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Physical Activity in Aging: Biological Outcomes, Functional Autonomy, and Policy Implications

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PHYSICAL ACTIVITY IN AGING: BIOLOGICAL OUTCOMES, FUNCTIONAL AUTONOMY, AND POLICY IMPLICATIONS

By
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A Thesis Submitted in partial fulfillment of the requirements for the degree of Master of Science in Science, Technology, and Public Policy

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Contents

Abstract

A 2016 study concluded that the elderly spend 2.5 times the national average on health services (De Nardi 2016). Despite consisting of only 14 percent of the United States population, the elderly accounted for 34 percent of all medical spending, and accounted for 73 percent of all deaths (De Nardi 2016). In addition, current projections estimate that with the aging of the baby boomer generation, the percentage of the population that is older than 65 will swell to approximately 20 percent of the population by 2030 (Ortman 2014). If the medical spending holds, this will coincide with massive increases in health service utilization and costs. Costs of health services are currently a contentious topic at both the state and federal levels, with a seemingly insurmountable divide existing between the two main US political parties. This research attempted to gain better understanding of the health effects that physically active lifestyles elicit in older populations. Previous research connected biological outcomes across several systems to improvements in systemic health, but our efforts attempted to apply similar analysis to generalized activity levels in the form of various reported activities standardized using metabolic equivalent task metrics. For this study, the examined age group expanded beyond individuals that are older than 65, and instead included all ages over 50. Analysis used Metabolic Equivalent Task Minutes (METS) as a representative variable of general activity, using ordinary least squares regression to analyze effects on biological systems. It was found that with the selected model, there was minimal to no impact biologically that correlated with increasing general activity levels among the 50+ community. Secondary analyses were performed that lacked sufficient statistical power, however their results may be useful in determining further course of study. In the first of the secondary analyses, we used the exercise model to assess changes in individual perception of health. In this there were very few correlations found between biological health and perceptions of health. Finally, biological health and perception of health were regressed against several variables that were indicative of medical service utilization Analysis found that for the selected cohort, there were minimal measurable biological effects relating to exercise, but that the more active respondents correlated with higher belief in control over their health, as well as reductions in health-based restrictions on ability to perform intermediate level activities of daily living.

Chapter 1: Background and Literature Review

Introduction

"Keep moving or die." "Exercise is one of the best things for a person at any age." "Americans need to exercise more." These and many similar terms are commonplace in American society, and there is a strong recognition of exercise as being excellent for either maintaining or improving health, but is there merit to it? What constitutes sufficient exercise? Is it a specific training regimen, is it just being "active?" What does the average American view as active? How does this compare to physicians and those in the health professions' views of what constitutes activity? While there are existing guidelines for what might constitute and active lifestyle, the definition of what 'active ' is might differ strongly from person to person. This represents an inherent problem with reporting activity levels, as a person who considers themselves to be active might not truly check all the boxes of having a sufficiently active lifestyle to see purported health benefits, irrespective of their belief. A person in such a situation who experiences minimal to no physical benefits for their efforts may question the importance of remaining active. This disconnect between an individual's belief in sufficient activity levels, versus the standards for what constitutes a sufficiently active lifestyle put forth by scholarly sources can represent a significant amount of noise in any data that seeks to measure changes in health status that might be affected by increasing activity levels. In 2012, elderly individuals aged over 65 years old accounted for 13 percent of the United States population and were responsible for 34 percent of all medical spending (De Nardi 2016). Further exacerbating the problem, the elderly are expected to reach twenty percent of the overall US population by 2030 and hold somewhat steady there through 2050 (Figure 1). The combination of increased need for services seen with aging, as well as an increased percentage of the population falling into the elderly demographic group means that medical service usage and medical costs could also be expected to increase as a response to the demographic shift.

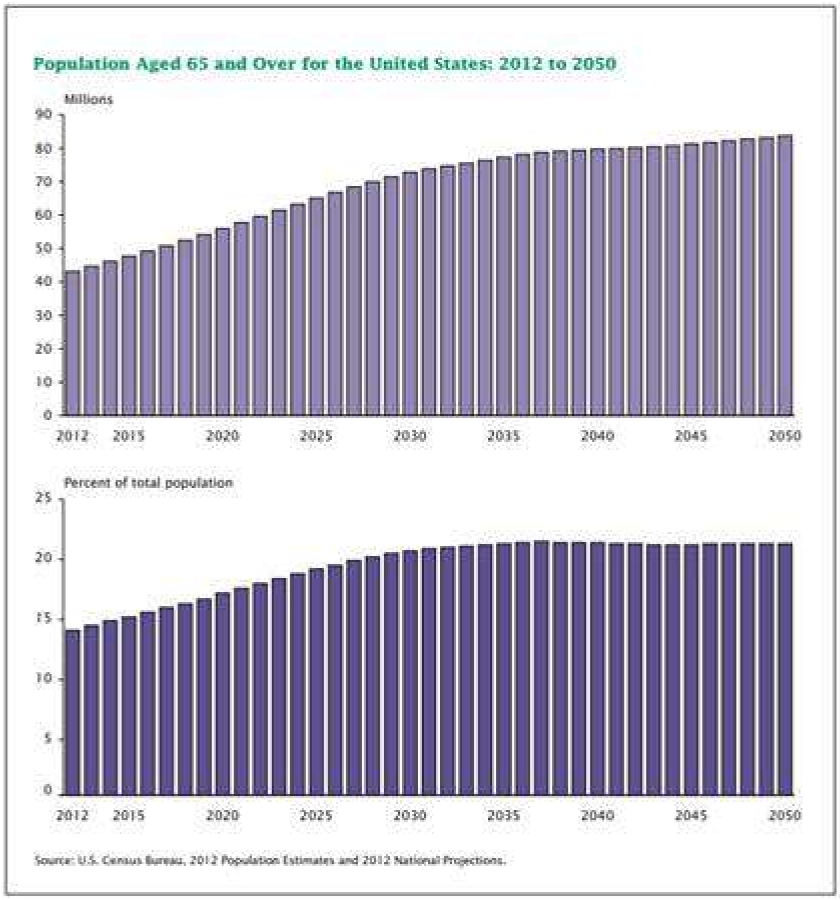

Figure 1: Projections for numbers of US residents over the age of 65, as well as their percentage of the overall projected population from 2012-2050 (Ortman 2014, Page 2).

