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The Relationship Between Upper Body Muscular Power and Objectively Measured Physical Function in Healthy Older Adults

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Objectively Measured Physical Function in Healthy Older Adults

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Abstract

The population of older adults is growing rapidly worldwide. There are significant challenges associated with an aging population, many of which are related to declining physical function. Muscular power has previously been postulated as an important physical characteristic for preserving physical function, however, much of the research has measured lower body muscular power against functional outcomes. The importance of upper body muscular power (UBMP) for physical function outcomes is less clear, thus, this study sought to examine that relationship. Forty-two older adults between the ages of 50 – 70 (*avg* = 60.5 years ± 5.7) were recruited for the current study. Each participant performed a battery of physical tests to measure UBMP and functional outcomes. UBMP was assessed with a seated medicine ball throw test, and the test setup allowed for the use of the Tendo Weightlifting Analyzer to capture objective power data. Physical function was assessed using the Senior Fitness Test (SFT), a 6-test battery measuring upper/lower body strength and flexibility, aerobic endurance, and dynamic agility. The Hand Grip test was also performed as an additional measure of upper body function. Pearson's correlations were conducted to determine the relationship between each measure of muscular power collected (throw distance, Tendo avg. power, Tendo peak power) and each measure of physical function. Of those, only the Hand Grip and Back Scratch (upper body flexibility test from SFT) showed a strong relationship with UBMP measures. Hand Grip was highly correlated with UBMP (r = .58 - .82, p < .001), while Back Scratch was moderately correlated (r = -.41 – -.49, p < .01). No other measure of physical function showed a substantial relationship to UBMP (r < .20). Additionally, forward stepwise regression analysis was conducted to determine predictors of individual physical function variables. Measures of UBMP were found to be significant unique contributors in regression models predicting Back Scratch,

Sit and Reach (lower body flexibility), Arm Curl (upper body strength), 6-Minute Walk (aerobic endurance), and Hand Grip (upper body strength) performance. These results show that UBMP is clearly an important physical characteristic for upper body physical function, however, the relationship between UBMP and overall physical function is still unclear. Further research is needed to test different assessments of UBMP and physical function in a more diverse sample with regard to age and functional ability.

Contents

Introduction

The world's population is aging. In most developed countries, life expectancies have been increasing almost linearly with no apparent signs of decelerating (Christensen et al., 2009; Oeppen & Vaupel, 2002). This increase is primarily driven by declining rates of mortality seen in older adults since the 1950s (Christensen et al., 2009; Kannisto et al., 1994; Oeppen & Vaupel, 2002; Vaupel et al., 1998). In 1950, no country had more than 11% of its population over the age of 65 years old; in 2000 that rose to 18%, and in 2050 it is possible some will reach 38% (Rudnicka et al., 2020). U.S. projections indicate that by 2060 more than 23% of the population (almost 95 million adults) will be over the age of 65, which is nearly double the amount reported in 2016 (Division, 2018). Older adults are now the most rapidly increasing age group in most developed countries (CDC, 2013; Christensen et al., 2009; Kannisto et al., 1994; Nelson et al., 2007; Vaupel et al., 1998). And these increases appear to be accelerating with advancing age; older age groups (80+) show even greater rates of growth (Christensen et al., 2009; Division, 2018). While this is a positive trend for humankind, it presents significant challenges for social, economic, and health care systems (Vaupel et al., 1998). Thus, the World Health Organization has dubbed the aging of the global population the most important medical and social demographic concern worldwide (Rudnicka et al., 2020).

With an aging population comes significant economic impact. Aging is associated with high health care cost and utilization due to increased risk of disease, disability, falling, and their related outcomes (Marengoni et al., 2011; Prince et al., 2015; Smith, 2001). In the U.S., the cost of providing care to an adult over the age of 65 is three to five times greater than an adult under the age of 65, with another twofold increase from age 65 to 85 and above (Hoffman et al., 1996; Statistics, 2012). Further, health care expenditures substantially increase with worsening health status, particularly in the case of functional dependence (Lubitz et al., 2003; Rice & Fineman, 2004). One study showed that, on average, yearly health care expenditures were about ten times greater for institutionalized older adults than their counterparts that reported no limitations (Lubitz et al., 2003). However, cumulative expenditures from age 70 to death appear to be similar for healthy adults compared to unhealthy adults, possibly due to healthy adults possessing more years in which to incur cost (Lubitz et al., 2003). Thus, projections of increased health care spending over the next several years are in part due simply to the overall increase in number of older adults (CDC, 2013). As this is the case, finding ways to limit further health care expense in this population will be of great importance.

One of the most important outcomes of the aging process may be the general decline in physical function. The progression of physical decline begins with reduced function among bodily systems, which then leads to functional limitations and difficulty performing activities of daily living, and finally disability or loss of independence (Lawrence & Jette, 1996; Nagi, 1991). This decline is caused by the biological mechanisms of the aging process itself as well as other risk factors related to aging such as disease and sedentary lifestyle ((CDC), 2009; ACSM, 1998; Aunan et al., 2016; CDC, 2013; Christensen et al., 2009; Runge et al., 2004; Satariano et al., 2012). Continued declines in bodily systems lead to difficulty performing everyday tasks such as walking, rising from a chair, and climbing stairs ((CDC), 2013; Lawrence & Jette, 1996; Nagi, 1991; Rikli & Jones, 1997). This ultimately leads to disability, which is characterized by limitations in ability to perform tasks within a socially defined environment, such as housework, personal care, and running errands (Lawrence & Jette, 1996; Nagi, 1991; Rikli & Jones, 1999). Disability may lead to loss of independence, increased health care utilization, and decreased enjoyment of life (Fried et al., 2004). Ultimately, the presence of disability strongly influences mortality in older adults independent of other confounding factors (Landi et al., 2010). Another important outcome of decreased physical function is an increased risk of falling (Tinetti et al., 1988). On average, 1 in 3 U.S. older adults fall each year ((CDC), 2013; Blake et al., 1988; Tinetti et al., 1988). Falls are the leading cause of injury-related death in older adults ((CDC), 2009, 2013), but non-lethal falls also pose a significant threat. In addition to sustaining injuries ((CDC), 2013; Tinetti et al., 1988), the fear of falling again discourages continued activity, which results in further declines in physical function and thus further increased risk of falling (Grundstrom et al., 2012; Vellas et al., 1997). Altogether, the resulting outcomes of declining physical function are decreased quality of life and increased risk of mortality for the elderly adult (Grundstrom et al., 2012; Landi et al., 2010; Satariano et al., 2012). Reduced function or fall outcomes may lead to difficulty performing meaningful activities that bring enjoyment, connecting with friends and family, or simply a loss of independent living. Thus, it is clear that preserving physical function is imperative for maintaining quality of life in this population.

Recently, muscular power has been postulated as an important physiological quality for preserving functional ability (Bean et al., 2002; Cuoco et al., 2004; Foldvari et al., 2000; M Gray & S Paulson, 2014; Sayers et al., 2005). One of the mechanisms for declining physical function is sarcopenia, or age-related decreases in muscle mass and function (Cruz-Jentoft & Sayer, 2019). Muscular function, which includes muscular strength and power, is a key determinant of functional status (Cruz-Jentoft & Sayer, 2019). While muscular strength (the ability to produce force) is certainly important, muscular power (the ability to rapidly produce force) appears to be the greater predictor of functional limitations, decreased mobility, fall risk, and loss of physical independence (Bean et al., 2002; Foldvari et al., 2000; Mc Dermott et al., 2022; Sayers et al., 2005). Lower body muscular power is positively correlated with objective measures of physical function, such as walking speed and rising from a chair (Bassey et al., 1992; Bean et al., 2002; Foldvari et al., 2000; Glenn et al., 2017; Herman et al., 2005). It has also been shown to be a strong independent predictor of functional status among older women (Foldvari et al., 2000). However, of concern is that muscular power declines from an earlier age and more rapidly than muscular strength (Izquierdo et al., 1999; Mc Dermott et al., 2022; Skelton et al., 1994). The mechanisms of age-related declines in muscular power will be discussed further in the literature review. The rapid decline of muscular power may be one of the most significant contributors to declining physical function and the development of functional limitations. Thus, the preservation of muscular power as people age is a critical component of mitigating negative outcomes from declining physical function.

