THE EFFECT OF FUNCTIONAL EXERCISE TRAINING ON PHYSICAL FUNCTION ASSESSED USING THE FUNCTIONAL MOVEMENT SCREEN IN MIDDLE-AGED POSTMENOPAUSAL WOMEN

by

LAUREN PETERSON

(Under the Direction of Ellen Evans)

ABSTRACT

Several assessments of physical function have been developed for use in older adult populations; however, these tools lack sensitivity and normative values to measure physical function in the middle-aged cohort. The Functional Movement Screen (FMS) may provide a solution to address this need. Postmenopausal women (N=18; 55.7 ± 2.8 years) were randomized based on age and body mass index (BMI) to a 10 week functional exercise training intervention group (N=11, 55.? ± 2.4 years) or non-exercise control group (N=7, 56.9 ± 3.1 years) and were assessed for body composition, physical function via FMS, muscle strength, leg power, and muscle quality (MQ). No significant differences in changes in muscle capacity, MQ, FMS composite scores, or physical function assessments between groups were detected. Moderate correlations were observed between change in FMS composite score and change in muscle power, MQ strength, MQ power, Transfer Task, and 30-second chair stand.

INDEX WORDS: Physical Function, Functional Movement Screen, Postmenopausal

The Effect of Functional Exercise Training on Physical Function Assessed using the Functional Movement Screen in Middle-Aged Postmenopausal Women

by

Lauren Q. Peterson

B.S., Miami University 2012

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTERS OF SCIENCE

ATHENS, GEORGIA

2014

THE EFFECT OF FUNCTIONAL EXERCISE TRAINING ON PHYSICAL FUNCTION ASSESSED USING THE FUNCTIONAL MOVEMENT SCREEN IN MIDDLE-AGED POSTMENOPAUSAL WOMEN

By

LAUREN QUINN PETERSON

Major Professor: Ellen M. Evans
Committee: Patrick J. O'Connor
Michael D. Schmidt
Jennifer L. Gay
Bhibha M. Das

Electronic Version Approved:

Julie Coffield
Associate Dean of the Graduate School
The University of Georgia
August 2014

ACKNOWLEDGEMENTS

I would like to thank my family for their continual love and support throughout this process. Dad, Mom, Andrew, Kerri, Uncle Scott, Aunt Monica, Austin, and Madison, thank you for encouraging me to pursue the passions God has placed on my heart, and for reminding me of my true purpose in life.

My mentor, Dr. Ellen Evans, thank you for your support and guidance throughout my master's program. You have encouraged and helped me to grow as a student and a person.

My friend and mentor, Dr. Christie Ward-Ritacco, thank you for your guidance, advice and encouragement throughout this process. Thank you for taking the time to help mold me as a student, researcher, and writer.

Thank you to Dr. O'Connor, Dr. Schmidt, Dr. Gay, and Dr. Das for serving on my committee. I appreciate your investment in this project.

Thank you to Jeremy Dean, Corey Funk, Simon Higgins, and Brad David for your help in the execution of this project. I greatly appreciate all of your time and efforts.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Significance

The aging process is associated with decreased levels of physical activity (PA) and adverse changes in body composition, including increased total fat mass and reductions in muscle mass, contributing to decreased muscle capacity (i.e. muscle strength, power, etc.) and quality (i.e. capacity relative to lean mass) and physical functional ability [1-5]. Due to physiological changes occurring during the menopausal transition, postmenopausal women (PMW) are at an increased risk for physical functional impairment and disability compared to their male counterparts, a health disparity that is evident in the middle-age cohort [6-8]. In addition, previous research has linked the experience of pain to physical functional impairment and disability in middle-aged women [9-13]. While it is well established that greater levels of PA and exercise (EX) are positively correlated with physical functional ability and negatively correlated with pain, what is less established in the middle-aged cohort is the effectiveness of recently developed functional EX training programs designed to improve physical function, in addition to improving muscle capacity and muscle quality (MQ) [14-20].

A related issue in the middle-aged cohort is the lack of sensitive tools currently available to measure physical function and a dearth of normative values for this population [21]. The contemporary Functional Movement Screen (FMS) may provide an adequate solution to address this need. In an effort to consider both pain and function together, FMS was developed to serve as a tool for injury risk management and assessment of functional movement patterns in highly functioning individuals [21]. However, as FMS was originally developed for use with young, athletic populations, additional research is needed to establish the sensitivity of FMS for measuring physical function in middle-aged adults and more work with this age group is necessary to develop normative FMS values for the middle-aged cohort. It is especially relevant to evaluate this technique in women, as they are known to be at higher risk for physical disability compared to men in late life [22, 23]. The associations among body composition, muscle capacity, MQ, physical function, and the relative effectiveness of EX interventions to positively influence physical function in the middle-aged PMW (MA-PMW) are not well characterized in the literature due to the following: 1) the majority of available studies which examine body composition and muscle capacity and their influence on physical function focus on older populations, 2) self-report measures are most often used to assess both PA and physical function, and 3) the physical performance tools/measures commonly used to assess physical function in the MA-PMW population may lack sensitivity or exhibit floor/ceiling effects if originally developed for older adults. To improve functional status in middle-aged women and to prevent physical disability in late age, effective, multi-modal EX interventions, focused on improving the determinants of physical function are needed.

In this context, the objectives of this study were to determine the efficacy of a functional exercise training program to enhance muscle capacity, MQ, and physical functional ability measured using FMS, and the strength of the associations among the changes in muscle and functional outcomes. In addition to the well- established relationship between PA/EX and physical functional ability, pain has also been associated with decreased functional ability [24]; therefore, an additional secondary objective was to explore the prevalence of pain reporting and its potential influence on composite and individual FMS test scores. The specific primary and secondary aims of this investigation were as follows.

1.2 Specific Aims and Hypothesis

Specific Aim 1: To determine the effects of a 10-week functional exercise training intervention (EX) on muscle capacity, MQ, and physical functional ability measured using the FMS in MA-PMW compared to a non-exercise control group (CON). It is hypothesized that in response to the intervention, the EX group will have greater improvements in muscle capacity, MQ and physical functional ability, as measured by FMS, when compared to CON.

Specific Aim 2: To determine the strength of the relationship between change in FMS score and change in muscle capacity, MQ, and traditional measures of physical function. It is hypothesized that changes in FMS will be significantly related to changes in muscle capacity, MQ, and to conventional measures of physical function.

1.3 Secondary Aim

Secondary Aim 1: To explore the prevalence of pain reporting in the study cohort and evaluate if: 1) pre-existing pain influences composite FMS test scores, and 2) if reported pain and RPE change in response to the PA/EX intervention.

1.4 Public Health Significance

The intersection of the aging U.S. population, with the currently high prevalence of obesity and physical inactivity, creates a complex challenge for longevity and disability prevention, as obesity and physical inactivity have been linked to loss of physical functional ability and increased risk for physical disability [3, 5, 25, 26]. Recent data indicates that late-life disability is increasing among younger generations moving into older adulthood when compared to previous generations [25, 27]. Two cross-sectional waves (1988-1994 and 1999-2004) of the National Health and Nutrition Examination Survey found that activities of daily living (ADL) disability, instrumental activities of daily living (IADL) disability, and impaired mobility increased significantly among respondents aged 60 to 69 years in the more recent survey period compared to the previous [27]. In addition, when comparing the latter wave to the earlier wave, respondents aged 70 to 79 years, reported a significant increase in IADL disability, while respondents aged 80 years and older reported a non-significant decrease in IADL, suggesting that younger cohorts are becoming less physically functional [27].

Menopause, characterized by a decline in estrogen levels, has been linked to unfavorable changes in body composition, including increased total fat mass and central adiposity, and decreased muscle mass and muscle strength [6, 7, 28, 29]. Additionally, compared to younger age cohorts, PMW report lower levels of PA and EX, and an increased experience of pain [9, 10, 30]. In the literature, the positive relationship between PA and EX and physical function and the negative relationship between the experience of pain and physical function are well established [9-12, 31]. The physical manifestations of menopause, coupled with PMW reporting less PA and EX, greater experience of pain, and poorer physical function compared to males in the same age cohort, presents a need for preventative interventions for middle-aged women [4].

Exercise interventions including aerobic, resistance, and combined aerobic and resistance training have been shown to improve physical function performance, muscle capacity and MQ in older adults [15-20, 32]; however, these relationships are relatively unstudied in MA-PMW. In addition, while traditional exercise interventions address physical function as the ability to move or complete a task, they neglect to address the quality of the movement. The basis of functional exercise training is to improve the quality of fundamental movement patterns by improving mobility and stability, reducing asymmetries, and restoring the body system to balance, with the goal of long-term functional success and injury prevention. Recent research has examined the efficacy of functional exercise training to improve balance, coordination, muscular force, power, and endurance, in addition to improving physical functional ability in middle-aged men and women and middle-aged, active duty military personnel [33, 34]. Both studies observed that functional exercise training was successful in improving functional capacity in these cohorts. Though initial results are promising, further research is needed to determine the efficacy of functional exercise training to preserve or enhance muscle capacity and physical function ability in PMW.

The lack of literature regarding physical function in MA-PMW may be in part due to inadequate measures of functional ability for the middle-aged adult population. While many assessments are available for the measurement of the functional status of older adult populations, there is a lack of normative values and data on the sensitivity of these assessments to measure the increased functional capacity of the middle-aged adult population. The contemporary FMS may provide a potential alternative for measuring functional status in the middle-aged cohort [22, 23]. A limited number of studies have examined functional status in the middle-aged population using FMS [33, 34]; therefore, further research is needed to establish normative values and assess the sensitivity of FMS to detect changes in function in middle-aged cohorts.

The present study will add to the literature for MA-PMW regarding the efficacy of a 10-week functional exercise intervention for improving muscle capacity, MQ, and physical function measured using the FMS. Importantly, the strength of the relationships between muscle capacity, MQ, and physical function will be assessed, especially with regard to change. Moreover, the present study will control for age and BMI, both known correlates of physical function, when investigating the relationships between muscle capacity, MQ, and physical function at baseline and following a 10-week functional exercise intervention.

1.5 References

1. Delmonico MJ, Harris TB, Visser M, Park SW, Conroy MB, Velasquez-Mieyer P, et al. Longitudinal study of muscle strength, quality, and adipose tissue infiltration. The American Journal of Clinical Nutrition. 2009;90(6):1579-85. doi: 10.3945/ajcn.2009.28047. PubMed PMID: 19864405; PubMed Central PMCID: PMC2777469.

2. Kamel HK. Sarcopenia and aging. Nutrition Reviews. 2003;61(5):157. PubMed PMID: 9846166.

3. He XZ, Baker DW. Body mass index, physical activity, and the risk of decline in overall health and physical functioning in late middle age. American Journal of Public Health. 2004;94(9):1567-73.