Economics of care notwithstanding, the crossing over of such a significant percentage of the US population into the age where there is typically a marked increase in medical service need does not bode well for the current healthcare system. The current overall medical system in the United States is experiencing difficulty in meeting the needs of patient populations, and such a significant increase in the number of patients requiring high volumes of services that would come of the continued aging of the baby boomers will be expected to put significant strain on a system that is already heavily criticized heavily for medical waste, futile care, high costs, overcrowding and a litany of other longstanding problems. To make the problem of increased volume worse, there is an increasing trend toward nationalized health care, treating a person's health and subsequent maintenance care as a legal right. While it might be difficult to expound on the right to another person's skilled services and labor, the popularity of nationalized healthcare policy is a double-edged sword. It may be true that such a policy would greatly expand access, but it would also open the floodgates in terms of patient load and patient backlogs for a field that is already experiencing a labor shortage that is only expected to widen (Rosenstock 2008, AAMC 2019). In this sense, it might create a severe negative impact if other problems are not addressed first.

Physical fitness is frequently touted as a near cure-all within society at large with wide recognition as something an invested patient can do to take a greater role in maintaining their health, and all care associated with it. In addition, the fitness industry itself is a multi-billion dollar endeavor. If there is an expressed need or desire for a specific fitness-based service, there is a strong likelihood that it exists. So in light of this, why are so many people in the United States so unhealthy? Current estimates the number of people in the US with diabetes at 30 million, or just under ten percent of the total population. Furthermore, an additional 70 million people are currently characterized as prediabetic, placing the total affected population that is either at risk for diabetes or currently suffers from diabetes at almost one third of the United States population. Type 1 cases notwithstanding, type 2 diabetes represents the majority of new onset cases, and also represents what amounts to a largely preventable disease, if conscious attempts at good nutrition are used in conjunction with regular exercise. Cardiovascular diseases typically follow a similar vein; while are heritable genetic components for both cases, the majority of cases are viewed by the medical community as being largely preventable through patient initiative. Within the United states healthcare system, five diseases that are viewed as being largely preventable make up a staggering sum of health spending: Heart Disease, Cancer, Diabetes, COPD, and Hypertension. These five diseases accounted for 30% of all medical spending in 2010 and are viewed as prime targets for reductions in medical service needs and attached costs (American Public Health Association, 2016). Improvements in health and subsequent service use reductions allow more time and resources available for attention to be paid to other areas within medicine. Health science has progressed rapidly over the past half-century, but upcoming financial-logistical challenges will be exacerbated by an aging population that, due to life choices, is at a high risk for onset of numerous preventable diseases. While it is possible to live with these conditions, presence of an expensive, debilitating chronic illness can represent a sever detriment to the quality of life that the patient would experience, versus the life they want to live.

Deliberately maintaining an active lifestyle represents a set of actions that invested patients can take of their own volition, which are believed to factor into a reduction of need for medical products and services. Despite this, there is minimal existing literature available that attempts to examine how activity might produce whole-body effects within a population sample through the lens of assessing its impact on expressed need and utilization of medical services. This study hopes to better understand how general activity, measured through a standardized metric, can present itself in terms of biological outcomes within the aging and elderly populations.

Literature Review

Literature search

The literature search process primarily used the Google Scholar search engine, augmented with secondary use of the Web of Science literary search engine. Searches covered a wide range of terms based on known areas where seniors were especially prone to functional deficiencies. Within these broader areas, several subgroups were identified, such as muscle tone, immune function, bone density, vascular function, and biomechanical breakdown falling under the biophysical category. These were terms were combined with "exercise" and either "elderly" or "aging" in searches performed for all subcategories. A preference was shown for articles published within the last 20 years, with increasing weight placed on the most recent work. From these, an initial group of articles was selected. The secondary selection process involved reviewing the identified articles for content and relevance to the review, with irrelevant or minimally relevant publications being discarded. For each section searched, the google scholar custom search yielded between 200 and 300 potential articles. Across five areas covered, this represented a range of roughly 1,000 to 1,500 articles total. For each section, the articles were then screened for relevance and specificity – articles that were not relevant based on cohort demographics, as well as those with results that had too high a degree of specificity were discarded. The rationale behind exclusion of literature focusing on smaller parts of the whole for each system surveyed was that regardless of the impact on a single step, if the impact on a single step in the process was significant, it would be reflected in the overall outcome. Demographics-related exclusions were made in cases where the study centered around chronic disease elements that were not applicable to the general population. From this process, a total of 35 sources were selected and reviewed in their entirety.

Organization of Content

This review focused on the biophysical benefits of exercise – this represents the research found that focused on results irrespective of chronic conditions and disease management. While chronic condition management is the reality for most of the aging and elderly, the literature in this subsection focused on effects on particular body systems that resulted from the introduction of exercise to the study populations. The goal of these studies was largely unrelated to management of diagnosable medical conditions and placed a greater emphasis on assessing measurable physical changes within the system of interest. This review of biological benefits of activity divided the body into several major subcategories. The major theme for research methodologies for these papers was the response of a singular system to the addition of exercise. This posed a difficult challenge in the search for articles studying translational effects, as it vastly expanded the available literature pool within the search for benefits of exercise and activity. Resource-related challenges often preclude researchers from collecting the volume of information required to project results beyond the single body system of interest. Subcategories reviewed from literature included immune function, muscular function, vascular function, skeletal strength, and avascular tissue function. As previously stated, the primary goal of papers within this organization was to elucidate the benefits of exercise activities that would potentially be available to all members of the senior community and not just those with chronic health conditions.

Selected body systems

This review was not exhaustive with respect to all ten recognized body systems. Instead, the review covered critical systems which coincide with what are well-acknowledged as preventable diseases among older patients, in addition to systems that represent areas of significant comorbidities when other systems fail. The systems body system components for review were immune, muscular, bone and structural, avascular connective tissue, and vascular. All of these represent an overlap between common problems in elderly and aging populations, as well as those commonly associated with exercise within society at large. The circularities, complexities, and interdependencies of the human body meant that since in theory, any impact on one type of body system could affect all others, the primary selection criteria for body systems within the review were those that were believed could see direct effects from exercise. In short, a single input would be compared to single outputs after direct action on the systems in question with minimal intermediary steps.