Much of the literature on the relationship between muscular power and physical function in older adults is concerned with the lower body, specifically (Bassey et al., 1992; Bean et al., 2002; Cuoco et al., 2004; M Gray & S Paulson, 2014; Sayers et al., 2005). It is generally thought that lower body function is more important for overall functional status given the lower body demand of many everyday activities, such as walking, climbing stairs, and rising from a chair (Lawrence & Jette, 1996). Additionally, there is a strong association between the two (Bassey et al., 1992; Bean et al., 2002; Cuoco et al., 2004; Guralnik et al., 1995; Sayers et al., 2005) However, the role that the upper body plays should not be ignored. Upper body function is related to many activities of daily living, such as carrying, picking things up off the ground, and lifting things overhead. Yet, the relationship between upper body muscular power and functional ability in older adults is still unclear. To the author's knowledge, only two studies have looked at this relationship specifically and they provide mixed results (Foldvari et al., 2000; Herman et al., 2005). More research is needed to clarify this relationship, with implications for clinical assessments of functional ability and exercise prescription in older adults wishing to improve functional ability.

Therefore, the primary purpose of this study was to examine the relationship between upper body muscular power and outcome measures of physical function in healthy older adults with respect to age and sex.

Literature Review

Introduction

As the world's population continues to age, the burden of an aging population will become an increasingly important issue for world health leaders ((CDC), 2013; Christensen et al., 2009; Rudnicka et al., 2020). Aging is related to many factors that may increase mortality and decrease quality of life (Aunan et al., 2016; CDC, 2013; Christensen et al., 2009; Guralnik et al., 1994; Holloszy, 2000; López-Otín et al., 2013; Makovski et al., 2019; Marengoni et al., 2011; Prince et al., 2015), however this review will focus primarily on declining physical function. Muscular power has been shown to be an important physiological quality for preserving physical function and maintaining functional independence for older adults (Bassey et al., 1992; Bean et al., 2002; Foldvari et al., 2000; Glenn et al., 2015, 2017; Gray et al., 2018; Hazell et al., 2007; Herman et al., 2005; Runge et al., 2004). However, much of this research is concerned with the lower body muscular power specifically. The importance of upper body muscular power for preserving or improving physical function is less clear (Foldvari et al., 2000; Herman et al., 2005; Lawrence & Jette, 1996). The purpose of this literature review is to explain the importance of maintaining physical function for older adults and describe the relationship between physical function and muscular power.

Systemic Burden of an Aging Population

Recent medical advancements have increased life expectancies worldwide such that older adults are the fastest growing population (Christensen et al., 2009; Marengoni et al., 2011). After successfully combating infectious diseases among children during the first half of the 20th century, the continued increases seen in life expectancy have come from declining mortality in older adults (Oeppen & Vaupel, 2002). In the U.S., longer life spans and aging baby boomers will lead to the number of older adults rapidly increasing; by 2060, the number of Americans over the age of 65 will likely reach about 95 million, or roughly 23% of the total population (Division, 2018). In addition to more people reaching the age of 65, more adults are living even longer, many well into their ninth decade. Since the 1970s, rates of mortality in adults over the age of 80 have continually declined, and in some countries at an accelerating pace (Christensen et al., 2009; Christensen et al., 2008; Kannisto et al., 1994; Rau et al., 2008). Data from more than 30 developed countries show that in 1950 the probability of survival from age 80-90 was about 15% for women and 12% for men. In 2002, those values were 37% and 25%, respectively (Rau et al., 2008). While this is a positive trend, the increase in longevity has not come with a relative increase in healthy years. In the last century, leading causes of death have transitioned from infectious diseases and acute illnesses to chronic diseases and degenerative illnesses (CDC, 2013; Christensen et al., 2009; Marengoni et al., 2011). Aging is related to nearly all of these conditions, including cardiovascular disease, cancer, metabolic diseases, and neurodegenerative conditions (CDC, 2013; Marengoni et al., 2011; Paneni et al., 2017; Prince et al., 2015). The presence of these chronic conditions often leads to an extended period of decline associated with high healthcare utilization and costs (Boult et al., 1994; CDC, 2013; Lawrence & Jette, 1996; Prince et al., 2015). Multimorbidity, or the cooccurrence of several diseases in one individual, has been found to be even more prevalent than the individual diseases themselves (Fried et al., 2004; Marengoni et al., 2011). And multimorbidity, which is marked by even further declines in quality of life and increased health care costs, is much more prevalent in older adults (Marengoni et al., 2011). Thus, the cost of providing care to one person over the age of 65 is three to five times higher than the cost for someone younger than 65 and increase more than twofold for adults over the age of 85 (Hoffman et al., 1996; Statistics, 2012). This issue, which will become increasingly important with more passing time, is not just unique to the U.S. The World Health Organization has described an aging global population as the most important medical and social demographic problem worldwide (Rudnicka et al., 2020). As people continue to live longer, understanding the mechanisms of the adverse effects related to aging becomes imperative to increase the number of healthy, functional years lived and decrease the burden placed on the health care system.

Importance of Physical Function for Older Adults

Of the many issues that are related to the aging process, perhaps one of the most critical is declining physical function ((CDC), 2013; Chodzko-Zajko et al., 2009; Guralnik et al., 1995; Satariano et al., 2012). In the present study physical function is defined as the ability to perform functional tasks such as walking, rising from a chair, and climbing stairs. The importance of maintaining physical function for older adults is significant. Reductions in physical function lead to difficulty performing activities of daily living such as feeding oneself, maintaining personal hygiene, and housework ((CDC), 2013; Lawrence & Jette, 1996; Nagi, 1991; Rikli & Jones, 1997). Eventually, further decreases in function may lead to an increased risk of falls and adverse fall related outcomes (Blake et al., 1988; Campbell et al., 1989; Sattin, 1992; Tinetti et al., 1988), functional dependency ((CDC), 2013; Guralnik et al., 1995; Lawrence & Jette, 1996), and decreased quality of life ((CDC), 2013; Runge et al., 2004; Satariano et al., 2012). Decreased physical function is preceded by declines in physiological capacities such as balance, muscular function, and aerobic capacity (Lawrence & Jette, 1996; Nagi, 1991; Rikli & Jones, 1997). Aging as a process is related to these declines. Primarily, a combination of three age-associated factors contribute to the physiological impairments that underlie and precede decreased physical function: aging as an unavoidable, irreversible biological process that is universal to all humans (Aunan et al., 2016; Holloszy, 2000; Rikli & Jones, 1999), chronic disease ((CDC), 2013; Boult et al., 1994; Dunlop et al., 2002; Prince et al., 2015), and decreased physical activity (ACSM, 1998; Chandler & Hadley, 1996; Chodzko-Zajko et al., 2009; Nelson et al., 2007). A framework developed by Rikli and Jones shows this progression (Figure 1).