4. Prevalence of physical activity, including lifestyle activities among adults-United States, 2000-2001. MMWR Morbidity and mortality weekly report. 2003;52(32):764-9. Epub 2003/08/15. PubMed PMID: 12917582.

5. O'Brien AE, Evans EM. Physical activity, adiposity, and muscle quality: impacts on physical function in BMI and age- matched older men and women. Journal of Aging and Physical Activity. 2012;20:pS182-pS3. PubMed PMID: 000307433500313.

6. Aloia JF, Ross P, Cohn SH, McGowan DM, Vaswani AN. Relationship of menopause to skeletal and muscle mass. American Journal of Clinical Nutrition. 1991;53(6):1378-83. PubMed PMID: FNI91002803 Pagination: p. 1378-83. Identifiers: total body potassium.

7. Messier V, Rabasa-Lhoret R, Barbat-Artigas S, Elisha B, Karelis AD, Aubertin-Leheudre M. Menopause and sarcopenia: a potential role for sex hormones. Maturitas. 2011;68(4):331-6. doi: http://dx.doi.org/10.1016/j.maturitas.2011.01.014.

8. Sowers M, Pope S, Welch G, Sternfeld B, Albrecht G. Association of menopause and physical functioning in women at midlife. Journal of the American Geriatrics Society. 2001;49(11):1485-92.

9. Dugan SA, Powell LH, Kravitz HM, Everson Rose SA, Karavolos K, Luborsky J. Musculoskeletal pain and menopausal status. Clin J Pain. 2006;22(4):325-31. Epub 2006/05/13. doi: 10.1097/01.ajp.0000208249.07949.d5. PubMed PMID: 16691084.

10. Dugan SA, Everson-Rose SA, Karavolos K, Sternfeld B, Wesley D, Powell LH. The impact of physical activity level on SF-36 role-physical and bodily pain indices in midlife women. Journal of Physical Activity & Health. 2009;6(1):33-42. Epub 2009/02/13. PubMed PMID: 19211956; PubMed Central PMCID: PMCPmc3143463.

11. Vogt MT, Lauerman WC, Chirumbole M, Kuller LH. A community-based study of postmenopausal white women with back and leg pain: health status and limitations in physical activity. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences. 2002;57(8):M544-M50. doi: 10.1093/gerona/57.8.M544.

12. Cassidy JD, Cote P, Carroll LJ, Kristman V. Incidence and course of low back pain episodes in the general population. Spine. 2005;30(24):2817-23. Epub 2005/12/24. PubMed PMID: 16371911.

13. Frymoyer JW, Cats-Baril WL. An overview of the incidences and costs of low back pain. The Orthopedic clinics of North America. 1991;22(2):263-71. Epub 1991/04/01. PubMed PMID: 1826550.

14. Ward-Ritacco CL, Adrian AL, Johnson MA, Rogers LQ, Evans EM. Adiposity, physical activity, and muscle quality are independently related to physical function performance in middle-aged postmenopausal women. Menopause. 2014;Publish Ahead of Print:10.1097/GME.0000000000000225.

15. Straight CR, Dorfman LR, Cottell KE, Krol JM, Lofgren IE, Delmonico MJ. Effects of resistance training and dietary changes on physical function and body composition in overweight and obese older adults. Journal of Physical Activity & Health. 2012;9(6):875-83. PubMed PMID: 79553220.

16. Holviala JHS, Sallinen JM, Kraemer WJ, Alen MJ, Häkkinen KT. Effects of strength training on muscle strength characteristics, functional capabilites, and balance in middle-aged and older women. Journal of Strength & Conditioning Research 2006;20(2):336-44. PubMed PMID: 20970936.

17. Latham NK, Bennett DA, Stretton CM, Anderson CS. Systematic review of progressive resistance strength training in older adults. The journals of gerontology Series A, Biological sciences and Medical Sciences. 2004;59(1):48-61. Epub 2004/01/14. PubMed PMID: 14718486.

18. Lohne-Seiler H, Torstveit MK, Anderssen SA. Traditional versus functional strength training: effects on muscle strength and power in the elderly. Journal of Aging and Physical Activity. 2013;21(1):51-70.

19. Miszko TA, Cress ME, Slade JM, Covey CJ, Agrawal SK, Doerr CE. Effect of strength and power training on physical function in community-dwelling older adults. The Journals of Gerontology Series A, Biological Sciences and Medical Sciences. 2003;58(2):171-5. Epub 2003/02/15. PubMed PMID: 12586856.

20. Seguin R, Nelson ME. The benefits of strength training for older adults. Am J Prev Med. 2003;25(3 Suppl 2):141-9. Epub 2003/10/14. PubMed PMID: 14552938.

21. Cook G, Burton, L, Kiesel, K, Rose, G, Bryant, MF Movement: Functional Movement Systems. Aptos, BA: On Target Publications; 2010. 407 p.

22. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function - part 2. North American Journal of Sports Physical Therapy. 2006;1(3):132-9.

23. Cook G. Pre-participation screening: the use of fundamental movements as an assessment of function - part 1. North American Journal of Sports Physical Therapy. 2006;1(2):62.

24. Fowler Brown A. The mediating effect of chronic pain on the relationship between obesity and physical function and disability in older adults. Journal of the American Geriatrics Society. 2013;61(12):2079-86.

25. Lakdawalla DN, Bhattacharya J, Goldman DP. Are the young becoming more disabled. Health Affairs (Project Hope). 2004;23(1):168-76. PubMed PMID: 15002639.

26. Ward CL, Valentine RJ, Evans EM. Physical function is impacted more by adiposity than physical activity or lean mass in community-dwelling older adults. Journal of Aging and Physical Activity. 2013;22(2):284-93. Epub 2013/06/27. PubMed PMID: 23799829.

27. Seeman TE, Merkin SS, Crimmins EM, Karlamangla AS. Disability trends among older americans: national health and nutrition examination surveys, 1988--1994 and 1999--2004. American Journal of Public Health. 2010;100(1):100-7. PubMed PMID: 47519619.

28. Davis SR, Castelo-Branco C, Chedraui P, Lumsden MA, Nappi RE, Shah D, et al. Understanding weight gain at menopause. Climacteric: The Journal Of The International Menopause Society. 2012;15(5):419-29. doi: 10.3109/13697137.2012.707385. PubMed PMID: 22978257.

29. Wildman RP, Tepper PG, Crawford S, Finkelstein JS, Sutton-Tyrrell K, Thurston RC, et al. Do changes in sex steroid hormones precede or follow increases in body weight during the menopause transition? results from the study of women's health across the nation. Clin Endocrinol Metab. 2012; 97(9):1695-704.doi: 10.1210/jc.2012-1614.

30. Sims ST, Kubo J, Desai M, Bea J, Beasley JM, Manson JE, et al. Changes in physical activity and body composition in postmenopausal women over time. Medicine and Science in Sports and Exercise. 2013;45(8):1486-92. Epub 2013/02/27. doi: 10.1249/MSS.0b013e31828af8bd. PubMed PMID: 23439422; PubMed Central PMCID: PMCPmc3715578.

31. Puetz T. Physical activity and feelings of wnergy and fatigue: epidemiological evidence. Sports Medicine. 2006;36(9):767-80. PubMed PMID: 22173048.

32. Gudlaugsson J, Gudnason V, Aspelund T, Siggeirsdottir K, Olafsdottir AS, Jonsson PV, et al. Effects of a 6-month multimodal training intervention on retention of functional fitness in older adults: a randomized-controlled cross-over design. The International Journal of Behavioral Nutrition and Physical Activity. 2012;9:107. Epub 2012/09/12. doi: 10.1186/1479-5868-9-107. PubMed PMID: 22963328; PubMed Central PMCID: PMCPmc3522556.

33. Pacheco MM, Teixeira LA, Franchini E, Takito MY. Functional vs. strength training in adults: specific needs define the best intervention. Int J Sports Phys Ther. 2013;8(1):34-43. Epub 2013/02/27. PubMed PMID: 23439782; PubMed Central PMCID: PMCPmc3578432.

34. Peterson LQ, Evans, EM, Kennedy-Armbruster, C. Exercise training improves functional movements screen (FMS) in 40+ year-old active duty military personnel. [Abstract]. Forthcoming 2014.

CHAPTER 2

LITERATURE REVIEW

2.1 Physical Function: Body Composition and Physical Activity Determinants in Middle-Aged Postmenopausal Women

The gradual decline of skeletal muscle mass and strength associated with aging is known as sarcopenia [1]. Factors that may account for this include a decreased proportion of type II muscle fibers, increased connective tissue, fatty infiltration of the muscle, and altered muscle metabolism [2, 3]. Androgens act as anabolic agents contributing to increased muscle mass, MQ, and subsequently, physical functional ability [4]. The menopause associated decline in estrogen has been linked to unfavorable changes in body composition, including increased total fat mass and central adiposity, and decreased muscle mass and MQ [2, 4-7]. While decreased muscle mass and quality, and subsequent changes in physical function could be partially explained by the decline in estrogen levels, decreased skeletal muscle mass and strength following menopause may also be due in part to increased levels of pro-inflammatory cytokines, such as tumor necrosis factor alpha (TNF-α) and interleukin-6 (IL-6), and reductions in androgens such as bio-available testosterone, and decreased levels of the pro-hormone dehydropiandrosterone (DHEA) [2, 4, 5].

In addition to physiological factors affecting the loss of muscle mass and strength, behavioral factors including PA and EX are also important contributors to body composition, muscle capacity, and MQ, all of which influence physical functional ability. The recent eight year longitudinal Women's Health Study reported that women ages 50-59 years at baseline who reported moderate (>500 to 1200 MET•min•week^{-1}) and high (>1200 MET•min•week^{-1}) levels of physical activity had significantly less weight gain compared to sedentary women (≤100 MET•min•week^{-1}), who reported significantly less PA [8]. Previous research with older adults has determined that lower levels of PA, higher adiposity (%Fat), and lower levels of lean mass, muscle capacity, and MQ are associated with poorer functional performance [9, 10]. These findings are a composite of a large literature examining the relationships between PA and EX, muscle strength and power, body composition, and functional decline in older adults [9, 11, 12].