Literature Review findings

Immune system

The immune system is a critical area for the elderly, as their ability to fight infection is known to decrease with age. This reduction in effective immune responses can result in infections that a young, healthy person would normally be able to fight off, but that could place the elderly in critical condition. A strong example of the degree to which the elderly immune system is compromised compared to youth is the combination of their increase chances of contracting Influenza, as well as poor physiological responses to administration of vaccines that would help to combat the infection (Montecino 2013). For this reason, the ability to help preserve and bolster immune system would be a critical input in the healthy aging equation. Journal articles on this topic seem to be in consensus. All articles concluded that the group that participated in exercise regimens experienced improved immune system function versus the control groups (Table A.1).

A.1 Exercise and Immune Function

Authors	Year	Body System	Type	Sample Size	Major findings
Senchina	2007	*Immune*	Review	n/a	Regular exercise reduces deterioration of innate immune response in elderly.
Silva et. al.	2016	*Immune*	Study	46	Moderate and Intense exercise reduced age-related telomere shortening and improved survival of T-cell populations.
Walsh	2016	*Immune*	Review	n/a	Excessive strenuous physical exercise greater than 1.5 hours daily results in a 15-25% increase in both innate and adaptive immunity.
Araújo et. al.	2015	*Immune*	Study	61	Moderate to intense exercise lifestyles resulted in improved antibody generation in response to Influenza vaccines, with no significant difference between moderate and intense exercise sample groups.
Passos et. al.	2014	*Immune*	Study	21	Moderate aerobic exercise improved sleep quality, reduced depressive symptoms, reduced cortisol levels, and decreased inflammation in the cohort.
Simpson	2015	*Immune*	Book	n/a	Moderate intensity exercise enhances immune responses and improves vaccine responses in at-risk patients.
Nieman	1999	*Immune*	Review	n/a	Intensive exercise improves function and potency of Natural Killer cells. A near-daily brisk walk can halve the number of sickness days over the course of 12-15 weeks.

Table A.1 :Articles reviewed examining correlations between exercise and changes in immune system functional response.

While exercise groups resulted in better relative function, several concluded that function itself does not actually improve – rather, exercise slows deterioration of immune function (Silva 2016, Senchina 2007). This is in contradiction to several other articles, which identified positive developments in the innate immune system via increased function and potency of Natural Killer cells, as well as increased adaptive immunity relating to improvements in antibody generation in response to the influenza vaccine (Nieman 1999, Araújo 2015). Overall, research on exercise and immune function shows that in order to achieve maximal benefit, moderate intensity exercise is preferable. Too high intensity for too long a duration results in the opposite effect, where the immune system is compromised, and the patient may have a higher chance of falling ill (Walsh 2015). For the elderly, the stressing of avoiding too high of intensity is likely less of an issue – reduced physical capabilities mean that elderly people may, for the most part, lack the ability to match the combination of intensity and duration of exercise required to compromise the immune system. As a result of this, cases where exercise is excessive could be expected to be extremely rare, and not indicative of any risk added by using exercise to attempt to improve their medical outcomes.

Muscular Function

Muscular function and discussing healthy aging, but having relatively strong, functioning muscles can have medical benefits in addition to granting greater autonomy which has been previously identified as an important contributor towards happiness in older populations (Tesch-Römer 2016). Improved muscle tone in the body and extremities has been shown to have significant benefits on venous return to the heart (Wieling 2016). The associated tension from the muscles surrounding he blood vessels helps to maintain pressure, even in the areas furthest from the heart. This in turn helps prevent pooling of blood in the veins that would result from the inability of veins to contract. Unlike arteries, which have their own associated smooth muscle, capable of contraction when provided with the correct stimuli, veins have minimal muscle of their own, and instead rely on passive pressure from pumping through arteries, as well as tension from surrounding connective tissue to maintain enough pressure to effectively return blood to the heart (Bazigou 2013). When blood is somewhat static, it immediately begins to clot. The formation of blood clots at any age can be deadly. Despite the importance of muscular contribution to vascular function, evaluation of this outcome was relatively rare in literature that focused on elderly populations. Much of the significant research within this field had a minimal focus on microscale biological changes, and instead focused on more easily measurable parameters, such as the ability of the cohort to get up and walk from a sitting position (Table A.2).

A.2 Exercise and Muscular Function

Authors	Year	Body System	Type	Sample Size	Major findings
Flansbjer	2008	Musculoskeletal	Study	24	Resistance training significantly improved strength, but not muscle tone. Participants saw improved gait and better ability to stand up and move.
Larson	1986	Musculoskeletal	Review	n/a	Regular physical activity helps reduce instances of falls, significantly decreases vascular resistance, and slows the progression of Osteoporosis
Clark	2009	Musculoskeletal	Study	1	The patient exhibited statistically significant improvements in balance and showed significant improvement in time to complete an alternating stepping activity.
Teixeira-Salmela	1999	Musculoskeletal	Study	13	After 10 weeks of regular structured exercise, all subjects showed increased strength in all muscle groups, faster gait speed, and better ability to climb stairs.
Fiatarone	1990	Musculoskeletal	Study	10	High-resistance weight training led to significant increases in muscle strength, muscle size, and functional mobility in frail, institutionalized volunteers over the age of 90.
Nelson	2004	Musculoskeletal	Study	72	Home-based exercise programs are effective in improving functional performance for community-dwelling elders with some form of functional impairment.
Frontera	1988	Musculoskeletal	Study	12	Capacity for increasing muscle mass is retained in old age for men, improvements in strength that result from training regimens are partially due to muscular hypertrophy

Table A.2: Studies examining correlations between exercise and changes in muscular function.

