, women have approximately 71% of the leg power of men. Rantanen and Avela (1997) reported that 80-year-old women display 66% of the leg extensor power of age-matched men, and this sex difference increases in 85-year-olds, with women possessing 54% of the leg power of the men.

Recent research has revealed that losses in muscular power are directly associated with a decrease in functional ability including a decreased capacity to walk up stairs (Bassey et al., 1992), reduced ability to stand up from a chair (Bassey et al., 1992; Skelton et al., 1994), reduced gait speed (Bassey et al., 1992; Rantanen and Avela, 1997; Rantanen, Guralnik, et al., 1998), reduced capacity to step up (Skelton et al., 1994), and reduced stair climbing power (Bassey et al., 1992). Leg power (as determined by the vertical jump) has also been shown to be directly associated with perceived health and mobility (during stair climbing) in men (Suni et al., 1998). Investigators (Lamb et al., 1995) have also shown that post-surgery mobility (i.e., walking speed and stair climbing time) is directly related to leg extensor power.

Given the strong relationship between muscular power and functional status, the evaluation of muscular power (especially leg extensor power) may be useful in the detection of elderly patients at risk for functional disabilities (Bassey et al., 1992). However, it is important to note that muscular power may only account for a small portion of the variance in functional capacity. As Rantanen, Guralnik, and colleauges (1998) postulated, other factors such as hip extensor strength, plantar flexor strength, and/or balance may also affect measures of functional capacity such as walking ability.

Flexibility and Independent Living/Disability

Much of the literature regarding the relationship between flexibility and indicators of health status is specifically related to the impact of aging on flexibility and the associated changes in functional status. Aging is associated with a decline in the range of motion (flexibility) about a joint (Bell and Hoshizaki, 1981; Brown and Miller, 1998; Payne, Gledhill, Katzmarzyk, Jamnik, and Keir, 2000), especially in the lower extremities (Bell and Hoshizaki, 1981), which could lead to several functional limitations.

An improvement in flexibility is thought to result in a decreased incidence of injuries and an increased performance during physical activities (Stone et al., 1991). A reduced flexibility has been associated with decreased functional abilities, including a lowered walking velocity (Cunningham et al., 1993; Escalante et al., 1999), a reduced capacity to enter public transport, increased reliance on walking aids, and increased difficulty climbing stairs and getting up from a chair (Bergstrom et al., 1985). Reduced flexibility has also been associated with a reduction in health status, including increased self-reported pain (Escalante et al., 1999), reduced independence (Cunningham et al., 1993), and a reduction in perceived health, physical function, social function, mental health, and overall QOL (Payne, Gledhill, Katzarmzyk, Jamnik, and Ferguson, 2000). However, considerable reductions in flexibility may exist without noticeable disability (Bergstrom et al., 1985; Jette and Branch, 1984).

Major impairments in functional status as a result of aging are reduced walking velocity and mobility. The age-associated decline in gait velocity is believed to be due primarily to a decrease in step length (Crowinshield et al., 1978; Hageman and Blanke, 1986; Himann et al., 1988; Larish et al., 1988; Murray et al., 1969), which is directly related to a reduced range of motion about the pelvis and hip (Hageman and Blanke, 1986; Murray et al., 1969). Hence, reductions in mobility may result from low levels of flexibility about the pelvis and hip, which in turn limit step length and gait velocity.

Musculoskeletal Fitness and the Prevention of Falls and/or Fractures

Falls and their associated injuries are very common among the elderly and account for a large portion of their medical ailments (Hayes et al., 1996). Approximately one third of elderly persons experience a fall (Graafmans et al., 1996; Tinetti et al., 1988), and recurrent falls occur in a significant proportion of these individuals (Graafmans et al., 1996). In a frail elderly population, approximately 66% had fallen during the previous year (Fiatarone et al., 1994).