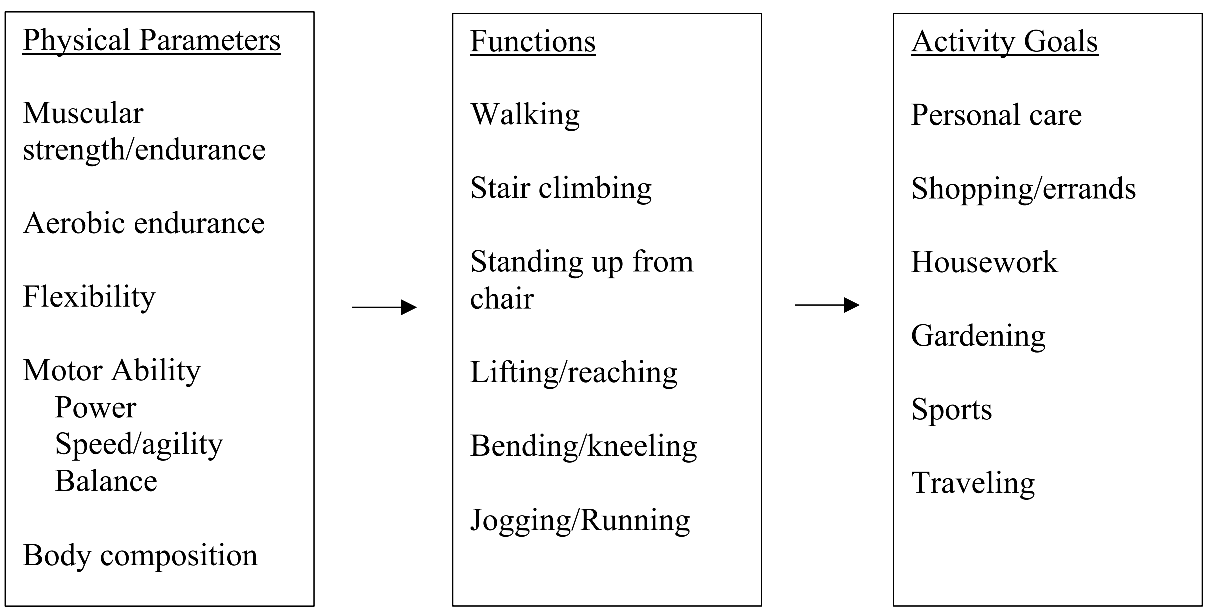

Figure 1. A framework indicating key physical parameters that are required for basic functional ability and ultimately the completion of activities of daily living (Rikli & Jones, 1997).

Predictors of Physical Function

The physiological parameters outlined in the first column of Figure 1 represent important contributors to functional ability (ACSM, 1998; Foldvari et al., 2000; Guralnik et al., 1995; Guralnik et al., 1994; Rikli & Jones, 1999; Tinetti et al., 1988). This is key when considering the evidence that a direct relationship between physiological impairments and functional limitation only exists in the lower end of the performance spectrum with respect to basic activities such as walking and climbing stairs (Buchner et al., 1996; Rikli & Jones, 1999). In other words, reductions in physiological parameters, such as muscular strength or power, directly relate to functional limitations only when physical declines have nearly reached the point of limitation. Many older adults may be operating with close to their maximum capacity for these parameters, where any further decrement would result in functional limitations (Chandler & Hadley, 1996; Rikli & Jones, 1999). This underscores the importance of assessing declines in physical parameters (as opposed to functional ability) before they manifest in difficulty performing these tasks of everyday living (Buchner & Wagner, 1992; Fried et al., 1996; Morey et al., 1998).

Muscular Power as a Predictor of Physical Function

Muscular power is an important component of physical function (Bean et al., 2002; Cuoco et al., 2004; Foldvari et al., 2000; M Gray & S Paulson, 2014; Herman et al., 2005). In simple terms, muscular power is defined as the ability to produce muscular force quickly (power = force*velocity) (Bean et al., 2002). Muscular power is positively correlated with measures of physical function such as walking speed, stair climbing, and chair rise time (Bassey et al., 1992; Bean et al., 2002; Foldvari et al., 2000; Glenn et al., 2017; Herman et al., 2005). It has also been shown to be a strong, independent predictor of self-reported functional status among community-dwelling women (Foldvari et al., 2000). Muscular power is directly related to physical function due to its influence on muscular function. Muscular function, defined by muscular strength, power, or physical performance, has been consistently shown to be a more powerful predictor of clinically relevant outcomes that muscle mass alone (Cruz-Jentoft & Sayer, 2019). And when compared to muscular strength, another important component of function, muscular power has been shown to be the stronger predictor of functional performance (Bean et al., 2002; Cuoco et al., 2004; Foldvari et al., 2000; Sayers et al., 2005; Suzuki et al., 2001). The precise mechanism for this difference is not yet clear, however one potential explanation includes the importance of contractile velocity for functional outcomes. Declines in muscular power seen with age do appear more related to declines in contractile velocity as opposed to force production (Bosco & Komi, 1980; De Vito et al., 1998; Perry et al., 2007). Some research has shown the independent effect of the velocity component of muscular power demonstrates stronger associations with functional performance than maximal strength (Sayers et al., 2005). This is especially true for functional tasks involving walking, where movement speed is highly important (Satariano et al., 2012; Sayers, 2008). Thus, functional ability may not be more dependent on how strong muscles are, but how quickly they can be moved.

Decreasing Muscular Power with Age

Another reason for the importance of muscular power in relation to physical function is that power is lost sooner and more rapidly compared with other physiological attributes (Izquierdo et al., 1999; Metter et al., 1997; Skelton et al., 1994). Sarcopenia, or the gradual and progressive loss of muscle mass and function with advancing age, is an important age-associated factor relating to physical decline (Cruz-Jentoft & Sayer, 2019; Glenn et al., 2017; Walston, 2012). Previous research suggests that reduced levels of muscle mass alone do not account for the decreases seen in physical function that are attributed to age-related sarcopenia (Cruz-Jentoft

& Sayer, 2019; Runge et al., 2004). Rather, a combination of factors related to muscular function and structure account for this decline (Dhillon & Hasni, 2017; Runge et al., 2004). These factors include changes in relative body composition and tissue composition within skeletal muscle (Baumgartner et al., 1993), increased atrophy of type II (fast twitch) muscle fibers specifically (Aoyagi & Shephard, 1992; Doherty, 2003; Lexell et al., 1983), and neural deterioration leading to reduced motor unit firing rate (Aoyagi & Shephard, 1992; Barry & Carson, 2004; Scaglioni et al., 2002). Type-II muscle fibers, which are responsible for producing large amounts of muscular force in relatively short periods of time, can be reduced in size up to 50%, while type-I fibers are much less affected (Dhillon & Hasni, 2017; Doherty, 2003). Altogether, these factors affect muscular power more so than other qualities of muscular function, such as strength (Sayers, 2008). This is evidenced by the earlier onset and greater intensity of age-related declines in muscular power compared to muscular strength (Metter et al., 1997; Petrella et al., 2005). Reductions in strength typically begin around age 50 and are about 1-2% per year, while reductions in power can begin in the third and fourth decades of life and are around 3-4% per year (Skelton et al., 1994).

Muscular power shows a clear relationship with performance of activities of daily living (Bassey et al., 1992; Bean et al., 2002; Cuoco et al., 2004; Foldvari et al., 2000; M Gray & S Paulson, 2014; Herman et al., 2005). Thus, these findings provide support that maintenance of muscular power is highly important for delaying age-related declines in physical function and its associated negative outcomes.