Despite this minimal focus on assessing effects on blood vessels themselves, muscular function saw perhaps the greatest effects resulting from the introduction of exercise regimens to elderly adults. Methodology for examining effects on muscle function primarily employed resistance training, as opposed to aerobic exercise. Several studies found that the patients saw rapid gains in overall mobility and reduced need to assistance (Fiatarone 1990, Clark 2009, Flansbjer 2008, Nelson 2004, and Teixeira-Salmela 1999). In addition, it was determined that the majority of gains in muscular performance in the elderly was the result of muscular hypertrophy, highlighting the ability to build muscle even at an advanced age (Fiatarone 1990, Frontera 1988.) While it was not determined that muscle tone during inactive periods showed improvement with exercise (Flansbjer 2008), there were still significant differences observed in the form of reduced vascular resistance. Nelson (2004) also noted the importance of home-based exercise, which was determined to be similarly effective in improving functional muscular performance. Due to limitations on mobility and logistics-related challenges, it may me more difficult for elderly adults to access the facilities they would need to achieve the outcomes they need. The ability to avoid such pitfalls, therefore, is paramount to the success of any initiative seeking to increase participation of elderly adults in exercise activities.

Vascular Function

Vascular function represents the ability of the body to circulate not only oxygen, but also essential nutrients away from the heart. Similar to cardiac function, which describes the ability of the heart to pump and distribute nutrients throughout the body from its central position, vascular function is more related to what occurs at the end points of the heart-driven process. Affected processes may involve promoting overall tissue health, wound healing, and some aspects of the immune response, which all require transport of either important compounds or cells throughout the body. Another perspective of assessing vascular function is the elasticity of veins and arteries. Veins need to retain their elasticity to ensure there is sufficient tension to return blood to the heart, but high blood pressure can result in plastic deformation of the veins, where they may experience a reduced ability to respond to changes in blood pressure that result from daily activity (Anwar 2012). Arteries also need to retain strong elasticity, albeit for different reasons. Elasticity in arteries induces a damping effect on the oscillatory blood flow produced by the heart. Loss of arterial elasticity has been shown to be a significant contributor to onset of cardiovascular diseases (Cecelja 2012). Based on literature found, exercise yielded considerable gains in vascular function (Table A.3)

A.3 Exercise and Vascular Function

Authors	**Year**	**Body System**	**Type**	**Sample Size**	**Major findings**
Fuchsjäger-Mayrl	2000	Vascular	Study	26	Aerobic exercise improves vascular function in diabetics at risk of diabetes-related vascular disease, but exercise must be maintained, or the benefits will be lost.
Green	2010	Vascular	Review	n/a	Exercise directly contributes to compliance in blood vessels in elderly subjects and those at risk of cardiovascular disease.
Mitchell	2008	Vascular	Review	n/a	Peripheral blood vessels experience lesser degrees of functional degradation with age versus major blood vessels. Muscular hypertrophy can help offset changes in arterial compliance as age increases.
Yokoyama	2003	Vascular	Study	23	Short-term aerobic exercise resulted in statistically significant decreases in arterial stiffness and decreases in insulin resistance in type-2 diabetics.
Tabara	2007	Vascular	Study	99	Mild to moderate aerobic exercise can help improve arterial compliance in older adults.
Collier	2008	Vascular	Study	30	Resistance training was more effective than aerobic exercise in improving vasodilatory capacity. Aerobic exercise led to a decrease in arterial stiffness.
Gates	2003	Vascular	Study	138	Regular aerobic exercise contributes to greater compliance in arteries but is not able to reduce the adverse changes that occur in Left Ventricular structure with age.

Table A.3: Articles reviewed which examined exercise-derived changes in vascular function.

Among these, exercises studies were almost exclusively aerobic-based exercise (Gates 2003, Tabara 2007, Yokoyama 2003, Green 2010, and Fuchsjäger-Mayrl 2000). While consensus agreed that overall function was significantly improved, Collier (2008) noted that aerobic and resistance training yielded improvements in different areas. Aerobic training, in concurrence with other literature (Table A.3), found that resistance training led to marked improvements in arterial compliance, while resistance training was shown to increase vasodilatory capacity (Collier 2008). Several articles specifically mentioned improvements in vascular function for diabetics, who frequently suffer complications in peripheral circulation as a result of their condition (Fuchsjäger-Mayrl 2000 and Yokoyama 2003). While vascular problems are exacerbated in diabetic patients as a result of their condition, improvements in vascular function have benefits that can be enjoyed by all elderly patients and are not exclusive to those with chronic diseases. Mitchell (2008) also discussed the co-dependencies of muscular and vascular function, noting that muscular hypertrophy in older age can help to offset age-related reductions in vascular compliance. Vascular function carries whole-body implications and affects nearly every major organ system. Therefore, taking actions that may improve vascular function could be expected to result in wide-ranging health benefits.

Bone Density and Structural Strength

Bone density is an important consideration that is known to change with age and can be responsible for degradations in quality of life. While decreased bone density does not necessarily directly affect a person, it creates an increased risk for serious musculoskeletal injuries even while doing seemingly mundane, everyday things. A common example is with falls and other similar circumstances in elderly – while a younger person would be extremely unlikely to suffer any lasting injury, weak bones may mean that a fall could result in broken bones. Decreased bone strength also means larger bones may break, as seen by the increase rate in hip fractures as age increases (CDC 2016). Coincidentally, the CDC also states that over 95% of hip fractures are caused by falling (CDC 2016). Along with the increased chance to break bones as age increases, there is also a decreased regenerative response to broken bones with advanced aging (Gruber 2006). While patients may not necessarily suffer from Osteoporosis, changes in catabolic processes within the body result in a high likelihood of older patients having reduced skeletal strength versus their younger counterparts (Gruber 2006). Selected literature found that exercise led to improvements in skeletal strength (Table A.4).

A.4 Exercise and Bone Density

Authors	**Year**	**Body System**	**Type**	**Sample Size**	**Major findings**
Korpelainen	2006	Skeletal	Study	160	Impact Exercise had no effect on Bone Mineral Density but had a positive effect on Bone Mineral Composition. Exercise may reduce fall-related fractures in elderly women.
Vincent	2002	Skeletal	Study	62	High intensity resistance exercise training was shown to improve Bone Mineral Density in the femoral neck.
Rhodes	2000	Skeletal	Study	44	One year of strength training in older women led to increased muscular strength and increase Bone Mineral Density.
Nguyen	2009	Skeletal	Study	1789	Increased muscle strength and higher calcium intake led to an approximate 5% increase in Bone Mineral Density at the femoral neck.
Lau	1992	Skeletal	Study	50	Moderate load-bearing activities were not effective at preventing bone loss but may have helped maximize the benefits of calcium supplementation.
Kelley	1998	Skeletal	Review	n/a	Site-specific aerobic exercise has a moderate positive effect on hip bone density in postmenopausal women. Additional studies are needed before exercise can be recommended as a non-pharmacological intervention.