The incidence of fractures (especially of the hip) is directly related to the frequency of falling, the severity of the fall (e.g., directly impacting the hip), osteoporosis, and body habitus (Hayes et al., 1996; Schwartz et al., 1998). Hip and wrist fractures resulting from falling are associated with the greatest impairments in both men and women (Frost, 1997). Hip fractures occur in approximately 1% of all falls, and their impact on the health care system is enormous (Hayes et al., 1996).

Postmenopausal women commonly exhibit a progressive loss of bone mineral density and sarcopenia as they age. These combined effects put women at an even greater risk for the development of fractures, and the presence of hip fractures in women (after adjusting for age) increases the likelihood of impaired functional status by 2- to 3-fold (Ensrud et al., 1994).

The direct impact of musculoskeletal fitness on the prevention of falls and/or fractures has not been adequately evaluated. Physical activity that improves muscular strength, muscular power, muscular endurance, and balance has been postulated to reduce the risk of falling and the incidence of fractures (Lewis and Modlesky, 1998). Muscular dysfunction (particularly of the lower body) and concomitant reductions in mobility are prevalent among the elderly and are strong predictors of the risk of falling, developing fractures, reduced mobility, and the establishment of functional dependence (Buchner, 1997; Fiatarone et al., 1990; Fiatarone et al., 1993). Thus, a reduction in musculoskeletal fitness is likely associated with an increased risk of falling and its associated injuries, especially in the frail elderly (Fiatarone et al., 1993; Tinetti et al., 1988).

Low leg extensor power has been postulated to be related to the high incidence of falling in older individuals owing to its relationship with walking velocity (Bassey et al., 1992). For instance, Bassey and colleagues (1992) reported that leg extensor power (independent of balance) accounted for over 86% of the variance in walking speed in older women who were residents of a chronic care institute. They postulated that the "maintenance of leg extensor power may reduce the prevalence of falls and associated fractures by helping to maintain gait speed, as well as improving the QOL" of individuals with a history of falls. Poor flexibility has also been shown to be a significant predictor of falls in the elderly (Gehlsen and Whaley, 1990). Hence, improvements in each component of musculoskeletal fitness may be associated with a reduction in the incidence of falls and their associated injuries (Rutherford, 1999). However, experimental data supporting this hypothesis is lacking, and the topic requires further investigation.

Musculoskeletal Fitness and Psychological Function

The impact of physical activity on psychological function has recently received considerable attention in the literature. Longitudinal investigations have revealed that resistance training that improves muscular strength and/or muscular endurance may improve several indicators of psychological well-being, including mood state, perceived anger, tension, anxiety, and self-efficacy (Warburton et al., 2001). Also, improvements in flexibility may be associated with improved psychological well-being. However, very little is known about the relationship between musculoskeletal fitness and psychological function.

Bassey and Harries (1993) revealed how important hand grip strength is in the determination of psychological well-being. They evaluated the relationship between longitudinal changes (over 4 years) in hand grip strength and health and psychological well-being in 620 men and women over the age of 65 living in their own homes. Those with the highest hand grip strength had higher self-reported health, psychological well-being, social engagement, and customary activity. The age-associated decline in muscular strength over the 4 years was associated with a concomitant decline in self-reported hand grip activities, customary activity, and health scores in both men and women. Furthermore, in the women, the decline in muscular strength was directly associated with a significant decline in psychological well-being. Singh and colleagues (1997) also reported that patients with depression who had the greatest increase in muscular strength after strength training had the largest increase in total sleep quality.

Payne, Gledhill, Katzarmzyk, Jamnik, and Ferguson (2000) recently reported that muscular endurance (as evaluated by push-ups according to the *CPAFLA*) was a strong predictor of perceived health, physical function, social function, mental health, and overall QOL in males and females aged 15 to 69 years. Flexibility levels may also be related to psychological well-being. For instance, Suni and colleagues (1998) reported that male participants placed in the low and mid tertiles for flexibility scores had poorer perceptions of health in comparison to those placed in the highest tertile for flexibility. In women, the correlation between levels of flexibility and perceptions of health were weaker. The relationship between muscular power and psychological well-being is unclear and requires investigation.