However, little research has explored the independent and interactive relationships among muscle performance, body composition and physical function variables in MA-PMW. A recent study by Ward-Ritacco et al. [13] examining physical functional ability in MA-PMW, found significant associations between lower levels of adiposity, higher daily levels of both total PA and minutes of moderate to vigorous PA (MVPA), and better functional performance. These findings also suggest that MQ independently influences physical functional ability. Upper leg MQ, calculated using isokinetic strength of the quadriceps and hamstrings normalized for lean mass is important for functional tasks requiring endurance, and MQ calculated using leg extension power is most essential for tasks requiring speed and agility [13]. If physical functional limitations are increasing due to reductions in PA and adverse changes in body composition and muscle capacity, and subsequently MQ, in the middle-aged female population, the rate of disability may also increase at an earlier age. This in turn will not only influence life expectancy, but also quality of life, for aging populations, especially women.

2.2 Functional Fitness: Improving Physical Functional Ability

Progressive resistance training interventions in older adults have demonstrated that strength, body composition, and physical function can be improved, suggesting that particular aspects of MQ are modifiable in aging populations [12, 14, 15]. The most recent American College of Sports Medicine position statement for exercise training includes a new category, neuromotor exercise training (often referred to as functional training), defined as the use of strength training to improve balance, coordination, force, power, and endurance to improve an individual's ability to complete activities of daily living [16, 17]. Functional training is an important component of efforts targeted at improving physical function outcomes and quality of life. This type of training may be especially important for middle-aged adults, as EX of this type may be important to prevent physical disability commonly associated with the aging process.

Different training methods (i.e. conventional strength training vs. functional training) have been examined for their effectiveness in improving physical function outcomes, but the evidence for the efficacy of one method versus the other is still equivocal [18-20]. In addition, the majority of intervention studies recruit older adult populations, disregarding the need for prevention of physical function decline in the middle-aged population. This focus may also align with the lack of proper functional assessments for middle-aged populations. Several assessments have been developed to examine physical functional ability in older adults, but when used to measure functional ability in the middle-aged adult population, these assessments fail to take into account the increased functional capacity of the middle-aged adult compared to the older adult cohort. Therefore, these assessments potentially lack the ability to sufficiently assess the functional status of the population due to floor/ceiling effects and the use of self-report questionnaires. Furthermore, current studies in the area of functional training have negated the importance of muscle strength and power for functional fitness and have not obtained an objective measure of these variables; therefore, have been unable to account for their potential role in subsequent increases or improvements in physical function [21-23].

2.3 Functional Movement Screen: An Assessment Tool for Middle-Aged Adults?

A potential alternative to testing middle-aged adults with a conventional battery of tests designed to assess physical function in older adults is the use of the contemporary FMS assessment [24, 25]. FMS is an easily administered, low resource use, non-invasive test developed to assess overall fundamental movement patterns, physical preparedness, and injury risk prior to participation in a wide variety of activities [24, 25]. FMS is comprised of 7 component tests designed to identify physical weakness and asymmetries between the right and left sides, affecting the fundamental movement patterns that potentially influence injury risk. The 7 tests include: the deep squat, hurdle step, inline lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability. Each test is scored on a 0 to 3 ordinal scale. A score of 3 is awarded with perfect execution of the movement, a score of 2 is awarded if any compensation occurs during the movement but the movement is completed, a score of 1 is awarded if the participant is unable to complete the movement, and a score of 0 is awarded if pain is experienced with the movement. Five of the 7 movements are scored unilaterally. In the case that the right and left sides are scored differently, the lowest of the two scores is used to achieve the composite score or the sum of scores for the 7 individual movements. Three tests (shoulder mobility, trunk stability push-up, and rotary stability) have additional clearing screens that are scored as positive or negative. The clearing movements only consider pain, such that if pain is experienced with the movement the test is scored positive and if there is no pain with the movement the test is scored negative. If a positive score is received for a clearing test, the associated FMS test will automatically be scored zero. The highest achievable composite score for all 7 FMS tests is 21.

FMS was originally developed as a pre-participation screening for young, athletic populations under the premise that in order for an athlete to perform optimally, they must first possess the ability to complete fundamental movement patterns adequately without pain or asymmetry [24, 25]. Preliminary studies with FMS attempted to examine the relationship between FMS scores and injury risk in young athletic cohorts [26-30]. Kiesel et al. [29] obtained FMS scores for 46 National Football League players prior to the start of the season, and players with a composite score of ≤ 14 were 11.7 times more likely to sustain a serious injury during the season. Kiesel et al. [29] also noted lower scores among those who had experienced previous injury (14.3± 2.3) compared to those without previous injury (17.4 ± 3.1). The evidence for the relationship between FMS composite score ≤14 and injury prediction is still equivocal. Chorba et al.[28] and O’Connor et al. [30] observed that a score of ≤ 14 was significantly associated with injury in female collegiate athletes and military officer candidates [28]. Alternatively, two groups have reported that FMS scores were unrelated to injury rate in a group of 60 marathon runners, and 122 basketball athletes [26, 27].

While FMS was originally developed for use in young, athletic cohorts, recent research has examined the use of FMS for assessment of functional movement of middle-aged adults [31]. Perry and Koehle [31] sought to provide normative reference values for FMS in healthy, middle aged adults by testing six age groups of adults (20-39 yrs., n=53; 40-49 yrs., n=102; 50-54 yrs., n=68; 55-59yrs., n=72; 60-64yrs., n=50; 65+yrs., n=50,) [31]. They found that for all groups, higher levels of EX participation were associated with higher FMS scores, whereas, greater age was associated with lower FMS scores [31]. In addition, for all groups significant differences were found between individuals with high BMI values (>30 kg/m^2) compared to overweight (25-29.9 kg/m^2) or normal BMI values (18.6-24.9 kg/m^2), such that those in the obese group had significantly lower scores than those who were normal or overweight (gender was not controlled for in the analysis) [31]. These results parallel recent data collected on active duty military personnel over 40 years of age [32] which determined that greater upper body strength, as well as decreased waist circumference, were significantly associated with better total FMS score [32].

Two recent studies have examined the effectiveness of an exercise intervention for improving physical function measured by FMS in middle-aged and older adult cohorts [23, 33]. Pacheco and colleagues [23] compared 12 weeks of conventional strength training (i.e. weight training) with 12 weeks of functional strength training (i.e. body weight resistance) in their ability to improve physical function in 56 women (age: 53.55 ± 7.95 years) and 45 men (age: 56.24 ± 9.71 years). Both interventions led to physical function improvements with no significant differences found between the two training programs in effectiveness [23]. In addition, FMS scores for men and women differed significantly in the functional group, with men recording higher scores [23] . However, they did not control for BMI or PA/EX prior to enrollment (i.e. did not recruit sedentary participants), and groups were not matched based on BMI or baseline level of PA/EX. Due to the well-established relationships between BMI, PA/EX, and physical functional ability, not controlling for BMI or activity level may have influenced the results [11, 13, 23, 34]. Additionally, recent data reported in abstract form, examined the efficacy of the Senior Health Assessment Program Enterprise (SHAPE) program, a 3 month, multi-modal exercise intervention, for improving FMS scores in middle-aged active duty military personnel (n=332, 44.5±3.8y, 84% male) [33]. In this cohort, FMS composite score improved 18% (13±2.5, vs 15.4±2.4, p<.001) from baseline to post-training; however, the change was not related to age (r=0.04, p=.50), and was identical in men and women (2.3±2.2 vs 2.3±2.1, p=.91) [33]. Differences in scores between the left and right sides at baseline (i.e. asymmetry) were also examined and significant improvements occurred (all p<.001) in Hurdle Step (n=46), Inline Lunge (n=64), Shoulder Mobility (n=113), and Active Straight Leg Raise (n=57) [33]. Relatedly, Teyhen et al. [35] examined the interrater and intrarater reliability of FMS in middle-aged, active duty military personnel when FMS was assessed by novice raters. After calculating inter-class correlation coefficients of 0.76 and 0.74 for interrater and intrarater reliability, respectively, it was concluded that FMS has moderate to strong reliability when used with healthy, middle-aged military personnel. More research is needed to further establish normative reference values and to evaluate the utility of the FMS to assess physical function, especially in the middle-aged population [35].

2.4 Effect of Pain and Exertion Ratings on Functional Movement Screen Outcomes

Pathologies resulting in pain may lead to disability, as models of disablement from Nagi and other researchers [36-38] include the role of pathology and pain leading to functional limitations and disability. The Disease Handicap Model depicts a pathway of disablement from pathology to impairment (loss of physical attribute) to functional limitation (loss of ability to perform tasks required for daily living) to disability (loss of physical ability) [36]. Additionally, the World Health Organization Model of Disability includes the following stages: pathology, impairment, disability, and handicap [36].

Pain can affect various aspects of quality of life, including functional status [37]. Previous research has linked pain to physical functional impairment and occupational disability in middle-aged women [39, 40]. In a cross-sectional analyses of participants in the Study of Women Across the Nation, (SWAN), self-reported pain was significantly greater for PMW compared to premenopausal women after adjusting for socioeconomic status, medical issues (osteoarthritis, use of pain medications, and number of live births), depression (CES-D score), smoking, and BMI [41]. Furthermore, in a cross-sectional study of Caucasian MA-PMW, 49% of participants reported low back pain, with 41% of the participants also reporting leg pain. Participants reporting back and leg pain had lower scores on the Medical Outcomes Short-Form 36 (SF-36) role physical, physical function, and bodily pain components compared to participants without pain [39]. Furthermore, low back pain has been reported as the leading cause of occupational disability in individuals 45 years of age and older, with women reporting low back pain more often than their male counterparts [40, 42]. Finally, in an additional analysis of the SWAN participants, higher levels of PA was associated with a 7% greater likelihood of high SF-36 role-physical score (95% CI = 1.02-1.14) and a 10% greater likelihood of a low SF-36 bodily pain score (95% CI = 1.04-1.17) after adjusting for age, ethnicity, menopausal status, educational level, BMI, depression, smoking, and medical issues [43]. The link between pain and disability, and the positive impact of PA on pain, suggests the importance of pain assessment and the development of proper PA/EX interventions to slow the progression of the disablement model.

The experience of pain is subjective and cannot be directly observed; therefore, assessment of pain is based on self-report [44]. Two of the most commonly measured aspects of pain are pain location and pain intensity [45]. Previous research suggests pain location drawings be used to assess location of bodily pain, where participants are asked to shade on a diagram areas of their body that are in pain [46]. The total number of shaded areas on the pain locations diagram has been associated with additional aspects of pain, such as medication use and time spent being physically inactive [44]. Recommended to assess pain intensity is the 11-point Numerical Graphical Rating scale, with "0" representing "no pain" and "10" representing the "highest possible pain" [45]. In regards to the FMS assessment, the rating of "0", when pain is experienced during the execution of the FMS test, does not take into consideration chronic pain present prior to execution of the movement screen or the location or intensity of pain experienced during the screen. Additional research is needed to evaluate the influence of pain on the FMS scoring system. Specifically, research is needed to determine if chronic pain (location and intensity) influences composite and/or individual movement test scores.