Upper Body Muscular Power

Much of the current research on the relationship between muscular power and physical function in older adults is concerned with lower body muscular power (LBMP), specifically (Bassey et al., 1992; Bean et al., 2002; Cuoco et al., 2004; M Gray & S Paulson, 2014; Suzuki et al., 2001). However, impairments in function of both the lower *and* upper extremities contribute to functional limitations, especially activities of daily living (Lawrence & Jette, 1996; Rikli & Jones, 1999). The upper body is required for many functional tasks: carrying items, picking things up off the ground, lifting overhead, opening/closing doors, and pushing oneself up out of a chair (Rikli & Jones, 1999). Despite the understanding that upper body function is important for maintenance of overall functional ability, there is a paucity of literature on the association of upper body muscular power (UBMP) and physical function in older adults (Herman et al., 2005). In fact, very few studies even report measures of UBMP in this population segment. A meta-analysis by Ramsey et al., which looked at the association between muscular strength and power with objectively measured physical activity and sedentary behavior, found 9 studies that reported measurements of UBMP (Ramsey et al., 2021). Of the 9, 8 studies used a 30 second arm curl test for assessment of UBMP. The 30 second arm curl test has been shown to be a moderate to good indicator of overall upper body strength (Rikli & Jones, 1999), however to the author's knowledge there is no rationale in the literature that would support it as a test of UBMP. Two studies were identified that used computer-interfaced pneumatic resistance machines (Keiser Sports Health Equipment Inc., Fresno, CA) for assessment of muscular power for chest press and upper back movements (Foldvari et al., 2000; Morie et al., 2010). Their protocols were previously validated against standard lab and field tests of muscular power (Thomas et al., 1996). However, these studies looked at the association of muscular power with self-reported functional status and objectively measured physical activity, respectfully. A study by Bottaro et al. in 2007 compared the effects of a power training program versus traditional resistance training on outcome measures of muscular strength, power, and functional performance in 20 older men (Bottaro et al., 2007). To assess muscular power, they gathered peak power during a 4-repetition chest press exercise at 60% of the previously gathered one repetition maximum using a power control resistance machine (Technogym, Biomedical Line, Gambettola, Italy). Their measures of functional performance were selected tests from the Senior Fitness Test (Rikli & Jones, 1999); namely, an adapted 30-second arm curl test, the 30-second sit-to-stand test, and the 8-foot-up-and-go. These tests were selected as representative of important physical parameters related to functional ability. However, no statistical analysis was performed comparing measures of muscular power and functional ability. To the author's knowledge, only one study has compared UBMP to objectively measured physical function.

In 2005, Herman et al. looked at the relationship between upper and lower limb muscular power in mobility-limited older adults (Herman et al., 2005). They collected data from 37 participants for outcome measures of physical performance as measured by stair climb time, Short Performance Physical Performance Battery (SPPB), and 4-meter walk time (separately from SPPB score). Independent variables were upper and lower body muscular strength and power. For measurement of UBMP, participants used similar pneumatic resistance machines (Keiser Sports Health Equipment Inc., Fresno, CA), but for the triceps press movement (evaluating elbow extensors). Participants performed 5 repetitions at both 40% and 70% of previously determined one repetition maximum to account for the differences in power at each end of the force velocity curve. The main findings from this study show strong association between upper and lower body muscular power among mobility-limited older adults. In fact, the association between upper and lower body power (r=.88-.89) was even stronger than the association of upper and lower body strength (r=.69). These findings would suggest that muscular power may be dependent on a more universal physiological attribute that influences more than simply force production, such as age-related neuromuscular changes that impact velocity of movement. Additionally, regression models using triceps power were found to explain equivalent, and in some cases greater, amounts of variation in physical performance measures (stair climb, SPPB, 4-meter walk) than models using lower body power. That a measure of UBMP, as compared to a measure of LBMP, did not weaken the association with physical function has powerful implications for future clinical testing. If this relationship is found to be valid, it could lead to the use of upper body measures of muscular power as viable alternatives to lower body measures for predicting physical function. However, further research is required to clarify this relationship.

Age-related physical decline undoubtedly represents a significant problem for the aging population due to development of functional limitations and related adverse outcomes. Muscular power is an important determinant of physical function, however, the extent to which upper body muscular power specifically contributes to functional ability is currently unclear. Thus, the purpose of this study was to determine if a relationship exists between upper body muscular power and objectively measured physical function in healthy older adults.

Methodology

The purpose of this study was to examine the relationship between upper body muscular power and objectively measured physical function. This study's testing protocol utilized a variety of physical tests to determine upper body muscular power and physical function in the study participants. The outcome measures of physical function are measures of upper and lower body strength, upper and lower body flexibility, aerobic endurance, and motor ability/dynamic balance. Data on these characteristics of physical function was obtained through the 6 tests comprising the Senior Fitness Test (SFT): 30s chair sit to stand, arm curl, chair sit and reach, back scratch, 8-ft-up-and-go, and the 6-minute walk (Rikli & Jones, 1999), as well as hand grip strength. The SFT was selected as it is a valid and reliable measure of overall functional ability in older adults (Rikli & Jones, 1999). Measures of upper body muscular power were obtained through a seated medicine ball throw test utilizing the TENDO Weightlifting Analyzer (Tendo) (Trencin, Slovak Republic). The complete testing battery was performed in full by each subject during one testing session.

Participant Recruitment

Participants were recruited via the following methods: 1) University of Arkansas "Arkansas News", a daily email sent to all active, university affiliated email accounts containing campus-related news and updates, 2) targeted emails sent to potential participants of a concurrent study within the department, 3) social media posting via Facebook, 4) word of mouth. If potential participants expressed interest, they were sent an email detailing the study's purpose, participant responsibilities, time requirements, inclusion/exclusion criteria, and risks/benefits of participation. If they agreed to participate, participants were then sent an electronic survey created via Qualtrics to determine if they met all inclusion criteria and none of the exclusion criteria. Inclusion criteria were aged 50-70, able to understand written and verbal English, willingness to communicate via email, and ability to participate in vigorous physical activity without physician approval per ACSM guidelines (Riebe et al., 2015). The inclusion survey included questions adapted from the ACSM Preparticipation Screening Health Screening Recommendations that determine if the respondent should seek physician approval prior to testing. The selected age range was determined as appropriate to obtain participants that are likely beginning to experience age-related declines in muscular power while limiting risk of injury in adults over the age of 70 during the maximal effort tests included within this study (Lindle et al., 1997; Skelton et al., 1994). Exclusion criteria were uncontrolled or symptomatic hypertension, diabetes, or cardiovascular disease, physician diagnosis of a neurological disorder, any musculoskeletal condition that would prohibit physical activity, or not meeting all inclusion criteria. If all inclusion and none of the exclusion criteria were met, participants were digitally sent an Informed Consent form and another Qualtrics survey gathering basic demographical information (age, ethnicity, level of education, socio-economic status). All recruitment materials, including email language, surveys, and the informed consent form, were approved by the University of Arkansas Institutional Review Board.

Testing Protocol

Data was gathered on one participant at a time. Testing sessions were comprised of 4-5 subjects per session, and the researchers/research assistants were stationed at specific tests for efficiency. Each participant was given a specific time to arrive at the Exercise Science Research Center to properly stagger the participants throughout the testing battery. Upon arrival to the research center, the participants' height and weight was collected, followed by a Dual-Energy X-Ray Absorptiometry (DEXA) scan to obtain body composition data. Following the DEXA scan, each participant underwent a standard 5-minute warmup of treadmill walking. The treadmill was set to 2.0 mph with a 0% incline (Adams et al., 2000). After the warmup, each participant performed the remaining tests in the following order: chair sit and reach, back scratch, medicine ball throw/Tendo (tests were concurrent), hand grip strength, 8-ft-up-and-go, arm curl, 30 second sit-to-stand, 6-minute walk. Each component of the SFT was performed consistent with the original test protocol.

Dual-energy X-Ray Absorptiometry (DEXA)

This study used a total-body Prodigy DEXA (GE Healthcare, Boston, MA) scan to collect body composition data. The researcher began by collecting height and weight data using a Detecto physician's scale (Webb City, MO) without shoes and any other extraneous clothing/weight removed. Height was collected to the nearest centimeter while weight was collected to the nearest tenth kilogram. The researcher then had the participant remove any jewelry, accessories, or anything else containing metal that can be removed. The participants were instructed via email to wear clothing without any metal whatsoever prior to arriving for testing. Scrubs were available in the instance a participant arrived in non-removable clothing that contained metal. The researcher then entered the height and weight data into the computer and explained the DEXA scan procedure to the participant. They then appropriately positioned the participant for the scan (lying supine with arms and legs brought together) and explained the importance of remaining motionless for the entirety of the scan.