Table A.4: Studies examining changes in bone density resulting from exercise.

Nearly all studies employed resistance training as the primary exercise within the study (Vincent 2002, Rhodes 2000, Lau 1992, Nguyen 2009, and Korpelainen 2006). Physiologically, this is the most sensible method – bones are capable of responding to loading requirements by initiating a hormonal feedback loop that adds additional calcium to their structure (Martini 2017). Because of this known pathway, several researchers utilized exercise in conjunction with calcium supplementation and found it to be effective in improving bone composition within their respective cohorts (Nguyen 2009, Lau 1992). One area that saw frequent focus throughout the literature as the hip region (Korpelainin 2006, Vincent 2002, Kelley 1998, and Nguyen 2009). In older populations, fractures can be life threatening, especially in the hip region. Resistance exercise represents a method by which elderly populations can attempt to stave off bone degradations, thereby retaining a critical function in remaining independent into old age.

Avascular Connective Tissue and Joints

Similarly to changes in bone density, age and wear-related breakdown of the body may not directly increase probability of death, but it does contribute toward significantly reduced quality of life and increased potential for injury. Deviating slightly from simple weakening of bones, biomechanical breakdown is more related to a lifetime of use for parts of the body that have limited ability to repair itself. This is more in reference to tissue such as tendons, ligaments, and cartilage that lack significant vasculature and as a result are unable to get the nutrients they would need to repair themselves. A lifetime of sustained use creates cumulative wear on joints, tendons, and ligaments, and can eventually lead to Osteoarthritis, a condition that occurs when cartilage that cushions the joints is worn away, resulting in painful bone-on-bone contact with movement. Osteoarthritis is rarely considered to be a cause of death, but it is one of the leading causes of physical disability (Hochberg 2008). It has been noted that physical restrictions based on osteoarthritis in joints may result in undesirable secondary effects on health (Hochberg 2008). Osteoarthritis was the primary focus of literature covering aging-related breakdown of avascular tissues, and it represents a serious challenge that the elderly face as they age. Literature found was in near complete agreement that exercise represented a set of actions patients could complete that had both direct and indirect effects (Table A.5).

A.5 Exercise and Biomechanical Breakdown

Authors	**Year**	**Disease**	**Type**	**Sample Size**	**Major findings**
Roddy	2005	Osteoarthritis	Review	n/a	Aerobic walking and quadriceps exercise both reduce pain and disability from knee arthritis.
Van Baar	2001	Osteoarthritis	Study	183	Beneficial effects of exercise on osteoarthritis pain decline and eventually disappear over time if activity levels are not maintained.
Petrella	2000	Osteoarthritis	Review	n/a	There is evidence of short-term benefit of exercise for people with osteoarthritis, but long-term effects are unclear.
Powell	2005	Osteoarthritis	Review	n/a	Obesity is the main preventable risk factor for Osteoarthritis, and reduction in obesity will significantly contribute to reductions in osteoarthritis.
Fransen	2009	Osteoarthritis	Review	n/a	Land-based therapeutic exercise is associated with reductions in knee pain and disability for people with Osteoarthritis in the short term.
Bennel	2005	Osteoarthritis	Review	n/a	Exercise is important in osteoarthritis management and may have additive benefits when paired with additional intervention modes like weight loss.
Deyle	2000	Osteoarthritis	Study	83	After 1 year, patients experienced clinically and statistically significant gains versus the placebo group in WOMAC Osteoarthritis Index scores. Physical therapy and supervised exercise results in functional benefits for patients with OA of the knee and may reduce need for surgical intervention

Table A.5: Studies reviewed pertaining to changes in joint health and other biomechanical breakdown as affected by exercise.

Multiple studies found that exercise led to reductions in joint pain, especially within the knee region (Roddy 2005, Fransen 2009, and Deyle 2000). The knee joint is critical to human mobility, and reducing pain associated with movement can reduce barriers that stand in the way of maintaining activity levels in old age. Several studies questioned the permanence of benefits due to exercise. Petrella (2000) and Van Baar (2001) both noted that while the short-term benefits experienced by arthritic patients are non-negligible, they may disappear over a longer time period if activity levels decline. Several authors highlighted the factors obesity plays in the development of osteoarthritis, stressing the impact that exercise could have on joint pain in both the short term, as well as potential long-term effects that could be realized through patient weight loss (Bennell 2005 and Powell 2005).

Commentary on aging, exercise, and biological effects

Throughout all systems reviewed, there was considerable consensus within the literature relating to the high potential for benefits derived from regular exercise. While some of the systems such as muscular function and both bone structure and density experienced a greater benefit as a result of resistance training versus others like vascular function seeing the greatest benefit derived from aerobic exercise, the consensus held that remaining physically active is an integral part of healthy aging. Perhaps more importantly, the literature supported the notion that even with very advanced aging, significant gains can be made in autonomy and overall health with the addition of regular exercise (Fiatarone 1990). Beyond autonomy, improvements in bone density and muscular function could be expected to reduce both the incidence of adverse effects of common injuries like falls, which can be devastating for the health of the elderly (Rubenstein 2006). While the mechanisms are still somewhat unclear, exercise results in strengthening of the immune system in the elderly. The importance of this is twofold – the improved ability to fend off infection is critical in reducing the need for prescription, and the improved responses to immunizations decrease the likelihood of hospital admission resulting from major illness.