2.5 Summary

Aging is associated with adverse changes in PA and body composition, including reductions in lean mass and increased total fat mass. Improved body composition and higher levels of PA/EX are associated with improved physical functional ability. MA-PMW are at an increased risk for physical disability due to trends of poor body composition and low levels of PA/EX. Although several assessments exist to measure physical functional capacity in the older adult cohort, they lack sensitivity to assess functional status in the middle-aged population and there are few studies available to establish normative values. The FMS may provide a sufficient alternative to assess physical function in the middle-aged cohort; however, further study is needed to establish the efficacy of this testing modality and normative values for middle-aged individuals. In order to improve late life disability in middle-aged women, there is a need for effective, functional exercise training interventions.

2.6 References

1. Kamel HK. Sarcopenia and aging. Nutrition Reviews. 2003;61(5):157. PubMed PMID: 9846166.

2. Messier V, Rabasa-Lhoret R, Barbat-Artigas S, Elisha B, Karelis AD, Aubertin-Leheudre M. Menopause and sarcopenia: a potential role for sex hormones. Maturitas. 2011;68(4):331-6. doi: http://dx.doi.org/10.1016/j.maturitas.2011.01.014.

3. Visser M, Langlois, J., Guralnik, J.M., et al. Does body composition predict disability in older men and women of the Cardiovascular Health Study? The American Journal of Clinical Nutrition. 1998;68:584-90.

4. Aloia JF, Ross P, Cohn SH, McGowan DM, Vaswani AN. Relationship of menopause to skeletal and muscle mass. American Journal of Clinical Nutrition. 1991;53(6):1378-83. PubMed PMID: FNI91002803.

5. Davis SR, Castelo-Branco C, Chedraui P, Lumsden MA, Nappi RE, Shah D, et al. Understanding weight gain at menopause. Climacteric: The Journal Of The International Menopause Society. 2012;15(5):419-29. doi: 10.3109/13697137.2012.707385. PubMed PMID: 22978257.

6. Wildman RP, Tepper PG, Crawford S, Finkelstein JS, Sutton-Tyrrell K, Thurston RC, et al. Do changes in sex steroid hormones precede or follow increases in body weight during the menopause transition? results from the study of women's health across the nation. Clin Endocrinol Metab. 2012; 97(9): 1695-704. doi: 10.1210/jc.2012-1614.

7. Pollanen E, Sipila S, Alen M, Ronkainen PHA, Ankarberg-Lindgren C, Puolakka J, et al. Differential influence of peripheral and systemic sex steroids on skeletal muscle quality in pre- and postmenopausal women. Aging Cell. 2011;10(4): 650-60. doi: 10.1111/j.1474-9726.2011.00701.x.

8. Sims ST, Kubo J, Desai M, Bea J, Beasley JM, Manson JE, et al. Changes in physical activity and body composition in postmenopausal women over time. Medicine and Science in Sports and Exercise. 2013;45(8):1486-92. Epub 2013/02/27. doi: 10.1249/MSS.0b013e31828af8bd. PubMed PMID: 23439422; PubMed Central PMCID: PMCPmc3715578.

9. Ward CL, Valentine RJ, Evans EM. Physical function is impacted more by adiposity than physical activity or lean mass in community-dwelling older adults. Journal of Aging and Physical Activity. 2013. Epub 2013/06/27. PubMed PMID: 23799829.

10. Valentine RJ, McAuley E, Vieira VJ, Baynard T, Hu L, Evans EM, et al. Sex differences in the relationship between obesity, C-reactive protein, physical activity, depression, sleep quality and fatigue in older adults. Brain, Behavior and Immunity. 2009;23(5):643-8. PubMed PMID: 20093182674.

11. O'Brien AE, Evans EM. Physical activity, adiposity, and muscle quality: impacts on physical function in BMI and age- matched older men and women. Journal of Aging and Physical Activity. 2012;20:pS182-pS3. PubMed PMID: 000307433500313.

12. Straight CR, Dorfman LR, Cottell KE, Krol JM, Lofgren IE, Delmonico MJ. Effects of resistance training and dietary changes on physical function and body composition in overweight and obese older adults. Journal of Physical Activity & Health. 2012;9(6):875-83. PubMed PMID: 79553220.

13. Ward-Ritacco CL, Adrian AL, Johnson MA, Rogers LQ, Evans EM. Adiposity, physical activity, and muscle quality are independently related to physical function performance in middle-aged postmenopausal women. Menopause. 2014;Publish Ahead of Print:10.1097/GME.0000000000000225.

14. Wieser M, Haber P. The effects of systematic resistance training in the elderly. International journal of sports medicine. 2007;28(1):59-65. Epub 2006/06/09. doi: 10.1055/s-2006-924057. PubMed PMID: 16761216.

15. Harris C, DeBeliso MA, Spitzer-Gibson TA, Adams KJ. The effect of resistance-training intensity on strength-gain response in the older adult. Journal of Strength & Conditioning Research (Allen Press Publishing Services Inc). 2004;18(4):833-8. PubMed PMID: 15255977.

16. Garber C, Dlissmer, B, Deschenes, MR, Franklin, BA, Lamonte, MJ, Lee, IM, Nieman, DC, and Swain, DP ACSM Position Stand: Quanitity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: gudance for prescribing exercise. Medicine and Science in Sports and Exercise. 2011;43(7):1334-59. doi: 10.1249/MSS.0b013e318213fefb.

17. Thompson WR. Now trending: worldwide survey of fitness trends for 2014. ACSM's Health & Fitness Journal. 2013;17(6):10-20. doi: 10.1249/FIT.0b013e3182a955e6.

18. Gudlaugsson J, Gudnason V, Aspelund T, Siggeirsdottir K, Olafsdottir AS, Jonsson PV, et al. Effects of a 6-month multimodal training intervention on retention of functional fitness in older adults: a randomized-controlled cross-over design. The International Journal of Behavioral Nutrition and Physical Activity. 2012;9:107. Epub 2012/09/12. doi: 10.1186/1479-5868-9-107. PubMed PMID: 22963328; PubMed Central PMCID: PMCPmc3522556.

19. Lohne-Seiler H, Torstveit MK, Anderssen SA. Traditional versus functional strength training: effects on muscle strength and power in the elderly. Journal of Aging and Physical Activity. 2013;21(1):51-70.

20. Holviala JHS, Sallinen JM, Kraemer WJ, Alen MJ, Häkkinen KT. Effects of strength training on muscle strength characteristics, functional capabilites, and balance in middle-aged and older women. Journal of Strength & Conditioning Research 2006;20(2):336-44. PubMed PMID: 20970936.

21. Cavani V, Mier CM, Musto AA, Tummers N. Effects of a 6-week resistance-training program on functional fitness of older adults. Journal of Aging & Physical Activity. 2002;10(4):443-52. PubMed PMID: SPHS-853441.

22. de Vreede PL, Samson MM, van Meeteren NLU, Duursma SA, Verhaar HJJ. Functional-task exercise versus resistance strength exercise to improve daily function in older women: a randomized, controlled trial. Journal Of The American Geriatrics Society. 2005;53(1):2-10. PubMed PMID: 15667369.

23. Pacheco MM, Teixeira LA, Franchini E, Takito MY. Functional vs. strength training in adults: specific needs define the best intervention. Int J Sports Phys Ther. 2013;8(1):34-43. Epub 2013/02/27. PubMed PMID: 23439782; PubMed Central PMCID: PMCPmc3578432.

24. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function - part 1. North American Journal Of Sports Physical Therapy: NAJSPT. 2006;1(2):62-72. PubMed PMID: 21522216.

25. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function - part 2. North American Journal of Sports Physical Therapy. 2006;1(3):132-9.

26. Sorenson EA. Functional movement screen as a predictor of injury in high school basketball athletes [disseration]. [Eugene]: University of Oregon; 2009. p. 89.

27. Hoover D, Killian, CB, Bourcier, B, Shannon, L, Jenny, T, Willis, R Predictive validity of the functional movement screen in a population of recreational runners training for a half marathon. Medicine and Science in Sports and Exercise. 2008;40(5):219.

28. Chorba R, Chorba D, Bouillon L, Overmyer C, Landis J. Use of a functional movement screening tool to determine injury risk in female collegiate athletes. North American Journal of Sports Physical Therapy. 2010;5(2):47-54.

29. Kiesel KB, Butler RJ, Plisky PJ. Prediction of injury by limited and asymmetrical fundamental movement patterns in american football players. Journal of Sport Rehabilitation. 2014;23(2):88-94. PubMed PMID: 95694877.

30. O'Connor FG, Deuster PA, Davis J, Pappas CG, Knapik JJ. Functional movement screening: predicting injuries in officer candidates. Medicine & Science in Sports & Exercise. 2011, 43(12):2224-2230.

31. Perry FT, Koehle MS. Normative data for the functional movement screen in middle-aged adults. The Journal of Strength & Conditioning Research. 2013;27(2):458-62 10.1519/JSC.0b013e3182576fa6.

32. Kennedy-Armbruster C, Evans EM, Sexauer L, Peterson J, Wyatt W. Association among functional-movement ability, fatigue, sedentary time, and fitness in 40 years and older active duty military personnel. Military Medicine. 2013;178(12):1358-64. doi: 10.7205/MILMED-D-13-00186. PubMed PMID: 92877072.

33. Peterson LQ, Evans, EM, Kennedy-Armbruster, C. Exercise training improves functional movements screen (FMS) in 40+ year-old active duty military personnel. [Abstract]. Forthcoming 2014.

34. Ferreira RS, da Silva Coqueiro R, Barbosa AR, Pinheiro PA, Fernandes MH. Relationship between BMI and physical performance among older adults. Geriatric Nursing. 2013; 34(6): 465-8. Epub 2013/09/03. doi: 10.1016/j.gerinurse.2013.07.013. PubMed PMID: 23993659.

35. Teyhen D. The Functional Movement Screen: A Reliability Study. The Journal of Orthopaedic and Sports Physical Therapy. 2012;42(6):530.

36. Pope AM, Tarlov AR; Committee on a National Agenda for the Prevention of Disability. Disability in america: toward a national agenda for prevention 1991. Washington (DC): The National Institue of Health; 1991. 375 p.

37. World Health Organization G. International Classification of Impairments, Disabilities, and Handicaps: A Manual of Classification Relating to the Consequences of Disease 1993. Geneva (CH): World Health Organization; 1993. 207 p.

38. Verbrugge LM, Jette AM. The disablement process. Social Science & Medicine (1982). 1994;38(1):1-14. Epub 1994/01/01. PubMed PMID: 8146699.