Chair Sit and Reach

This test was used to assess lower body (primarily hamstring) flexibility. The participant began by sitting on the very front edge of a chair. The hip crease on the top of the leg should have been even with the edge of the chair. While keeping one leg bent and foot flat on the floor, the other (preferred) leg is fully extended (but not hyperextended) with the heel on the floor and the foot flexed approximately 90° toward the ceiling. The participant was then instructed to bend forward at the hip joint, keeping their back straight and head in line with the spine, as far forward as they can with their hands stacked on top of one another (middle fingertips should be even) and reaching for their toes. The reach must be held for 2 seconds. If the extended knee began to bend, the assistant instructed the participant to slowly sit back while trying to re-straighten their leg. Participants were reminded to exhale as they reach, to avoid "bouncing" or rapid forceful movements, and to stop before they experienced pain. Following a demonstration, the participant was asked to identify a preferred leg. They were then given two practice trials, followed by two test trials. The score is defined as the number of inches, to the nearest ½ inch, from the middle fingertips to the middle toe. If the fingertips were short of the middle toe it was recorded as a minus score, if they were past the middle toe it was recorded as a positive score, and if they were touching the middle toe it was recorded as a zero score. The better of the two test trials was used (Rikli & Jones, 1999).

Back Scratch

This test was used to assess upper body (primarily shoulder) flexibility. From a standing position, the participant reached the preferred-side hand behind their back, palm down, while reaching as far down the back as they could (elbow will be pointed up). Simultaneously, the other hand reached from the lower back, palm facing out, up towards the preferred hand in an attempt to touch or overlap the extended fingers of both hands. The research assistant verified that their hands were directed toward each other before collecting the measurement. Following a demonstration from the assistant, participants were then asked to determine the preferred arm and then perform two practice trials followed by two test trials. The score is defined as the distance between middle fingertips or the distance of overlap, measured in inches to the nearest half inch. A minus score was given if the fingertips did not reach each other, while a positive score was given if there was overlap. The better of the two test trials was used (Rikli & Jones, 1999).

Medicine Ball Throw

This test was used to assess upper body muscular power. The protocol for this test was based on that of a previous study which found the Seated Medicine Ball Throw to be a valid and reliable measure of upper body muscular power (Harris et al., 2011), however it was modified slightly to fit the parameters of this study. During the throw, power data was collected by the Tendo, which was fastened to a glove to be worn on participants' left hand. Participants began by sitting on a weight bench that had been raised to the highest incline setting. They were instructed to sit with their back to the bench and feet flat on the floor. On the floor was a tape measure running from the base of the bench straight out in the direction of the throw. Participants were then given a 1.8kg (4lb) medicine ball to throw for the test. For the throw, participants held the medicine ball with both hands and brought it to mid-chest level with elbows flared approximately 60° from the floor. At the researcher's signal, participants extended both arms and threw the ball as forcefully as they could from the chest, straight out. The researcher explained proper form by cueing the participant to "throw it like a basketball chest pass", that the throw should be straight out in parallel with the floor, and that they should throw the ball as hard as they possibly could. The researcher provided a visual demonstration. Following the demonstration, the participant was given 3 practice trials followed by 3 test trials. Participants rested for 90 seconds between trials and 3 minutes between the practice and test trials to allow for appropriate muscular recovery. The researcher cheered the participant on throughout the test to help them achieve maximal force production. After each test trial, the researcher marked approximately where the medicine ball made first impact with the ground to determine throw distance. Primary outcome measures were throw distance, average power as measured by the

Tendo, and peak power as measured by the Tendo. The averages of the three test trials were utilized.

Tendo

Tendo is a linear position transducer device that obtains power from input mass data (kg) and the velocity (m/s) of the Kevlar cord pulled during movement. Tendo has previously been reported as a valid and reliable measure of determining muscular power during a functional task (sit to stand) in older adults (M. Gray & S. Paulson, 2014). Tendo was utilized in conjunction with the medicine ball throw test and data was collected for both for additional measures of upper body muscular power. The device was setup behind the weight bench the participant sat on for the medicine ball throw and positioned so that the Kevlar cord was parallel to the participant's extended arm when pulled. The cord ran inside the elbow when setting up for the medicine ball throw and was attached via Velcro to the glove on the participant's left hand. The mass input into the Tendo was the approximate mass of the medicine ball used for the throw (2kg). Following each throw test trial, the researcher instructed the participant not to extend their arms again until data has been collected. The researcher recorded average power and peak power for each trial, and the average of the three test trials was utilized.

Hand Grip Strength

This test was used to assess upper body strength; however, it is also predictive of functional ability in older adults and was thus included as an additional outcome measure of physical function (ACSM, 2021; Bohannon, 1997, 2012). A Takei Hand Grip Dynamometer (HaB Direct, Southam, UK) was used. Participants sat on a chair with the dynamometer held at their side with the arm extended, beginning with the right side. The device grip width was adjusted for comfort for each participant. On the research assistant's cue, the participant squeezed the dynamometer as hard as possible for three seconds. The research assistant encouraged the participant through the trial to squeeze as hard as possible. Following the three second squeeze, the research assistant recorded the value of highest force produced (kg) and then cleared the device. The participant then switched hands and performed a trial with the left hand. The participant rested 60 seconds between trials of the same hand to allow for adequate recovery. Three test trials were collected for each hand, and the score was reported as the sum of highest values recorded for each hand and rounded to the nearest kilogram.

8ft-Up-and-Go

This test was used to assess agility and dynamic balance. To set up the test, a chair was placed against a wall with a cone set directly in front of the chair. The cone was 8ft away, measured from the front edge of the chair to the back of the cone. Ample clearance was provided past the cone to allow for the participants' turning. The participant began by sitting in the chair with fully erect posture, hands on thighs, and feet flat on the floor with one slightly in front of the other. At the research assistant's signal, the participant pushed off from the chair, walked as quickly as possible around either side of the cone, and returned to the chair. The assistant explained to the participant that this test is timed, and that their objective should be to walk as quickly as possible, without running, in order to return to the chair as quickly as possible. The assistant acted as a spotter and stood midway between the chair and cone to assist if needed. For reliability of testing, the assistant started the timer at their signal, regardless of the participant's movement, and stopped it as soon as they returned to a seated position in the chair. Following a demonstration, the participant was given two practice trials followed by two test trials. The score was defined as the amount of time elapsed from the assistant's signal to the instant the participant returned to a seated position back in the chair, measured to the nearest $1/10^{th}$ of a second. The better of the two test trials was used (Rikli & Jones, 1999).

Arm Curl

This test was used to assess upper body strength. The participant began seated in a chair with the preferred-arm side of the body closer to the edge of the chair. Weight was held by the preferred arm, starting down at the participant's side, with a neutral (palm facing in) grip. Male participants used an 8-pound dumbbell, while female participants used 5 pounds. At the research assistant's signal, the participant curled the arm through a full range of motion while rotating their wrist to a supinated position (palm facing behind) and then immediately returned to the fully extended position. The research assistant was knelt by the side of the participant to support the upper arm. One hand was positioned behind the elbow to establish complete extension as well as prevent any backward arm sway, while the other hand was positioned at mid-bicep level to establish complete flexion and prevent any forward arm sway. The participant was instructed to squeeze the assistant's fingers with their forearm. Following a demonstration, the participant completed one or two practice repetitions to establish form. The research assistant encouraged them to complete as many curls as possible in the 30 second window. The participant then completed one 30-second trial. The score was the number of complete curls performed in 30 seconds. If the arm was more than halfway up at the end of time, it was counted as a complete curl (Rikli & Jones, 1999).