Musculoskeletal Fitness and Morbidity and Mortality

Elevated musculoskeletal fitness is thought to be associated with a reduction in morbidity and mortality. However, little information exists to support this theory. Muscular strength and muscular endurance have been shown to be linearly related to a series of functional tests (Salem et al., 2000) which are highly predictive of future disability and premature death in older individuals (Guralnik et al., 1995, 1994). Two investigations have directly examined the relationship between musculoskeletal fitness and morbidity or mortality (Fujita et al., 1995; Rantanen, Masaki, et al., 1998). Rantanen, Masaki, and colleagues (1998) reported that those individuals who had a low grip strength or a large decline in grip strength (over a

27-year period) had a greater incidence of chronic disease and a greater chance of disability. Fujita and colleagues (1995) revealed that low muscular strength (i.e., hand grip), muscular endurance (i.e., sit ups), and muscular power (i.e., vertical jump) were significant predictors of all-cause mortality in men. Thus, a reduction in musculoskeletal fitness may be associated with an increase in morbidity and premature mortality.

Implications for the *Canadian Physical Activity, Fitness and Lifestyle Appraisal*

There is an intuitive belief that persons with the lowest scores on musculoskeletal fitness tests are more likely to have a negative health status. It is clear from the available literature that musculoskeletal impairments are associated with a series of negative health outcomes. However, prospective data evaluating the impact of different levels of musculoskeletal fitness on indicators of health status are lacking. The identification of musculoskeletal fitness thresholds from which to establish health risk categories would be especially important for the health-related interpretation of musculoskeletal fitness appraisal results in protocols such as the *CPAFLA*.

Currently, only a few investigators have attempted to categorize musculoskeletal fitness scores and relate this to health risk. For instance, Suni and colleagues (1998) examined the relationships of various components of health-related fitness with health outcomes in middle-aged men and women. They evaluated the impact of high, medium, and low levels of health-related fitness components (including cardiorespiratory fitness, musculoskeletal fitness, motor fitness/balance, and body composition) with the participants' perceptions of their health, mobility (regarding stair climbing), and back function. Participants were placed in categories with the lowest 20% being categorized as "low-fit," the next 40% as "mid-fit," and the remaining 40% as "high-fit." To establish the criteria for positive health outcomes, the "high-fit" group was used as the reference, while the "low-fit" group was used as the reference for negative health outcomes. For the evaluation of musculoskeletal fitness, they chose the jump and reach (vertical jump) for leg extension power, the one leg-squat with increasing weights for leg extensor strength, the static back extension for muscular endurance of the trunk, modified push-ups (distinct from that used in the *CPAFLA*) for upper body muscular strength, trunk side-bending for trunk flexibility, and the range of motion of the leg for lower extremity flexibility. Hence, the tests of musculoskeletal fitness were quite disparate to those in the *CPAFLA*, and direct comparisons with the *CPAFLA* measures of musculoskeletal fitness are difficult. Nonetheless, the findings are of interest because they shed light on the impact of high and low levels of musculoskeletal fitness on perceived health.

In men, a low leg power was associated with a poor perception of health and decreased mobility. Whereas, in the women, leg power was not associated with low perceptions of health status. Leg strength was not a strong predictor of health status in men. However, in the women a lower leg strength was associated with a negative perception of health status and decreased mobility. Trunk muscular endurance was associated with all measures of health status in both genders. In men, trunk muscular endurance was the strongest predictor of mobility, whereas in women, trunk muscular endurance was more strongly associated with perceived health. Low fitness in trunk muscular endurance was also associated with the greatest level of back dysfunction and pain. Low upper body muscular strength was related to negative perceptions of health, reduced mobility, and back dysfunction and pain in both genders. Low and mid flexibility were associated with poor perceived health and back dysfunction in men. In the women, there were weaker correlations between flexibility and health outcomes.