39. Vogt MT, Lauerman WC, Chirumbole M, Kuller LH. A community-based study of postmenopausal white women with back and leg pain: health status and limitations in physical activity. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences. 2002;57(8):M544-M50. doi: 10.1093/gerona/57.8.M544.

40. Cassidy JD, Cote P, Carroll LJ, Kristman V. Incidence and course of low back pain episodes in the general population. Spine. 2005;30(24):2817-23. Epub 2005/12/24. PubMed PMID: 16371911.

41. Dugan SA, Powell LH, Kravitz HM, Everson Rose SA, Karavolos K, Luborsky J. Musculoskeletal pain and menopausal status. Clin J Pain. 2006;22(4):325-31. Epub 2006/05/13. doi: 10.1097/01.ajp.0000208249.07949.d5. PubMed PMID: 16691084.

42. Frymoyer JW, Cats-Baril WL. An overview of the incidences and costs of low back pain. The Orthopedic Clinics of North America. 1991;22(2):263-71. Epub 1991/04/01. PubMed PMID: 1826550.

43. Dugan SA, Everson-Rose SA, Karavolos K, Sternfeld B, Wesley D, Powell LH. The impact of physical activity level on SF-36 role-physical and bodily pain indices in midlife women. Journal of Physical Activity & Health. 2009;6(1):33-42. Epub 2009/02/13. PubMed PMID: 19211956; PubMed Central PMCID: PMCPmc3143463.

44. Margolis RB, Tait RC, Krause SJ. A rating system for use with patient pain drawings. Pain. 1986;24(1):57-65. PubMed PMID: 1987-13414-001.

45. O'Connor PJ. Pain assessment in Journal of Athletic Training articles 1992-1998: implications for improving research and practice. Journal of athletic Training. 2000;35(2):151-4.

46. Turk DC, Melzack R. Handbook of pain assessment / Dennis C. Turk, Ronald Melzack, editors: New York : Guilford Press, c2001.2nd ed.; 2001.

CHAPTER 3

THE EFFECT OF FUNCTIONAL EXERCISE TRAINING ON PHYSICAL FUNCTION ASSESSED USING THE FUNCTIONAL MOVEMENT SCREEN IN MIDDLE-AGED POSTMENOPAUSAL WOMEN

Peterson, L.Q., Ward-Ritacco, C.L., Evans, E.M. To be submitted to *Journal of Strength and Conditioning Research.*

Abstract

Objective. Exercise training is associated with improved physical functional ability and reduced risk for disability. Several assessments of physical function have been developed for use in older adult populations; however, these tools lack sensitivity and normative values to measure physical function in the middle-aged cohort. The Functional Movement Screen (FMS) may provide a solution to address this need. The aim of this study was to examine the effectiveness of a 10-week functional exercise training intervention on, muscle capacity, muscle quality (MQ), physical functional ability measured using FMS, and traditional measures of physical function.

Methods. Postmenopausal women (PMW) (N=18; 55.7 ± 2.8 years) were randomized based on age and body mass index (BMI) to an exercise intervention group (N=11, 55 ± 2.4 years) or non-exercise control group (N=7, 56.9 ± 3.1 years) and were assessed for body composition via dual-energy x-ray absorptiometry (DEXA), physical function via FMS, 6-minute walk, Timed Up and Go, Transfer Task, and 30-second chair stand. Muscle strength was assessed using isokinetic dynamometry at 60° second. Leg power was assessed with the Nottingham Leg Extensor Power Rig. Muscle quality was calculated as: 1) the ratio of leg strength to upper leg mass (MQ strength), and 2) the ratio of leg power to total lower body lean mass (MQ power).

Results. Repeated measures ANOVA revealed no significant differences in changes in muscle capacity, MQ, FMS composite scores, or physical function assessments between groups. Moderate correlations were observed between change in FMS composite score and change in muscle power, MQ strength, MQ power, Transfer Task, and 30-second chair stand.

Conclusions. In middle-aged postmenopausal women, further study is needed to determine optimal length and intensity of functional exercise interventions. In addition to FMS, Transfer Task and 30-second chair stands may be effective tests for measuring physical function in the middle-aged cohort.

3.1 Introduction

Aging, in general, and menopause, specifically, are both associated with adverse changes in body composition, including, increased total fat mass, increased central adiposity, increased fatty infiltration of muscle, and reductions in lean muscle mass [1-5]. The adverse changes in body composition contribute to decreased muscle capacity (i.e. muscle strength, power, etc.) and muscle quality (MQ) (i.e. capacity relative to lean mass) [6]. In addition to physiological factors, behavioral factors including physical activity (PA) and exercise (EX) are important contributors to body composition, muscle capacity, and MQ [7, 8]. According to the 2012 National Health Interview Survey [9], middle-aged postmenopausal women (MA-PMW) are less likely than younger women and their male counterparts in the same age cohort to meet current physical activity guidelines for both aerobic and muscle strengthening.

Adequate physical functional ability is important for maintaining independence, or the ability to perform socially defined roles (i.e. self-care or employment) as one ages [10]. Disability models by Nagi and others [10] conceptualize that pathologies resulting in pain may lead to functional impairment and disability. Previous research in MA-PMW observed a relationship between bodily pain, physical functional ability, and physical activity; such that, those reporting increased levels of PA, report improved physical functional ability and decreased bodily pain [11].

Research with older adults has determined that lower levels of PA, higher levels of total fat mass, and lower levels of lean mass, muscle capacity, and MQ are associated with poorer physical functional ability [12-14]. However, little research has explored the independent and interactive relationships among these variables in MA-PMW. Recently, Ward-Ritacco et al. [8] examined physical functional ability in MA-PMW, and observed significant positive associations between lower levels of relative adiposity (%Fat), higher daily levels of both total PA and minutes of moderate to vigorous PA (MVPA), and better functional performance. These findings also suggest that MQ independently influences physical functional ability [8].

Progressive resistance training interventions in older adults have clearly determined that muscle capacity and physical function can be improved [14-16]. Exercise interventions specifically designed for the preservation of lean mass are important for disability prevention in older adults [14-16]; however, the relationship and its importance for disability prevention is relatively unstudied in MA-PMW. Moreover, while progressive resistance training interventions have demonstrated improvements in physical functional ability, they focus on the ability/capacity to complete a task, rather than the quality or coordination of the movement. The most recent American College of Sports Medicine position statement for exercise training includes a new category, neuromotor exercise training (often referred to as functional training), defined as the use of strength training to improve balance, coordination, muscle force, muscle power, and muscular endurance to improve an individual's ability to complete activities of daily living [17, 18]. The basis of functional exercise training is to address the quality of fundamental movement patterns, in an effort to address mobility and stability deficiencies, and left and right side asymmetries, to restore the body system to balance and enhance functional ability and prevent disability. Different training methods (i.e. conventional strength training vs. functional training) have been examined for their effectiveness in improving physical functional outcomes, but the evidence for the efficacy of one versus the other is still equivocal [19-21].

Although there is a large literature regarding exercise and physical function in older women, there is a paucity of data regarding MA-PMW. With the high prevalence of obesity [22] and physical inactivity [9] in MA-PMW, the risk for physical disability will undoubtedly increase in this cohort afflicting greater numbers of women for more of their lifespans [23] .The lack of literature regarding physical function in MA-PMW may also be in part due to insufficient measures of functional ability for the middle-aged adult population. While several well established assessments exist to measure the functional status of older adult populations, these tools may not be appropriate due to floor or ceiling effects. Thus, there is a lack of sensitive tools and normative values to measure the functional capacity of MA-PMW. The contemporary Functional Movement Screen (FMS) may provide a potential alternative for measuring functional status in this cohort [24, 25]. A limited number of studies have examined functional status in a middle-aged cohort using FMS; therefore, further research is needed to establish normative values and assess the sensitivity of FMS to detect changes in function in response to exercise training in MA-PMW [26, 27].

In this context, the aim of the present study was to determine the effects of a 10-week functional exercise training program (EX) on muscle capacity, MQ, and physical functional ability measured using FMS and to determine the associations between change in FMS score and changes in muscle capacity, MQ, and well established measures of physical function. In addition, a secondary aim was to explore the prevalence of pain reporting and ratings of perceived exertion (RPE) and their potential effect on FMS test scores.

3.2 Materials and Methods

Participants and Overview

The study sample included 18 PMW (age: 55.7 ± 2.8 years, range: 50-64 years; 83.3% Caucasian). Inclusion criteria were as follows: sedentary lifestyle (less than 1hr/week of planned PA/EX and a sedentary job), self-reported weight stable (within 2kg) for the past 6 months, medication stable for the prior 3 months, and a passing score on Physical Activity Readiness Questionnaire. Because physician clearance was not required for study participation, the following exclusion criteria were included: current tobacco use or those who quit less than 2 years prior, history of recent or unstable cardiovascular disease, treatment for cancer within the past 5 years, COPD including severe asthma or allergies, severe arthritis, or currently taking anti-inflammatory or steroid medications, current diagnosis or history of dizziness or balance disorders, history or current diagnosis of mental illness including clinical depression or dementia, use of assistive walking devices, and refusal to undergo a dual energy X-ray absorptiometry (DEXA) scan. Women were recruited from the faculty and staff at the University of Georgia and from the Athens community and surrounding areas through university email, fliers placed on approved bulletin boards in campus buildings and community buildings, local print media, community postings, and word of mouth.

This study was approved by the University of Georgia Institutional Review Board and all participants signed an informed consent document prior to enrollment.

Following the screening visit, participants were stratified based on age (50-54, 55-59, 60-64) and BMI (≤ 24.9, 25-29.9, ≥ 30), and randomly assigned to an exercise intervention group (EX) or a control group (CON). Individuals randomized to the EX group were enrolled in a 10 week functional exercise training intervention. While individuals randomized to the CON group were asked to not alter their PA/EX patterns and to remain weight stable.

Functional Exercise Training Intervention

Participants randomized to the EX group, were prescribed a functional exercise training program performed during 20 (2 times per week for 10 weeks), 60-minute supervised functional exercise training sessions consisting of 30 minutes of moderate intensity (11-14 on Borg's 6-20 scale) [28] aerobic exercise (walking) and 30 minutes of functional exercise training. In addition to the supervised exercise sessions, participants completed 1 additional day of the training program unsupervised. In addition to the functional exercise training program, participants completed 3 additional days of unsupervised moderate intensity aerobic exercise (walking). Exercise sessions and walking bouts performed at home were self-reported with exercise logs and collected and reviewed weekly for completion by the study team. All aspects of the functional exercise training program were progressive in terms of volume and intensity with optimal training overload (i.e. set and repetitions) varied every 3 to 4 weeks. With specific regard to the functional exercise training program, exercises emphasizing and combining dynamic movements, balance, and stabilization were chosen. The chosen exercises were adapted from the Navy Operational Fitness and Fueling System (NOFFS) Large Deck Series [29]. Level 1 of the NOFFS program was completed during weeks 1-4 of the functional exercise intervention, level 2 during weeks 5-7, and level 3 during week 8-10. In accordance with the NOFFS program, exercise sessions were broken into 4 components: pillar preparation, movement preparation, strength, and flexibility. Example exercises include: pillar bridge variations for core stability, glute bridge variations for glute strength and hip stability, squat variations for lower body strength, push-up for upper body strength, and band rows for upper body strength. Exercise sessions requiring attendance were conducted and supervised by trained researched assistants.