30s Sit-to-Stand

This test was used to assess lower body strength. The participant began by sitting in the middle of a chair with their back straight, feet flat on the floor, and arms crossed across their chest. At the research assistant's signal, the participant rose to a full stand and then immediately returned to a fully seated position. Following a demonstration, the participant performed 1-3 practice repetitions to establish the form. The research assistant encouraged them to complete as many full stands as possible in the 30 second window. The participant then completed one 30-second trial. The score was defined as total number of completed stands. If the participant was more than halfway up at the end of time, it was counted as a complete stand (Rikli & Jones, 1999).

6-minute walk

This test was used to assess aerobic endurance. The walking course, modified slightly from the original protocol, was two cones set 25 yards apart from each other in a straight line, thus creating a 50 yard "lap". The walking surface was non-slippery, in a well-lit hallway free from obstacles. The research assistant explained to the participant that they were being assessed based on how much distance they were able to cover in 6 minutes, and that they should therefore try to get as many laps as possible. They then explained that ultimately the participant was free to walk at a pace of their choice and could stop if needed. To accurately record distance, research assistants marked completed laps as they were completed. The assistant provided updates on elapsed time at the 3:00, 4:00, 5:00, and 5:50 marks. At the 6:00 mark, the assistant instructed the participant to stop where they were to record the final, partial segment length. The test would be discontinued if any participant showed signs of dizziness, pain, nausea, or undue fatigue. Following the test, participants were instructed to slowly continue walking for an additional minute to cool down. The score was the number of yards, measured to the nearest yard, traveled in 6 minutes (Rikli & Jones, 1999).

Statistical Analysis

All statistical analyses was completed using SPSS (IBM, Armonk, NY). Descriptive statistics for participant characteristics (anthropometric data, age, sex), measures of physical function per SFT and Hand Grip (upper/lower muscular strength, upper/lower flexibility, aerobic endurance, dynamic agility), and upper body muscular power (medicine ball throw, Tendo) were calculated as means $\pm$ standard deviation. The association between upper body muscular power and physical function was assessed using Pearson Product Moment Correlations between each measure of physical function (upper body strength, lower body strength, upper body flexibility, lower body flexibility, aerobic endurance, and dynamic agility) and measures of upper body muscular power (medicine ball throw, Tendo). Multiple regression analysis was used to predict each measure of physical function from measures of upper body muscular power, age, sex, body weight, and height. Statistical significance was set at $\alpha = .05$.

Results

Participants

Baseline characteristics of the participants are presented in Table 1. The mean age of the sample was 60.5 (*SD* = 5.7) years. The majority of the sample was female (31 female, 11 male). Significant sex differences existed for all descriptive characteristics except 8-ft-Up-and-Go, Arm Curl, 30-sec Sit to Stand, and 6-Minute Walk.

Table 1

Participant Demographic Characteristics.

Participant Characteristic	Mean	SD	95% CI
Age, years	60.5	5.7	58.37 – 62.67
Height, cm	166.72	8.77	163.39 – 170.06
Weight, kg	70.51	14.99	64.81 – 76.22
Lean body mass, kg	42.78	9.29	39.25 – 46.31

Table 2

Participant Demographic Characteristics by Sex

Participant Characteristic	Males *(n = 11)*		Females *(n = 31)*		
	Mean	SD	Mean	SD	*p-value*
Height, cm	181.1	7.5	162.7	5.2	< .001*
Weight, kg	89.14	17.54	65.03	9.59	< .001*
Lean body mass, kg	60.76	3.21	38.69	4.23	< .001*

* indicates statistical significance *($p < .05$)*

Table 3

Participant Baseline Performance

Performance Measure	Mean	SD	95% CI
MBT: Distance, m	3.18	0.81	2.88 – 3.49
MBT: Average Power, W	32.2	6.2	29.88 – 34.60
MBT: Peak Power, W	168.6	66.0	143.59 – 193.79
Back Scratch, in.	-0.16	3.81	-1.61 – 1.30
Sit and Reach, in.	1.50	4.28	-0.13 – 3.13
8-ft-Up-and-Go, sec	4.85	0.53	4.65 – 5.05
Hand Grip, kg	57.33	17.91	50.51 – 64.14
Arm Curl, reps	24.6	6.4	22.12 – 26.99
30-sec Sit to Stand, reps	20.8	5.8	18.63 – 23.03
6-Minute Walk, yd	650.5	70.8	623.54 – 677.36

Note. MBT = Medicine Ball Throw

Table 4

Participant Baseline Performance by Sex

Performance Measure	Males *(n = 11)*		Females *(n = 31)*		
	Mean	SD	Mean	SD	*p-value*
MBT: Distance, m	4.53	0.80	2.85	0.41	< .001*
MBT: Avg Power, W	38.9	6.9	30.6	3.9	< .001*
MBT: Peak Power, W	269.6	69.6	148.9	47.4	< .001*
Back Scratch, in.	-4.63	4.64	0.66	2.57	< .001*
Sit and Reach, in.	-2.82	3.57	2.34	3.43	< .001*
8-ft-Up-and-Go, sec	4.87	0.68	4.76	0.63	.63
Hand Grip, kg	93.65	14.73	50.21	6.66	< .001*
Arm Curl, reps	26.5	7.7	23.9	4.8	.21
30-sec Sit to Stand, reps	20.7	6.2	21.0	5.6	.89
6-Minute Walk, yd	694.3	82.6	639.9	75.5	.06

Note. MBT = Medicine Ball Throw

* indicates statistical significance *($p < .05$)*

Relationships Between Variables

Correlations between UBMP and measures of physical function are presented in Table 5. Of these measures, only Hand Grip and Back Scratch showed a statistically significant relationship to all measures of UBMP ($p < 0.01$). Performance in the Hand Grip test was highly correlated with UBMP as measured by throw distance ($r = .82$, $p < .001$) and peak power ($r = .72$, $p < .001$) and moderately correlated with average power ($r = .58$, $p < .001$). Back Scratch was inversely related to UBMP and moderately correlated with each measure of power ($r = -.49$, throw distance; -.45, average power; -.41, peak power). Sit and Reach, Arm Curl, and 6-Minute Walk all showed weak to moderate correlations to measures of UBMP ($r = .16$ - .38). 8-ft-Up-and-Go and 6-Minute Walk showed very weak correlations to measures of UBMP ($r < .20$).

Table 5

Correlation Matrix between Physical Function and UBMP

Dependent Variables	Independent Variables		
	MBT: Distance (m)	MBT: Avg. Power (W)	MBT: Peak Power (W)
Back Scratch, in.	-.494*	-.447*	-.406*
Sit and Reach, in.	-.362*	-.308*	-.300
8-ft-Up-and-Go, sec	.088	-.012	.196
Hand Grip, kg	.816*	.583*	.716*
Arm Curl, reps	.221	.377*	.258
30-sec Sit to Stand, reps	-.028	.146	-.079
6-Minute Walk, yd	.264	.331*	.157

* indicates statistical significance *($p < 0.05$)*

Regression Analysis

Multiple regression analysis was used to examine the association between measures of physical function and various predictor variables, including measures of UBMP. In one model predicting Back Scratch performance, throw distance accounted for 18.7% of the variance with body weight accounting for an additional 12.9%. In another model predicting Back Scratch performance, average power accounted for 10.9% of the variance with body weight accounting for an additional 20.6%. In the model predicting Sit and Reach performance, throw distance accounted for 11.8% of the variance and sex accounted for an additional 17.3%. All measures of UBMP were significant predictors of Hand Grip performance (R^2 = .63, throw distance; .32, peak power; .34, average power), with sex accounting for an additional 14.9% of the variance beyond throw distance, 46.5% beyond peak power, and 44.2% beyond average power. Average power was the only UBMP measure that was a significant predictor of Arm Curl and 6-Minute Walk performance, accounting for 18.4% and 15.4% of the variance, respectively.