These observations indicate that high levels of musculoskeletal fitness are associated with positive perceptions of health in both men and women, and low levels of musculoskeletal fitness are associated with negative perceptions of health. These results may also imply that there are gender differences in the relationship between musculoskeletal fitness scores and perceived health status.

Rantanen, Masaki, and colleagues (1998), in their analysis of changes in grip strength over a follow-up period of approximately 27 years, reported that those individuals who died at an earlier age had significantly lower grip strength scores at baseline. Those with a faster decline in muscular strength (>1.5% per year) and/or a very low grip strength (<21 kg) had a greater incidence of chronic disease, such as diabetes, stroke, arthritis, coronary heart disease, and pulmonary disorders. The investigators postulated that those in the lowest grip strength tertile had an approximate 8-fold increase in the risk for disability.

Rantanen, Guralnik, Foley, and colleagues (1999) reported recently that the participants who were placed in the lowest tertile for grip strength had an increased risk for a series of functional limitations (including walking speed and the ability to rise from a chair) and disability outcomes regarding ADLs (including walking 0.8 km, walking up 10 steps, lifting 4.5 kg, doing heavy housework, dressing, bathing, eating, and using the toilet), even after adjustment for the confounding variables of age, weight, height, education, occupation, smoking, physical activity, and chronic conditions. Those placed in the middle tertile for grip strength had an intermediate risk for functional limitations and disability. Thus, hand grip strength may be a good measure in the prediction of men at risk for physical disability in old age. Also of importance for the interpretation of grip strength scores in the *CPAFLA* was the finding that there was a direct relationship between health status and grip strength, such that those with highest grip strength had the lowest risk for disability, those with an intermediate grip strength had a moderate risk for disability, and those with the lowest grip strength score had the highest risk for functional limitations.

A recent investigation by Payne, Gledhill, Katzarmzyk, Jamnik, and Ferguson (2000) has specifically evaluated the health implications of the *CPAFLA* health-related fitness measures. They reported that grip strength, push strength (Gledhill Force Metre™), pull strength (Gledhill Force Metre™), push-ups, and trunk forward flexion (sit and reach) are significant predictors of health status and QOL. Of particular significance was the finding that higher levels of musculoskeletal fitness were associated with positive health status, and lower levels of musculoskeletal fitness were associated with negative health status. There were between-gender differences with regard to the strongest predictor of health status. In males, muscular endurance (push-ups) and muscular strength (push strength and pull strength) were significant predictors of health status, whereas in females, muscular strength (grip strength and pull strength) and trunk forward flexion were significant predictors of health status.

The establishment of cut-off scores for varying levels of health status is a very difficult task for researchers. Health risk is commonly predicted based on the assumed relationship between health status and musculoskeletal fitness (Canadian Society for Exercise Physiology, 1996). That is, individuals receiving lower scores on musculoskeletal fitness batteries are thought to have increased health risk. This generally appears to be a safe assumption according to the available literature, which reveals graded linear relationships between the individual components of musculoskeletal fitness and several indicators of health status.

However, it is important to note that each component of musculoskeletal fitness may affect the various indicators of health status in disparate ways. Thus, the musculoskeletal thresholds for health status may change according to the indicators of health used (Salem et al., 2000). Also, the thresholds for varying levels of health are likely to be dissimilar between genders and ages. Thus, the establishment of specific cut-off scores for health risk (such as the minimum threshold for functional independence) is not straightforward and requires additional investigation. Currently, we must be content with the knowledge that there appears to be a direct relationship between musculoskeletal fitness and health status. Quantifying the dose-response characteristics of this relationship will be the next challenge for researchers.

Discussion

Table 1 contains a summary of the relationships between high levels of musculoskeletal fitness and indicators of health status. The majority of the empirical data regarding the relationship between musculoskeletal fitness and health status relates to functional outcomes. These data indicate that high levels of musculoskeletal fitness are associated with positive health status.