Anthropometric Measures

Body weight was measured with participants wearing light clothing and no shoes using a calibrated electronic scale (Tanita, Model WB100, Arlington Heights, IL). Barefoot standing height was measured to the nearest 0.1 cm with a digital stadiometer (SECA 424, Chino, CA). Central adiposity was measured using the average of 3 umbilical waist circumference measurements to the nearest 0.1 cm.

Body Composition

Whole body and regional lean tissue composition were measured by DEXA (GE iLunar). Whole body %Fat, lower body lean mass, and upper leg lean mass were used in the computation of MQ. Lower body lean mass was defined as the lean mass values measured from the top of the iliac crest, while upper leg lean mass was defined as the lean mass values from the bisection of the femoral neck to the center of the knee cap.

Physical Activity

Accelerometers (NL-1000, New Lifestyles, Lees Summit, MO) were used to obtain objective measures of PA. Participants were asked to wear the accelerometer fastened to the waistband of their non-dominant hip during all waking hours, except when swimming or bathing. Participants tracked accelerometer usage over a 7 day period for the entirety of the study, and the researchers collected a seven-day recall (steps per day and minutes of MVPA per day) each week. 10 hours or more of wear time was considered a valid day, and 4 or more valid days was considered a valid week. Average steps per day and average total minutes of MVPA were calculated from valid wear days.

Physical Function

<u>FMS.</u> The FMS is comprised of 7 tasks: overhead squat, hurdle step, inline lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability. Each test is scored on a 0 to 3 scale. A score of 3 is awarded with perfect execution of the movement, a score of 2 is awarded if any compensation occurs during the movement but the movement is completed, a score of 1 is awarded if the

participant is unable to complete the movement, and a score of 0 is awarded if pain is experienced with the movement. Five of the 7 movements are scored unilaterally. In the case that the right and left sides receive different scores, the lowest of the two scores is used in the summation of the composite score for the 7 individual movements. Three tests (shoulder mobility, trunk stability push-up, and rotary stability) have additional clearing tests that are scored as positive or negative. The clearing tests only consider pain. If pain is experienced with the movement the test is scored positive and if there is no pain with the movement the test is scored negative. If a positive score is received for a clearing test, the associated FMS test will automatically be scored zero. The highest achievable composite score for all 7 FMS tests is 21. The test order was not randomized because the FMS has a standardized testing sequence and all participants received the same script of instructions.

Two raters scored participants during each FMS test, and all rater's were FMS-level 1 certified. One rater was constant for all FMS tests (2 at baseline and 2 at post). The constant rater's test scores were used in the analysis to determine the effect of the intervention. Furthermore, the first FMS test completed at baseline and post was used in the analysis. Completed FMS protocols were assessed for intrarater and interrater reliability. Based on weighted kappa scores, agreement of the 7 component FMS tests indicated substantial to excellent agreement between raters at pre- and post-testing. The interrater reliability of the FMS composite scores resulted in an ICC of 0.95 (95% CI: 0.63, 0.85) and 0.99 (95% CI: 0.98, 0.99) at pre- and post-testing respectively, representing excellent reliability. The intrarater reliability (test-retest at 8-10 days) of the FMS composite scores was established at pre- and post-testing sessions and resulted in an ICC of 0.77 (95% CI: 0.33, 0.92) and 0.91 (95% CI: 0.75, 0.97) and represented good reliability.

6 Minute Walk Test. Cones were placed 39 meters apart, and participants were instructed to complete as many laps as possible in 6 minutes. Distance was recorded to the nearest 0.1 m.

Transfer Task. Participants began in a standing position and were instructed to move to a sitting position on the floor (buttocks touching the floor) and return to the starting position as quickly as possible without support. Time was recorded to the nearest 0.1 seconds.

8 Foot Up and Go. Participants began seated in a chair and on the word "Go", stood, walked around a cone placed 4 feet away, and returned to a seated position in the chair as quickly as possible. Time was recorded to the nearest 0.1 seconds.

30 Second Chair Stand. Participants began seated with arms folded across their chest, and on the word "Go", were instructed to stand up completely and return to a seated position as many times as possible in 30 seconds. The number of repetitions completed in 30 seconds was recorded.

Muscle Capacity and MQ

Muscle strength was assessed bilaterally using isokinetic dynamometry (Biodex System Pro 4, Biodex Medical Systems, INC., New York); 2 sets of 4 repetitions at 60°/sec. The highest peak torque of the right and left leg was used in the analysis. Leg power was assessed with the Nottingham Leg Extensor Power Rig. Participants performed up to 10 trials per leg, and the final velocity of the flywheel during each extension was used to calculate the average power output (Watts). The highest watts obtained for both the right and left leg was used in the analysis. Muscle quality was calculated as: 1) the ratio of leg strength (peak torque in Newton-Meters) at 60°/sec to upper leg lean mass and 2) the ratio of leg power to total lower body lean mass.

Pain and Perceived Exertion

Prior to completion of the 7 component FMS, participants were asked if they were currently experiencing bodily pain. If they indicated that they were experiencing pain, they were asked to locate the pain on a pain location drawing [30], and rate the intensity of the pain on a 0 to 10 scale (11-point) Numerical Graphical Rating Scale [31]. Following the completion of each FMS component test, participants were asked if they experienced any pain with the movement. When pain was reported, participants were asked to locate the site of the pain on a pain location drawing [30], and rate the intensity of the pain on a 0 to 10 (11-point) Numerical Graphical Rating Scale [31]. In addition, following the completion of each FMS component test, participants were asked to rate their perceived exertion using Borg's 6-20 scale [28]. At pre- and post- testing, participants completed the Medical Outcomes Short-Form 36 (SF-36) [32] questionnaire, from which the bodily pain subscale was used in analysis.

Statistical Analysis.

Statistical analysis was performed using SPSS statistical software, version 20 for Windows. The data was inspected for normality and outliers (greater than 3 standard deviations from the mean). Descriptive statistics and frequency counts were calculated, and a t-test of significance for independent groups was used to determine statistical differences between key outcomes at baseline. In order to be included in statistical analysis, participants in the EX group must have completed 75% of the exercise sessions. To examine the effectiveness of the functional exercise training intervention on primary outcomes of interest, a mixed-model repeated measures ANOVA with treatment time as the within-subject (baseline, post-test) and group (EX vs. CON) as the between subject factor was used. Pearson's bivariate correlations were used to explore the relationships between change in FMS composite score and changes in muscle capacity, MQ, and physical function in the EX group. To examine the influence of functional exercise training on rating of perceived exertion for FMS component tests, a mixed-model repeated measure ANOVA with treatment time as the within-subject (baseline, post-test) and group (EX vs. CON) as the between subject factor was used.

3.3 Results

Following analysis for normality and outliers, one participant in the EX group was deemed an outlier as her baseline and change scores of physical function were greater than 3SD from the mean, and she was subsequently removed from additional analysis. Groups did not statistically differ in demographics characteristics (Table 3.1) or key muscle capacity and functional measures (Table 3.2) at baseline. On average, our participants were obese based on a BMI $\geq$ 30.0 kg/m^2. In addition, based on average steps per day and average minutes of MVPA per day over a 7-day time period, neither group met the current recommendation of 10,000 steps per day or 150 minutes of moderate intensity PA per week, respectively [33]. One participant in the EX group discontinued the intervention due to other commitments, and one participant in the CON group did not return for post-testing due to an injury sustained outside of our study. All participants in the EX group, met the exercise session adherence rate of 75%.

There were no significant group differences for change in FMS composite scores, muscle capacity, MQ, or physical function tests as a result of the functional exercise intervention (all $p > 0.05$; Table 3.2); however, there was a trend for a difference in strength (d = .44). Change in FMS composite score was moderately (r range = 0.30-0.69) correlated with change in muscle power, MQ power, MQ strength, and 30 -second chair stands (Table 3.3). The functional exercise training intervention reduced RPE scores for the deep squat and hurdle step component FMS tests in the EX group compared to the CON group ($p < 0.05$,Table 3.4).

Change in bodily pain, as measured by the SF-36 did not significantly differ ($p > 0.05$) between the EX and CON groups (Baseline: 88.8 ± 9.9 and 75.7 ± 13.6; Post-Test: 77.3 ± 20.3 and 76.3 ± 16.9 for the EX and CON group respectively). Additional observations regarding self- reported pre-existing pain, using the pain body locations drawing, and the impact on composite FMS scores were made; however, chronic pain did not appear to influence FMS performance. In the complete sample at baseline, no differences existed in FMS for those who reported chronic pain compared to those who did not (pain (n=9): 9.67 ± 2.25, no pain (n=7): 10.00 ± 2.83). Additionally, the change in reported pain location and intensity within group was highly variable (i.e. individuals with chronic pain at baseline reported no pain; however, some individuals with no chronic pain reported pain at post-test).

In regards to pre-existing pain locations, in the complete sample at baseline, the top pain locations were knees (n=3), feet and ankles (n=2), hand and wrist (n=2), low back (n=2), and shoulders (n=1). Following the functional exercise intervention, participants in the EX group who reported pre-existing pain at baseline (n=4), (n=3) no longer reported pre-existing pain, (n=1) experienced the same pre-existing pain, and (n=3) reported pre-existing pain not reported at baseline. At post testing for the CON group, all participants who reported pre-existing pain at baseline (n=5) reported the same sites of pre-existing pain, with 1 additional participant reporting pain.

3.4 Discussion

This study aimed to evaluate the impact of a 10-week functional exercise training intervention on muscle capacity, MQ, and physical functional ability in MA-PMW measured using FMS and conventional physical function tests. In addition, we aimed to establish a relationship between change in composite FMS score and change in muscle capacity and MQ and conventional physical function tests. Finally, we explored the relationship between chronic pain and performance on the FMS.