Table 6

Model Predicting Back Scratch Performance from MBT Distance.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Distance	.187	.007*	-2.009	.007*
	Model 2			
MBT: Distance			-.270	.772
Weight	.316	.014*	-.134	.014*

* indicates statistical significance *($p < 0.05$)*

Table 7

Model Predicting Back Scratch Performance from MBT Peak Power.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Peak Power	.086	.054	-.019	.054
	Model 2			
MBT: Peak Power			.010	.420
Weight	.328	.001*	-.174	.001*

* indicates statistical significance *($p < 0.05$)*

Table 8

Model Predicting Back Scratch Performance from MBT Average Power.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Avg Power	.109	.034*	-.235	.034*
	Model 2			
MBT: Avg Power			-.026	.823
Weight	.315	.003*	-.140	.003*

* indicates statistical significance *($p < 0.05$)*

Table 9

Model Predicting Sit and Reach Performance from MBT Distance.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Distance	.118	.029*	-1.881	.029*
	Model 2			
MBT: Distance			2.261	.166
Sex	.291	.006*	10.182	.006*

* indicates statistical significance *($p < 0.05$)*

Table 10

Model Predicting Sit and Reach Performance from MBT Peak Power.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Peak Power	.078	.064	-.021	.064
	Model 2			
MBT: Peak Power			.007	.612
Sex	.250	.008*	6.653	.008*

* indicates statistical significance *($p < 0.05$)*

Table 11

Model Predicting Sit and Reach Performance from MBT Average Power.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Avg Power	.083	.057	-.241	.057
	Model 2			
MBT: Avg Power			.058	.711
Sex	.247	.009*	6.404	.009*

* indicates statistical significance *($p < 0.05$)*

Table 12

Model Predicting 8-ft-Up-and-Go Performance from MBT Distance.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Distance	-.032	.921	-.013	.921

Table 13

Model Predicting 8-ft-Up-and-Go Performance from MBT Peak Power.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Peak Power	-.024	.614	.001	.614

Table 14

Model Predicting 8-ft-Up-and-Go Performance from MBT Average Power.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Avg Power	-.028	.727	-.007	.727

Table 15

Model Predicting Hand Grip Performance from MBT Distance.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Distance	.633	<.001*	16.664	<.001*
	Model 2			
MBT: Distance			1.160	.757
Sex	.782	<.001*	-38.116	<.001*

* indicates statistical significance *($p < 0.05$)*

Table 16

Model Predicting Hand Grip Performance from MBT Peak Power.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Peak Power	.321	<.001*	.159	<.001*
	Model 2			
MBT: Peak Power			-.025	.429
Sex	.786	<.001*	-43.341	<.001*

* indicates statistical significance *($p < 0.05$)*

Table 17

Model Predicting Hand Grip Performance from MBT Average Power.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Avg Power	.340	<.001*	1.821	<.001*
	Model 2			
MBT: Avg Power			-.117	.739
Sex	.782	<.001*	-41.579	<.001*

* indicates statistical significance *($p < 0.05$)*

Table 18

Model Predicting Arm Curl Performance from MBT Distance.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Distance	.001	.320	1.271	.320
	Model 2			
MBT: Distance			-1.102	.508
Height	.099	.045*	.318	.045*

* indicates statistical significance *($p < 0.05$)*

Table 19

Model Predicting Arm Curl Performance from MBT Peak Power.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Peak Power	.043	.128	.025	.128

Table 20

Model Predicting Arm Curl Performance from MBT Average Power.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Avg Power	.184	.007*	.475	.007*

* indicates statistical significance *($p < 0.05$)*

Table 21

Model Predicting 30-sec Sit to Stand Performance from MBT Distance.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Distance	-.031	.851	.239	.851

Table 22

Model Predicting 30-sec Sit to Stand Performance from MBT Peak Power.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Peak Power	-.032	.971	.001	.971

Table 23

Model Predicting 30-sec Sit to Stand Performance from MBT Average Power.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Avg Power	-.015	.473	.132	.473
	Model 2			
MBT: Avg Power			.500	.038*
Height	.117	.024*	-.345	.024*

* indicates statistical significance *($p < 0.05$)*

Table 24

Model Predicting 6 Minute Walk Performance from MBT Distance.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Distance	.089	.064	30.578	.064

Table 25

Model Predicting 6 Minute Walk Performance from MBT Peak Power.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Peak Power	.016	.239	.242	.239

Table 26

Model Predicting 6 Minute Walk Performance from MBT Average Power.

Predictor Variable	Adjusted R Square	Sig. F Change	Unstandardized B	Sig.
	Model 1			
MBT: Average Power	.154	.020*	4.894	.020*

* indicates statistical significance *($p < 0.05$)*

Discussion

The current study examined the relationship between upper body muscular power and measures of physical function in healthy older adults. UBMP was highly correlated with upper body strength as measured by Hand Grip (r = .58 - .82, p < .001) and moderately correlated with upper body flexibility as measured by the Back Scratch test (r = -.41 – -.49, p < .01). In regression models used to predict physical function, UBMP and sex were significant predictors of Hand Grip performance, while UBMP and body weight were significant predictors of Back Scratch performance. These results suggest that UBMP is an important physical characteristic in regard to upper body physical function, however, the importance of UBMP for overall physical function remains unclear.

Muscular power has previously been found to be an important contributor to physical function in older adults (Bean et al., 2002; Cuoco et al., 2004; Foldvari et al., 2000; M Gray & S Paulson, 2014; Herman et al., 2005; Runge et al., 2004). However, much of the literature reporting this relationship utilized a measure of lower body muscular power (Bean et al., 2002; Cuoco et al., 2004; M Gray & S Paulson, 2014; Runge et al., 2004). To the author's knowledge, only two studies have examined the relationship between UBMP and physical function in an older population. In the first, Foldvari et al. compared a host of variables, including upper and lower body muscular power, to physical function (Foldvari et al., 2000). While UBMP was found to be moderately correlated with function, function was assessed using a functional status questionnaire from the NHANES I Epidemiological Follow-Up Study. This survey allowed participants to self-report their perceived functional status and did not obtain objective data regarding physical function. In the second, Herman et al. compared measures of upper and lower body power against objectively measured physical function (Herman et al., 2005). The results from their regression analysis showed that UBMP predicted physical function measures equally or better than LBMP. However, the chosen tests of physical function were stair climb time, Short Performance Physical Battery (SPPB) (Guralnik et al., 1994), and 4-meter walk time, which are all primarily tests of lower body function. Another difficulty shared by both previous studies is the use of pneumatic resistance machines to assess UBMP, which are costly and unavailable in a wide range of testing settings. For future researchers looking to examine muscular power, pneumatic resistance machinery may not be available. Therefore, the current study was designed to build upon the limitations of the two previous studies, and as such, there are some noticeable differences. First, the study by Herman et al. did not include any measures of upper body function in outcome variables of physical function. The current study utilized the Senior Fitness

Test, which validated the use of the Arm Curl test as a measure of upper body strength and the Back Scratch test as a measure of upper body flexibility (Rikli & Jones, 1999). Use of the Senior Fitness Test also provides objective data on overall physical function. Second, rather than pneumatic resistance equipment, the current study utilized a modified version of a previously validated protocol for a medicine ball throw test (Harris et al., 2011) for the measurement of UBMP. The medicine ball throw test is easier to administer in a greater number of settings due to equipment availability. Additionally, participants of the previous study performed 5 non-ballistic repetitions when testing for muscular power. The use of a single, ballistic repetition with the medicine ball throw test may reflect a more accurate measurement of muscular power due to greater neuromuscular power in this type of contraction (Mc Dermott et al., 2022).