Literature Review Discussion

Literature Review Summary

Exercise has the ability to create a non-trivial impact on every one of the body systems examined. Differences exist in the methods for achieving the described benefits, however. Within the literature review, every study falls into one of two main categories – resistance or aerobic. While both categories share some overlap, they have been shown to produce different results on their affected body systems. Perhaps the best example from literature was the differences observed in vascular function, where resistance training resulted in improved vasodilatory ability, while aerobic activities led to improvements in blood vessel elasticity compared to the control groups. Both are highly desirable results, although their importance may not be necessarily equal. Despite this, it can be inferred that some combination of the two improvement states would likely produce the optimal result for the complete health of the individual. In theory, this maximization point could be established for any at-risk body system after accounting for other lifestyle and individual-specific factors that may affect function. Such factors may include genetic predispositions, dietary habits, alcohol, tobacco, and other drug use, as well as occupational information. In this review, much has been discussed regarding structural improvements, on both a macro- and micro- scales. This is due to the evidence suggesting that all bodily function is derived from various hierarchies of structure, from muscle tone helping maintain pressure in peripheral blood vessels to cellular and even chemical-level changes improving the ability of the immune system to generate antibodies and prevent death of T-lymphocyte populations. It is widely believed that function at any level follows form (Martini 2017). For this reason, many studies with medical implications assess form-related changes at the cellular and tissue level that, when summed across an entire body can have significant effects.

Research Implications

Perhaps the most glaring weakness of the available literature has been the focus on specific exercise regimens, rather than whether the activities an individual completes over the course of a day that have active components may contribute towards improvements in health. The effects of these more generalized activities which may be included in an individual's assessment of whether they are active are an area where there is very little analysis. All of the studies that were analyzed within the literature review focused on specificity of the exercise with respect to affected body systems, versus general applicability to wide-ranging populations. In this the results were near universal in the finding of purported benefit from exercise, each of the studies. While some made commentary on how the results from the exercise might extrapolate to retaining functional capabilities for day to day activities in the elderly, the most significant shortcoming throughout was the general applicability that might suffer when considering adding an exercise regimen to the lives of elderly Americans. While such a plan may be feasible for some who could then expect to see such benefits, there is a sizeable subset of the population who lead lifestyles they consider to be active but that do not meet many, if any, of the recognized standards put forth by the American heart association and other health-promoting organizations. Identifying apparent differences in physiological function that might come from activities that fall outside of what is traditionally considered to be exercise may be useful in advising courses of action for older people seeing greater involvement in their health management.

Policy Implications

The passage of the Affordable Care Act in 2010 has led to a back-and-forth between the two major parties in American politics over the role of government in health care ever since. Furthermore, the increasing popular support for national-level socialized medicine suggests that future legislation may have the effect of increasing government role in healthcare. As with any insurance, health insurance is especially susceptible to moral hazards, which represent a disincentive to change behaviors due to real costs being hidden or waived. With this expected decrease in up front medical costs, it could be expected that there would be greater systemic utilization across the board. Considering the rising costs of the care itself coupled with the increased service utilization, this would likely result in massive cost increases to the point of federal financial insolvency, unless preventive action is taken. Due to the disproportionately high medical needs of the elderly versus younger demographic groups, a meaningful reduction in spending and service utilization for the elderly would amount to a meaningful reduction in spending for the population as a whole. For this reason, preventive action has been a popular topic of conversation for ‘solving’ spending-related problems in the health industry. A major problem with this focus on preventive action is the reliance on changing health habits during youth as the primary effector of related reductions in medical needs. This is a poor representative of the true problem faced, which is more a function of the health of the population that is middle aged or elderly. For much of this section of the population, it is too late for them to avoid poor health due to cumulative lifestyle effects, so their focus needs to be rooted in managing any health problems that arise and maximizing their outcomes with the physiological challenges they have brought onto themselves. Despite its apparent closure with the defeat of the Republican-led overhaul plans for the Affordable Care act in 2017, the opportunity to enact health reform is highly cyclical, returning every several years. The opening of this “policy window” described by Kingdon (2014) is represented by the combination of problems faced by society at large, politics, and availability of potential policies to solve the problem. When the combination of popular demand for change, political agreement on the need for change, and the presence of policy propositions occur, the policy window opens, leading to the passage of legislation and the enactment of policy (Kingdon 2014). Due to the cyclical nature of the health policy window, reforms passed are less likely to be as comprehensive as the ACA was in 2010. Rather, health reform is an agenda that is accomplished incrementally, with the sum of the changes often representing significant effects. Stone (2012) underscores the importance of gradual reform due to the natural resistance of people to major changes. By introducing small changes over a longer time period, the fundamental system can be changed without nearly as much resistance. Fostering a stronger degree of patient involvement in their own health, as well as promoting exercise as a way to help manage or even avoid adverse conditions altogether represents a small, albeit highly important part in the continuous effort to reform health care.

Review Conclusions

Literature related to the effects of exercise on common outcomes associated with aging suggests that exercise can elicit marked improvements in a wide range of areas that impact the aging experience. Regular physical activity, even as simple as a brisk walk on a near-daily basis, can have a substantial impact on overall health of an elderly person.

Exercise represents a set of activities that nearly anyone has the capacity to complete which can have wide-ranging benefits for patient health. As the population ages, it may be necessary to promote or even incentivize participation in exercise programs to reduce the need for medical services and improve the ability of patients to self-manage their conditions to at least some degree. In addition to improving upon individual physical systems, one of the strongest arguments for regular exercise are increases in patient autonomy, a major factor in evaluations of quality of life among the elderly (Rowe 1987).

Hypothesis generation

Based on the literature review process, there were several hypotheses generated based on exercise and biological well-being (Table 1).

Table 1: Primary Hypothesis and Subsets		
Number	**Hypothesis**	**Importance**
H.1	Physical activity has a significant impact on maintaining health in old age.	n/a
H.1a	Physical activity improves musculoskeletal function	Maintain Functional independence
H.1b	Physical activity improves vascular health.	Blood distribution throughout body.
H.1c	Physical activity has a positive impact on body composition.	Strain on body increases likelihood of injury.
H.1d	Physical activity reduces onset of chronic diseases.	Many of the most prevalent chronic diseases in the US are preventable.
H.1e	Physical activity improves peripheral neurological function.	Maintaining functional independence.

Table 1: Central hypothesis generated from literature review, with subsets based on body systems covered during the review.

From this, another set of hypotheses were generated (Table 2).

Table 2: Secondary Hypotheses	
Number	**Hypothesis**
H.2	Physical activity can exert a measurable impact on overall health through biological improvements.