Although improvements were not statistically significant for composite FMS scores, improvements were observed from pre- to post in the EX group; however, the CON group also showed changes. A learning effect may have accounted for the change in the CON group scores and our findings parallel results found by Pacheco et al. [26]. In their study, although improvements were observed in both groups, improvements were not statistically significant $p > 0.05$ for change in FMS score following either a conventional exercise training intervention or a functional exercise training intervention among 56 women and 45 men. However, our findings are not compatible with recent data , reported in abstract form, examining the efficacy of the Senior Health Assessment Program Enterprise (SHAPE) intervention for improving FMS scores in middle-aged active duty military personnel [27]. In this cohort, we observed an 18 % improvement (13 ± 2.5, vs 15.4 ± 2.4, $p < .001$) from baseline to post testing with identical changes in men and women (2.3 ± 2.2 vs 2.3 ± 2.1, $p = .91$). Nonetheless, it is possible that these findings differ as a result of the differences in the study samples (i.e., middle-aged active duty military personnel with a responsibility to be generally and physically prepared vs. sedentary, MA-PMW), and it is possible that baseline physical function and fitness levels of each sample influenced the subsequent outcomes. In addition, the SHAPE intervention was slightly longer, 3 months, compared to the current study's 10-week time frame, and exercise prescriptions were individually modified to improve functional impairments exposed by FMS. While the specificity and intensity of the SHAPE program may have influenced improvements, our EX group reported decreased rates of perceived exertion on FMS component tests following the completion of the intervention, leading us to assume that the relative intensity of the intervention may be sufficient to cause improvement.

In the current study, moderate correlations were observed between change in FMS composite score and change in lower body power, MQ assessed by muscle strength and power, and 30 second chair stand. Although the correlations were not significant, certainly the sample size influenced the observation of statistically significant relationships. This result supports previous research showing that increased MQ is related to improved functional performance [8]. Additionally, the relatively high BMI and previously sedentary lifestyle of the sample may have attenuated any significant increase in MQ because of the emerging association among PA and BMI and MQ [5, 8, 34]. A longer intervention or an intervention coupling weight loss with functional exercise training may be optimal to observe significant improvements.

Previous studies have observed a relationship between FMS composite scores of ≤ 14 and increased injury risk [35-37]. Only one participant in our sample achieved a composite FMS score > 14, alternatively, using the predictive value of 14 suggests that 94% of our sample is at high risk for injury related to movement. Previous studies using 14 as reference point were completed in young, athletic cohorts; therefore, because of the decreased functional status of the middle-aged cohort, it is possible that a specific and different cut point for injury risk is needed for the middle-aged cohort. However, a differing perspective is that while FMS is a possible solution for assessing functional status in an active middle-aged cohort, particular component tests of FMS may be too great of a challenge to assess functional ability in sedentary, middle-aged individuals. Further research is needed to establish normative values and if FMS is an appropriately sensitive tool for measuring physical function in the middle-aged cohort.

We did not observe a significant decrease in pain reporting following the functional exercise intervention. Several participants who previously reported pain at baseline, no longer reported pain following the intervention, and a few who did not report pain at baseline subsequently reported pain. Several confounding factors may contribute to pain reporting variability including: previous injury, previous sedentary lifestyle, and activities performed outside the exercise intervention; therefore, because of the small sample size, it is beyond the scope of our data to report the influence of the intervention on pre-existing pain reporting.

FMS was developed to assess mobility and stability of basic functional movement (i.e. squatting, lifting, stepping, reaching) required for daily activity. While strength training is important for the maintenance of lean muscle, as well as muscle capacity and MQ, functional exercise training may be important to improve the quality of basic patterns for longevity and disability prevention. Future research should focus on determining the optimal PA/EX combination intervention to maximize lean muscle maintenance while improving basic foundational movement patterns. In addition, to establish an optimal battery of physical functional tests and normative values for MA-PMW, further research is needed. Establishment of normative values will assist exercise specialists in developing effective interventions to improve physical function in the MA-PMW, aimed towards preventing physical disability, especially in late life.

3.5 References

1. Messier V, Rabasa-Lhoret R, Barbat-Artigas S, Elisha B, Karelis AD, Aubertin-Leheudre M. Menopause and sarcopenia: a potential role for sex hormones. Maturitas. 2011;68(4):331-6. doi: http://dx.doi.org/10.1016/j.maturitas.2011.01.014.

2. Aloia JF, Ross P, Cohn SH, McGowan DM, Vaswani AN. Relationship of menopause to skeletal and muscle mass. American Journal of Clinical Nutrition. 1991;53(6):1378-83. PubMed PMID: FNI91002803.

3. Davis SR, Castelo-Branco C, Chedraui P, Lumsden MA, Nappi RE, Shah D, et al. Understanding weight gain at menopause. Climacteric: The Journal Of The International Menopause Society. 2012;15(5):419-29. doi: 10.3109/13697137.2012.707385. PubMed PMID: 22978257.

4. Wildman RP, Tepper PG, Crawford S, Finkelstein JS, Sutton-Tyrrell K, Thurston RC, et al. Do changes in sex steroid hormones precede or follow increases in body weight during the menopause transition? results from the study of women's health across the nation. Clin Endocrinol Metab. 2012; 97(9): 1695-704. doi: 10.1210/jc.2012-1614

5. Delmonico MJ, Harris TB, Visser M, Park SW, Conroy MB, Velasquez-Mieyer P, et al. Longitudinal study of muscle strength, quality, and adipose tissue infiltration. The American Journal of Clinical Nutrition. 2009;90(6):1579-85. doi: 10.3945/ajcn.2009.28047. PubMed PMID: 19864405; PubMed Central PMCID: PMC2777469.

6. Pollanen E, Sipila S, Alen M, Ronkainen PHA, Ankarberg-Lindgren C, Puolakka J, et al. Differential influence of peripheral and systemic sex steroids on skeletal muscle quality in pre- and postmenopausal women. Aging Cell. 2011;10(4): 650-60. doi: 10.1111/j.1474-9726.2011.00701.x

7. Sims ST, Kubo J, Desai M, Bea J, Beasley JM, Manson JE, et al. Changes in physical activity and body composition in postmenopausal women over time. Medicine & Science in Sports & Exercise. 2013;45(8):1486-92. Epub 2013/02/27. doi: 10.1249/MSS.0b013e31828af8bd. PubMed PMID: 23439422; PubMed Central PMCID: PMCPmc3715578.

8. Ward-Ritacco CL, Adrian AL, Johnson MA, Rogers LQ, Evans EM. Adiposity, physical activity, and muscle quality are independently related to physical function performance in middle-aged postmenopausal women. Menopause. 2014;Publish Ahead of Print:10.1097/GME.0000000000000225.

9. Adams PF, Kirzinger WK, Martinez M. Summary health statistics for the U.S. population: national health interview survey, 2012. Vital And Health Statistics Series 10, Data From The National Health Survey. 2013(259):1-95. PubMed PMID: 24784762.

10. Pope AM, Tarlov AR; Committee on a National Agenda for the Prevention of Disability. Disability in america: toward a national agenda for prevention 1991. Washington (DC): The National Institue of Health; 1991. 375 p.

11. Dugan SA, Everson-Rose SA, Karavolos K, Sternfeld B, Wesley D, Powell LH. The impact of physical activity level on SF-36 role-physical and bodily pain indices in midlife women. Journal of Physical Activity & Health. 2009;6(1):33-42. Epub 2009/02/13. PubMed PMID: 19211956; PubMed Central PMCID: PMCPmc3143463.

12. Valentine RJ, McAuley E, Vieira VJ, Baynard T, Hu L, Evans EM, et al. Sex differences in the relationship between obesity, C-reactive protein, physical activity, depression, sleep quality and fatigue in older adults. Brain, Behavior and Immunity. 2009;23(5):643-8. PubMed PMID: 20093182674.

13. Ward CL, Valentine RJ, Evans EM. Physical function is impacted more by adiposity than physical activity or lean mass in community-dwelling older adults. Journal of Aging and Physical Activity. 2013. Epub 2013/06/27. PubMed PMID: 23799829.

14. Straight CR, Dorfman LR, Cottell KE, Krol JM, Lofgren IE, Delmonico MJ. Effects of resistance training and dietary changes on physical function and body composition in overweight and obese older adults. Journal of Physical Activity & Health. 2012;9(6):875-83. PubMed PMID: 79553220.

15. Harris C, DeBeliso MA, Spitzer-Gibson TA, Adams KJ. The effect of resistance-training intensity on strength-gain response in the older adult. Journal of Strength & Conditioning Research (Allen Press Publishing Services Inc). 2004;18(4):833-8. PubMed PMID: 15255977.

16. Wieser M, Haber P. The effects of systematic resistance training in the elderly. International Journal of Sports Medicine. 2007;28(1):59-65. Epub 2006/06/09. doi: 10.1055/s-2006-924057. PubMed PMID: 16761216.

17. Garber C, Dlissmer, B, Deschenes, MR, Franklin, BA, Lamonte, MJ, Lee, IM, Nieman, DC, and Swain, DP ACSM Position Stand: Quanitity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: gudance for prescribing exercise. Medicine & Science in Sports & Exercise. 2011;43(7):1334-59. doi: 10.1249/MSS.0b013e318213fefb.

18. Thompson WR. Now trending: worldwide survey of fitness trends for 2014. ACSM's Health & Fitness Journal. 2013;17(6):10-20. doi: 10.1249/FIT.0b013e3182a955e6.

19. Gudlaugsson J, Gudnason V, Aspelund T, Siggeirsdottir K, Olafsdottir AS, Jonsson PV, et al. Effects of a 6-month multimodal training intervention on retention of functional fitness in older adults: a randomized-controlled cross-over design. The International Journal of Behavioral Nutrition and Physical Activity. 2012;9:107. Epub 2012/09/12. doi: 10.1186/1479-5868-9-107. PubMed PMID: 22963328; PubMed Central PMCID: PMCPmc3522556.

20. Lohne-Seiler H, Torstveit MK, Anderssen SA. Traditional versus functional strength training: effects on muscle strength and power in the elderly. Journal of Aging and Physical Activity. 2013;21(1):51-70.

21. Holviala JHS, Sallinen JM, Kraemer WJ, Alen MJ, Häkkinen KT. Effects of strength training on muscle strength characteristics, functional capabilites, and balance in middle-aged and older women. Journal of Strength & Conditioning Research 2006;20(2):336-44. PubMed PMID: 20970936.

22. Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999-2010. JAMA: The Journal Of The American Medical Association. 2012;307(5):491-7. doi: 10.1001/jama.2012.39. PubMed PMID: 22253363.

23. Seeman TE, Merkin SS, Crimmins EM, Karlamangla AS. Disability trends among older americans: national health and nutrition examination surveys, 1988--1994 and 1999--2004. American Journal of Public Health. 2010;100(1):100-7. PubMed PMID: 47519619.