The medicine ball throw protocol used in the current study was modified from that of Harris et al. Namely, the addition of the TENDO Weightlifting Analyzer was included to provide an objective measure of muscular power. Previous studies using a medicine ball throw typically report throw distance as the primary outcome, which is a proxy for power. The Tendo provides power in watts and was previously validated as a reliable measure of muscular power during a functional task (M. Gray & S. Paulson, 2014). However, the functional task used previously was a sit-to-stand, which is a lower body movement. The setup utilized in the current study aimed to mimic the parameters of the previous study such that the Tendo could accurately report muscular power during a throwing movement. Incidentally, throw distance was more closely related to upper body measures of physical function than peak power or average power collected by the Tendo (Table 3). This could reflect inaccuracies associated with the setup of the Tendo and its ability to collect power and should be addressed in future studies.

The results of this study would indicate that UBMP is not closely related to measures of physical function other than upper body strength and flexibility. This contrasts with the study by Herman et al., which found that UBMP may be just as effective as LBMP for predicting functional ability. However, this may be explained by differences in the testing protocols. First, the previous study assessed UBMP with 5 non-ballistic repetitions in a downward pressing movement using a pneumatic resistance machine at different % one-repetition max (1RM). From that, maximum power achieved during 5-repetitions at 40% 1RM and 70% 1RM was recorded. The current study used 1 ballistic repetition (throw) in a horizontal pressing motion with a weight that was held constant across all participants. From that, averages from three test trials were recorded for throw distance, average power from Tendo, and peak power from Tendo. These two protocols differ in movement mechanics, primary muscle groups utilized, and explosive intent of the movement. While a horizontal pressing movement is more prevalent in the literature for assessing UBMP, these results suggest a downward pressing movement may potentially be more related to physical function and activities of daily living (e.g. pushing to get up from a chair). Future studies should look to compare different tests of UBMP against functional outcomes. Second, the previous study assessed physical function with a timed stair climb, the SPPB, and the timed 4-meter walk from SPPB separately. Interestingly, ascending stairs as quickly as possible has been used elsewhere as a measure of lower body muscular power (Bean et al., 2002; Bean et al., 2007; M Gray & S Paulson, 2014). Unsurprisingly, in the previous study, measures of power were most closely associated with the timed stair climb. The SPPB consists of three tests assessing standing balance, 5-repetition chair stand, and a timed 4-meter walk. The outcome measure of function is an aggregate score based on performance of all three tests. This may reflect a more global measure of function than analyzing each component separately. In comparison, the Senior Fitness Test is comprised of 6 tests that, together, account for a broader range of physical characteristics underlying function. In the present study, analysis was performed with each test individually, which may explain the weaker association to muscular power. Comparing UBMP to overall functional ability as a combined measure may illicit a stronger relationship, as seen previously with the SPPB.

The Senior Fitness Test was developed to capture latent physical characteristics (muscular strength/endurance, aerobic endurance, power, etc) that precede and underly physical function needed for activities of daily living (Rikli & Jones, 1999). The test items, while similar to these basic functional movements, were carefully designed to reflect changes in their related physical characteristics (e.g. 30-sec sit-to-stand assesses lower body muscular strength, not the ability to rise from a chair). In the model used to explain this relationship, muscular power is categorized as a physical characteristic just like muscular strength and endurance, therefore, UBMP falls within the same category as the test items (Figure 1). Due to the principle of specificity, the low association seen between UBMP and many of the measures of function may be due to the large differences between those physical characteristics (e.g. upper body power vs lower body flexibility). Muscular power has been shown to be a strong predictor of physical function and disability (Cuoco et al., 2004; Sayers et al., 2005; Suzuki et al., 2001), however its relationship to each of the other physical characteristics captured by the SFT is less clear. In other words, the relationship between physical characteristics and related function abilities may be stronger than the relationship between the physical characteristics themselves. This also highlights the Arm Curl test, the SFT measure of upper body strength, which demonstrated a weak relationship to UBMP. The Arm Curl test involves a 30-second bout of as many repetitions as possible with a relatively light weight. By the principle of specificity, this is largely a test of upper body muscular endurance, not strength. This may explain the weaker relationship with UBMP seen for Arm Curl (r = .22 - .38) compared to Hand Grip (r = .58 - .87), which involves a 3-second maximal isometric contraction. Therefore, a limitation of the present study's design was the conceptual nature of the testing items selected to examine physical function, which by design are assessments of physical characteristics that precede physical function.

Other explanations for these results may be due to sampling. First, it is known that muscular power decreases sooner and more rapidly than other physical characteristics related to function, such as strength (Izquierdo et al., 1999; Metter et al., 1997; Skelton et al., 1994). This study's sample was relatively young (mean age = 60.52 years), as in the literature older adults are often categorized as 65 years and older. With muscular power declining sooner and more noticeably, a younger sample could show decrements in power with less pronounced changes in function. Second, this study sampled from a pool of relatively active older adults with a high level of fitness. Mean performance values for nearly every SFT item were substantially higher than proposed fitness standards based on normative data from a sample of over 2000 participants (Rikli & Jones, 2013). Additionally, many participants of this study reported engaging in regular physical activity comprised of walking, biking, yoga, pilates, etc. Many of the types of activities mentioned by the participants were conducive to improving aerobic and muscular endurance. It's not surprising that performance in these measures might reflect these activities, whereas power-based activity may be less common among this population. Further research is needed with a more diverse sample in regard to age and functional ability.

Conclusion

In the present study, UBMP as measured by a medicine ball throw was found to be a significant predictor of upper body measures of physical function in healthy older adults. The relationship between UBMP and overall physical function is less clear. The present study examined a relatively younger sample of older adults with a high level of functional ability. This was the first study of its kind to compare UBMP measured by a medicine ball throw against objective measures of overall physical function. The relatively weak association between UBMP and other measures of physical function besides those of the upper body could reflect issues with the testing protocol, the validity of the comparison of chosen tests, or the sampling of the study. More research is needed to determine the most appropriate test of UBMP and method of comparing to overall physical function. Additionally, this relationship should be explored in a more diverse sample with regard to age and functional ability.

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Appendix

UNIVERSITY OF ARKANSAS

To:	Michelle Gray
From:	Douglas J Adams, Chair IRB Full Board
Date:	12/08/2022
Action:	**Approval**
Action Date:	12/08/2022
Protocol #:	2207411325
Study Title:	Muscular power and physical function: The Power Aging study
Expiration Date:	08/21/2023
Last Approval Date:	
Risk Level:	

The above-referenced protocol has been approved following Full Board Review by the IRB Committee that oversees research with human subjects.

If the research involves collaboration with another institution then the research cannot commence until the Committee receives written notification of approval from the collaborating institution's IRB.

It is the Principal Investigator's responsibility to obtain review and continued approval before the expiration date.

Protocols are approved for a maximum period of one year. You may not continue any research activity beyond the expiration date without Committee approval. Please submit continuation requests early enough to allow sufficient time for review. Failure to receive approval for continuation before the expiration date will result in the automatic suspension of the approval of this protocol. Information collected following suspension is unapproved research and cannot be reported or published as research data. If you do not wish continued approval, please notify the Committee of the study closure.

Adverse Events: Any serious or unexpected adverse event must be reported to the IRB Committee within 48 hours. All other adverse events should be reported within 10 working days.

Amendments: If you wish to change any aspect of this study, such as the procedures, the consent forms, study personnel, or number of participants, please submit an amendment to the IRB. All changes must be approved by the IRB Committee before they can be initiated.

You must maintain a research file for at least 3 years after completion of the study. This file should include all correspondence with the IRB Committee, original signed consent forms, and study data.

cc: Anthony Campitelli, Key Personnel
Jordan Stroope, Key Personnel
Cody Diehl, Key Personnel
Jenna Kempkes, Key Personnel
Ray Urbina, Key Personnel
Rhayko Emanual Schwartz, Key Personnel
Kennedy Higgins, Key Personnel
Kelsey Carraway, Key Personnel
Katelyn Helberg, Key Personnel
Megan Danielle Jones, Key Personnel
Muhannad Abdin, Key Personnel
Ashlyn Jendro, Key Personnel