H.3	Activity-related improvements in health will lead to reduced medical service usage.
H.4	Remaining physically active improves a person's outlook on their health.
H.5	Due to other major non-physical factors, exercise will not exhibit a direct relationship with overall happiness and life satisfaction.
H.5a	Physiological health represents a meaningful contribution to life satisfaction and happiness.

Table 2: Additional hypotheses generated from the literature review. These were not tested in depth in the analysis, as they could only be tested if analysis rejected the null hypothesis of H.1a-e.

These are believed to be linked to biological health although not necessary directly. The hypotheses derived from the literature review guided the path of analysis that this study took.

Chapter 2: Study Design

Introduction

Based on the shortcomings found within literature on the subject, and area that has seen relatively little exploration within the study of aging has been how activities that fall outside the stricter parameters of exercise affect the health of older patient populations. The difficulty in attempting to quantify and assess the benefits of activities with such variability may be exceedingly difficult if not impossible, but accounting for them under the umbrella of remaining active is critical in determining a path forward for elderly patients who want to hold a greater stake in their continued health via maintaining 'active' lifestyles. The way such activities that fall outside of typical exercise parameters translate to supporting sustained or improved patient health are critical in assessing how patient time spent outside of exercise might supplement more concerted efforts at fitness, or to make up for any lack thereof given sufficient time spent on other active endeavors.

Primary Analyses

Patient-initiated health decisions are actions that an invested patient takes in an attempt to improve their health and improve medical outcomes, but that are not necessarily prescribed by a medical professional. These include both physical and mental components, although this study focused on the importance of physical habit inputs in health. Within this field, the biggest known individual-driven factors are dietary choices, exercise, and various other lifestyle choices like tobacco and alcohol consumption. This research focused on exercise, but accounted for other factors representing lifestyle inputs, given they were recorded within the selected database. The primary analysis in this study attempted to correlate increases in activity levels with biological outcomes in aging and elderly Americans. Secondary analyses lacked sufficient statistical power, but these secondary studies grouped study variables into discrete groups based on biological health, individual perceptions of health, physical activity with relevant lifestyle and socioeconomic controls, and two indicators of medical service usage. Based on a review of relevant literature, translational effects of exercise on overall patient health represents an area that has seen only small amounts of study, and even fewer within the context of generalized activity. Prior literature has pointed towards specifically targeted exercise as something that is able to produce statistically significant differences in health across a wide range of body systems. It has not, however, been generalized across all activities a person may participate in. Someone who does hours of gardening might consider themselves to be very active, and would show high weekly metabolic equivalent task time, but it is unknown whether this degree of generalization for activity can show meaningful changes in biology across individuals.

The effects of exercise on individual systems is a well-researched field with a large body of work, but the integration of the various effects on the body into a cohesive whole is an area that is only recently gaining traction within the health sciences (Friese 2013, Khoury 2010). Literary searches on the organ and individual system function yielded and abundance of studies, but no studies were found that attempted to describe how the benefits yielded on each individual system within the body affected the whole human.

Power analysis and criteria for success.

Study power was calculated using G*power software (Faul 2007). Effect size was determined by first assuming an expected R2 value of .05 or greater for the model with respect to each variable. Using Cohen's method, an estimated effect size, f2 was calculated to be 0.0526. This study used an alpha value of 0.10 in its assessment of whether a correlation met the minimum criteria for acceptance as being significant. Fifteen potential output variables were used in the primary analysis, and so a Bonferroni correction was used to account for this with the adjusted alpha value of 0.0066. Sixteen predictor variables were used in the model, with a sample size of 287, with study power calculated to be 0.8763. This is in line with literature estimates of desirable power of at least 80% (Das 2016). Further calculations involving an assumed alpha of 0.05 produced a power of 0.824 – still above the desirable 80 percent threshold. In the event that the coefficient of determination was to increase, there would be corresponding increases in implied power, ensuring satisfactory power even in instances where there was a very weak fit of 0.05. Similarly, increases in the alpha value also produced higher corresponding power. Criteria for success was established such that given one of several variables that would be categorized under one of the lettered subsets of H.1, that a statistically significant correlation between exercise and any one of the associated variables would be enough to satisfy the corollary to the hypothesis, and partially satisfy the full hypothesis. If greater than half of the subsets were supported by the analysis, then the overarching H.1 could be considered supported in a satisfactory manner.

Secondary Analyses

As alluded to prior, this study also includes secondary analyses that were conducted after preliminary results from the primary analyses were compiled. These analyses lacked statistical power, but they were performed regardless as the primary analysis left unanswered questions.

Health Services

One of the secondary analyses in this study attempted to find correlations between the usage of health services and physical activity levels. While all aspects of the United States health system are highly regulated, it is still subject to some degree of market forces, despite the true costs of care being mostly hidden by medical insurance (Pauly 2011). Due to the large projected increases in health service utilization in concurrence with the significant growth of elderly patients as a proportion of the national population, the costs of medical services are also expected to increase drastically to avoid shortages. After clarification of the strengths and weaknesses of exercise as a medical intervention, the next logical step along this pathway is to estimate how resultant changes in health would be reflected in need for medical services.

Service Utilization and medical costs

Insurance, whether government sponsored or private, acts as one of the main gatekeepers to health care. Due to the high costs of medicine, the majority of patients pay for medical services and medicine through their insurance provider, with those paying out of pocket for expenses being more of a rarity. Both groups of entities have a strong incentive to reduce costs, albeit for different reasons. The ability to identify clear physical benefits and link them to statistically significant decreases in service utilization can be used in conjunction with cost data for services rendered to estimate resulting changes in cost that may occur as a result of leading a more active life. While this step in the process may fall beyond the scope of this study, this study aims to lay the groundwork for similar studies, with the hope that they could impact the policymaking process.

Health outlook and Activities of daily living

In lieu of direct knowledge of biological function, there is a tendency of the individual to assess their health based on highly subjective self-assessments – i.e. how a person "feels." Someone who may be completely healthy biologically may perceive themselves to be unhealthy, or vice versa where a person who is very unhealthy biologically may still consider themselves to be healthy. One way to attempt to bridge such a gap between subjective and objective measures is through assessment of patient ability to perform activities of daily living (ADL's), which represent as set of activities that a person would need to be able to complete in order to live independently. ADL's present in several tiers, mainly as basic ADL's which typically involve ability to function by oneself around the home and intermediate ADL's, which encompass activities that normally fall outside the home with respect to physical and mental capability to perform actions within society at large. Within the context of a patient interview, these activities offer a good representation of patient function that a physician can use in the assessment of physical and mental abilities as they are sufficiently specific, while also being presentable in terms of the subjective function that the typical patient identifies with. The last of the secondary analyses attempted to find correlations between the individual's self-assessed health and their levels of physical activity.