The dose-response relationships between the individual components of musculoskeletal fitness and risk factors for cardiovascular disease are difficult to discern. Training programs that improve one or more components of musculoskeletal fitness may result in a reduction in one or more of the risk factors for cardiovascular disease (Warburton et al., 2001). Therefore, high levels of musculoskeletal fitness may be associated with improved health status through reductions in risk factors for cardiovascular disease. However, further epidemiological investigations are required to evaluate this hypothesis.

Impairment in muscular strength is associated with a reduced capacity to perform the ADLs, reduced independence, increased prevalence of disability, increased morbidity, and decreased overall QOL. A significant relationship between reduced muscular strength and premature mortality may also exist.

There also appears to be significant age and gender differences with regard to muscular strength. Aging is clearly associated with sacropenia and associated reductions in functional status and QOL. The age-associated decline in muscle mass and strength may be related partially to prolonged disuse or chronic disease, which may lead to a vicious cycle of decline. Many elderly persons may be at or near the functional threshold with regard to muscular strength for performing the ADLs. Women may likewise be at an increased risk for reductions in functional status and reductions in the capacity to perform ADLs. Therefore, as women grow older they may be particularly susceptible to reductions in functional status and overall QOL.

Table 1 Summary of the Effects of High Levels of Musculoskeletal Fitness on Indicators of Health Status

Indicators of health status								
	Quality of life indicators							
	Functional status							
Musculoskeletal fitness component	Bone health	Independent living/ mobility	Falls	Fractures	Psychological well-being		Morbidity	Mortality
Strength	↑↑↑	↑↑↑	↓↓	↓	↑↑	=	↓↓	↓
Endurance	↑↑	↑↑	↓	↓	↑↑	=	↓	↓
Power	n.a.	↑↑↑	↓	↓	↑	n.a.	↓	↓
Flexibility	n.a.	↑↑	↓	↓	↑/=	n.a.	↓	↓

↑↑↑, strong evidence to support an increase; ↑↑, moderate evidence to support an increase; ↑, potential for an increase; =, generally unchanged; ↓↓↓, strong evidence to support a reduction; ↓↓, moderate evidence to support a reduction; ↓, potential for a reduction; n.a., not enough information is available on this issue.

Muscular endurance is intuitively tied to functional status, since most ADLs require the performance of repeated submaximal contractions. However, very little is known about the benefits of high levels of muscular endurance on the indicators of health status. Limited data indicate that muscular endurance is a strong predictor of self-perceptions regarding health, physical and social function, mental health, and overall QOL. Research also indicates that elevated muscular endurance is potentially related to a reduced incidence of falling plus its associated injuries and a reduction in premature mortality.

Research indicates that muscular power is a strong predictor of functional capacity and resultant disability. Limited data also indicate that low levels of muscular power may be associated with an increased risk for premature mortality. There seems to be an age and gender difference in muscular power which is similar to that observed with muscular strength. The high incidence of disability in older women may be associated with the marked reductions in muscular power observed in this population. Hence, older women may be strong candidates for exercise interventions that improve muscular power (Warburton et al., 2001).

A decreased flexibility of the major joints of the body is associated with reduced mobility and decreased independence (especially in the elderly). However, it is important to note that considerable reductions in flexibility can occur before significant disability takes place. Low levels of flexibility may also be associated with decreased perceptions of health. The potential for reductions in morbidity and possibly premature mortality exists with high levels of flexibility owing to the role flexibility plays in the functional independence. However, further investigation is required to establish this relationship.

Conclusions

Similar to cardiovascular fitness (Bouchard et al., 1990), the dose-response for improvements in health status resulting from enhancements in musculoskeletal fitness is hard to determine. There is increasing evidence which indicates that high levels of musculoskeletal fitness are associated with positive health status. Individuals with high levels of musculoskeletal fitness generally have higher overall quality of life. As well, those individuals are more likely to engage in recreational activities, which will help offset the age-associated decline in musculoskeletal fitness and decrease disuse-related diseases. However, prospective evidence is required to fully understand the relationship between musculoskeletal fitness and health status. A major challenge for researchers is to determine appropriate cut-off scores for varying levels of health status with reference to gender and age.

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