24. Cook G. Pre-participation screening: the use of fundamental movements as an assessment of function - part 1. North American Journal of Sports Physical Therapy. 2006;1(2):62.

25. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function - part 2. North American Journal of Sports Physical Therapy. 2006;1(3):132-9.

26. Pacheco MM, Teixeira LA, Franchini E, Takito MY. Functional vs. strength training in adults: specific needs define the best intervention. Int J Sports Phys Ther. 2013;8(1):34-43. Epub 2013/02/27. PubMed PMID: 23439782; PubMed Central PMCID: PMCPmc3578432.

27. Peterson LQ, Evans, EM, Kennedy-Armbruster, C. Exercise training improves functional movements screen (FMS) in 40+ year-old active duty military personnel. [Abstract]. Forthcoming 2014.

28. Borg G, Ha PI, Sadja J, Tomfohr L, Jimenez JA, Edwards KM, et al. Ratings of Perceived Exertion. Scandinavian Journal of Rehabilitation Medicine. 2012;31(2):156-63.

29. Nutrition Operational Fitness and Fueling Series (NOFFS). Available from: http://www.navyfitness.org/fitness/noffs/.

30. Margolis RB, Tait RC, Krause SJ. A rating system for use with patient pain drawings. Pain. 1986;24(1):57-65. PubMed PMID: 1987-13414-001.

31. Turk DC, Melzack R. Handbook of pain assessment / Dennis C. Turk, Ronald Melzack, editors: New York : Guilford Press, c2001.2nd ed.; 2001.

32. Ware J. MOS 36-Item Short-Form Health Survey. Journal of advanced nursing. 2011;67(3):491-500.

33. 2008 physical activity guidelines for Americans [electronic resource] : be active, healthy, and happy!: [Washington, D.C.] : U.S. Dept. of Health and Human Services : For sale by the Supt. of Docs., U.S. G.P.O., 2008.; 2008.

34. Marcus R, Addison O, Lastayo P. Intramuscular adipose tissue attenuates gains in muscle quality in older adults at high risk for falling. A brief report. Journal of Nutrition, Health & Aging. 2013;17(3):215-8. doi: 10.1007/s12603-012-0377-5. PubMed PMID: 85974964.

35. Kiesel KB, Butler RJ, Plisky PJ. Prediction of Injury by Limited and Asymmetrical Fundamental Movement Patterns in American Football Players. Journal of Sport Rehabilitation. 2014;23(2):88-94. PubMed PMID: 95694877.

36. Chorba R, Chorba D, Bouillon L, Overmyer C, Landis J. Use of a functional movement screening tool to determine injury risk in female collegiate athletes. North American Journal of Sports Physical Therapy. 2010;5(2):47-54.

37. O'Connor FG, Deuster PA, Davis J, Pappas CG, Knapik JJ. Functional movement screening: predicting injuries in officer candidates. Medicine & Science in Sports & Exercise. 2011; 43(12): 2224-2230.

CHAPTER 4

CONCLUSIONS

The effect of a 10-week functional exercise training intervention was assessed using FMS, muscle capacity, MQ, and conventional measures of physical function in 9 MA-PMW and 6 non-exercise controls. In addition, we sought to explore the prevalence of pain reporting and its effect on FMS scores. Following the intervention, the changes observed in FMS scores, muscle capacity, MQ, or physical function tests were not significantly different between the EX and CON groups. However, bivariate correlations performed on the EX group, revealed moderate relationships between change in FMS composite score and change in muscle power, MQ strength, MQ power, and 30 second chair stands. Pain reporting was variable and no significant relationship was observed between pre-existing pain and FMS scores. Following the EX intervention, rate of perceived exertion decreased significantly for the deep squat and hurdle step. In conclusion, the findings of the present study are: 1) a 10 week functional exercise intervention does not appear to significantly improve FMS composite score, 2) change in FMS scores following the functional exercise intervention is moderately correlated with change in muscle power and MQ, and 3) a 10 week functional exercise intervention does not appear to impact reported pre-existing pain but does decrease ratings of perceived exertion on FMS component tests.

Future research should be directed towards developing optimal (i.e. dosage, volume, mode or combined strength and functional exercise) exercise interventions to improve muscle capacity, MQ, and physical function. In addition, future investigations should emphasize the development of FMS for use in the middle-aged cohort and to determine if it is sensitive enough to detect functional changes. Finally, from a measurement perspective, future research should examine the impact of reported chronic pain on the assessment of functional movement assessed using the FMS in MA-PMW.

Table 3.1 Participant characteristics

	EX Group (n=9)		CON Group (n=6)	
Variables	Mean ± SD	Range	Mean ± SD	Range
Age (yrs)	54.7 ± 2.6	52-59	56.5 ± 3.3	53-61
Body mass (kg)	81.2 ± 24.7	47.3-115.2	85.8 ± 22.9	62.1-117.3
Height (cm)	162.3 ± 6.8	153.4-174.5	164.5 ± 5.8	156-172.1
BMI (kg/m^2)	30.5 ± 8.8	18.7-44.9	34.4 ± 8.8	24-48.2
Waist circumference (cm)	102.8 ± 18.3	73.4-132	100.9 ± 17.5	80.2-124.5
Relative adiposity (%)	45.6 ±7.3	33.8-54.1	43.6 ± 7.3	33.4-53.6
Lower body lean mass (kg)	21.0 ± 4.7	15.13-28.7	23.8 ± 4.5	19.5-31.5
Upper leg lean mass (kg)	10.3 ± 2.6	6.6-14.0	11.5 ± 2.3	9.0-15.1
PA (steps • day^{-1})	7205.5 ± 3196.8	2545-11887	6387.8 ± 2600.4	2882-10014
MVPA (min per day)	11.39 ± 8.7	1-23	12.8 ± 8.3	5-27

BMI: body mass index; PA: Physical activity; MVPA: Moderate to vigorous physical activity.

Table 3.2 Effect of a functional exercise training intervention on muscle capacity measures and function.

	EX (n=9)		CON (n=6)		
	Pre	Post	Pre	Post	*p**
FMS	10.11 ± 2.44	11.33 ± 2.25	9.83 ± 1.33	11.33 ± 2.25	.89
Strength	138.58 ± 43.19	152.28 ± 32.96	158.17 ± 28.75	157.63 ± 24.90	.38
Power	228.48 ± 88.82	262.33 ± 83.95	238.30 ± 96.23	270.60 ± 78.94	.85
MQ Strength	26.75 ± 4.38	29.24 ± 3.24	27.69 ± 4.38	28.21 ± 5.54	.99
MQ Power	10.63 ± 2.54	12.10 ± 2.23	10.22 ± 3.72	11.63 ± 2.94	.77
6 Min Walk	484.31 ± 55.97	568.50 ± 41.75	489.57 ± 52.00	571.88 ± 34.76	.85
Transfer Task	5.23 ± 2.55	4.66 ± 1.80	5.60 ± 1.81	5.43 ± 1.78	.63
Up & Go	5.46 ± .80	5.46 ± .75	5.58 ± .57	5.37 ± .50	.96
Chair Stands	13.22 ± 3.80	14.33 ± 2.29	14.33 ± 2.25	15.17 ± 2.31	.48

**p* = test of significant group by time interaction; FMS: Functional movement screen composite score; MQ Strength: Muscle quality strength; MQ Power: Muscle quality power; 6 min walk: 6 minute walk test; Up & Go: 8 foot up and go; Chair Stands: 30 sec chair stands.

3.3 Correlations among changes in FMS score, muscle capacity, muscle quality, and physical function tests in EX group.

	Δ FMS	Δ Strength	Δ Power	Δ MQ Strength	ΔMQ Power	Δ 6 Min Walk	Δ Transfer Task	Δ Up & Go	Δ Chair Stands
Δ FMS	1	.366	.546	.553	.619	-.066	-.193	-.171	.415
Δ Strength		1	-.246	.929**	-.296	-.158	.166	.624	-.458
Δ Power			1	-.176	.966**	.450	.087	-.260	.706*
Δ MQ Strength				1	-.136	-.309	.220	.531	-.289
Δ MQ Power					1	.331	.108	-.333	.771*
Δ 6 Min Walk						1	.144	-.033	.178
Δ Transfer Task							1	.695*	-.143
Δ Up & Go								1	-.696
Δ Chair Stands									1

**$p < 0.01$,*$p < 0.05$; Δ FMS: Change in functional movement screen composite score; Δ Strength: Change in strength; Δ Power: Change in power; Δ MQ Strength: Muscle quality strength; Δ MQ Power: Change in muscle quality power; Δ 6 Min walk: Change in 6 min walk; Δ Transfer Task: Change in transfer task; Δ Up & Go: Change in 8 foot up and go; Δ Chair Stands: Change in 30 sec chair stands

3.4 Influence of a functional exercise training intervention on ratings of perceived exertion for FMS component tests.

	EX		CON		*p*
	Pre	Post	Pre	Post	
DS	11.25 ± 1.49	8.38 ± 2.83	7.33 ± .82	7.50 ±1.23	*.023
HS-left	10.63 ± 2.72	7.25 ± 1.75	7.33 ± 1.03	7.17 ± 1.17	*.017
HS-right	10.50 ± 2.67	7.25 ± 1.75	7.33 ± 1.03	6.83 ± .75	*.029
ILL-left	12.88 ± 2.00	10.12 ± 2.36	9.67 ± 2.34	9.83 ± 2.93	.059
ILL-right	12.13 ± 2.17	10.38 ± 2.45	9.67 ± 2.34	9.83 ± 2.93	234
SM-left	8.13 ± 3.40	8.00 ± 2.00	6.50 ± .55	7.50 ± 2.26	.438
SM-right	9.25 ± 1.75	8.13 ± 2.23	6.50 ± .55	6.67 ± .52	.128
ASLR-left	9.13 ± 2.10	6.63 ± 1.06	8.00 ± 2.45	6.83 ± 1.17	.216
ASLR-right	9.50 ± 1.85	6.75 ± 1.04	8.00 ± 2.45	6.83 ± 1.17	.118
TSPU	15.38 ±2.45	13.88 ± 1.46	13.17 ±3.71	13.50 ± 3.73	.200
RS-left	12.63 ± 1.19	10.63 ± 3.42	11.50 ± 3.67	13.17 ± 3.55	.078
RS-right	12.63 ± 1.69	10.63 ± 3.42	11.33 ±33.88	13.17 ± 3.55	.076

**p* = test of significant group by time interaction; DS: Deep squat; HS: Hurdle step; ILL: Inline lunge; SM: Shoulder mobility; ASLR: Active straight leg raise; TSPU: Trunk stability push-up; RS: Rotary stability.