Scope of the study

This study attempts to examine hypothesis H.1 and all its subsets (a-e). There is not sufficient statistical power to perform a full analysis on hypothesis H.2, hypothesis H.3, and hypothesis H.4 such that it would be possible to make any claims, so any exploration along those hypotheses would be considered parts of the secondary analyses. It is meant to look for meaningful interconnections between lifestyle choices and biological indicators of health, with secondary goals of making comparisons with individual health outlook and medical service usage. Hypothesis H.5 and H.5a, while important within the context of happy aging, will not be examined in any way, as they require the introduction of numerous psychological and sociological factors existing outside the scope of this study.

Data Collection

MIDUS database:

For this research work, utilizes a publicly available data series called Midlife in the US (MIDUS). MIDUS is a project funded by the National Institute on Aging, which is a subset of the National Institute of Health. The initial study was conducted in 1995 on a cohort of 7,108 participants, with several follow-ups conducted after the success of the first round. While initially intended as a study to assess psychological and social tendencies of aging Americans, the addition of quantitative physiological testing added a biological component, allowing for integrated analysis of biological data with psychosocial outcomes, and vice versa (Radler 2014). This study uses the biomarker dataset collected in conjunction with the follow-up study that ran from 2004-2006. While there is a newer biomarker dataset that was collected from 2011-2014, coding is not yet complete for the variable groups of interest, removing the possibility of analysis in this study. The collection of biomarker data in the follow-up to the original study grants the ability to study connections between biological information and psychosocial results. This can provide richer associations than the most recent study dataset, which was recorded using a new cohort and as a result would not be able to account for long-term effects that lifestyle disparities may impart. A combination of specific biomarker data from the MIDUS Biomarker study will be analyzed in combination with survey information from the parent study. The combination of these two data sets will allow for simultaneous analysis of biological data relating to physical activity, as well as any connections between more subjective metrics of health. When combined, the MIDUS main study and the biomarker dataset contain over 6,000 variables. This required careful selection of included variables, all of which have been backed by previous literature to have some relation under the broad umbrella of health. A unique aspect about MIDUS is that it is a combination of both quantitative measures and some more qualitative survey questions, within the same population sample. Because of this, it and similar data sets can be used to examine effects and produce conclusions that are considerably broader than most standalone studies are able to provide. It also allows for a vast range of either related or unrelated studies to be performed within the same dataset.

Matching and Filtering the Dataset

One of the first stages of data cleaning involved appending and matching the participants from the main study into those that also participated in the biomarker project. The biomarker dataset involved a series of medical tests performed on the participants. Among them, there is a blood test, a physical examination, a body scan, a sleep study, cognitive stress tests, and more. However, not all biomarker participants performed all the tests included in the study. In this study, the actual participants as a subset of those who participated in the biological tests was held constant across all respondents. Utilizing different sample populations for different tests would create results that would not be generalizable even within the MIDUS sample itself, let alone capable of extrapolation to the larger body of elderly in the US. The participants analyzed in this study not only performed all the tests and examinations used within this thesis, but also responded to all the survey questions of interest within the main study. MIDUS ID matching led to a sample size of 287 participants in the age range of 50 years to 86 years old.

Single Variables of Interest

Moving beyond the combined variables within the MIDUS biomarker dataset, there are several important standalone variables that can give important information about body function when compared against exercise habits. The MIDUS study performed several integrations of data they collected, creating composite variables for several areas. One such area was the construction of T-scores for the body composition scans. T-scores represent a “score” for bone strength, which involves a comparison with the bone density of a healthy 30-year old adult (National Osteoporosis Foundation 2019). The inclusion of a biological health dataset along with psychological and demographic information is one of the key identifiers that makes the Midlife in the US data series unique. This thesis utilized both datasets, relying heavily on the medical tests performed in order to drive the analysis forward. In addition to utilization of physical examination and body scan data, this study also considered several health indicators in terms of important biomarker values from the blood test portion of the database.

The majority of the biomarkers selected relate to biochemical indicators of muscular recovery within the blood, as a way to assess muscular recovery in the individual. These biomarkers were: blood n-telopeptide type 1 collagen, blood amino terminal propeptide type 1 procollagen, blood creatinine, and blood fibrinogen. All of these have been associated with supporting muscular recovery (Martini 2017). Muscular recovery is important within the context of health because it represents a known difficulty associated with aging (Martini 2017).

Other biomarkers were used as well, in addition to the biomarkers representing muscular recovery here. Additional biomarkers assessed were the concentration of Bone-Specific Alkaline Phosphatase, a protein that plays a significant role in adding calcium to bones and helps reinforce their structure, and urinary cortisol, which is often measured as a way to assess stress. The next single biomarker-based variable was insulin resistance, which was measured through a metric known as HOMA-IR (Yajnik 2015). Type 2 diabetes mellitus is largely defined by an individual's resistance to insulin, and so faring worse on a HOMA-IR could be indicative of where an individual stands in terms of healthy metabolism, prediabetes, or full-blown type 2 diabetes (American Diabetes Association 2019). Type 2 diabetes is a condition that while mostly avoidable, ravages the body far beyond the threat of organ failure with sugars too low and diabetic ketoacidosis with sugars too high (Martini 2017). It can also lead to conditions like vascular disease and renal failure to name just two, the latter of which can quickly become fatal (Burrows 2017). The final selected important biomarker variable within this study is urinary cortisol. Cortisol is one of the primary stress hormones, and prolonged periods of elevated cortisol levels may indicate high levels of stress and anxiety and reduced overall mental well-being (Martini 2017). The prior work validating their usefulness as being indicative of health in some way makes the selected biomarkers a good fit for this analysis. Given a significant activity-derived impact on the selected biomarkers, it could be inferred that there would be macro-scale change elicited in the body.

Health Coverage

One of the central questions of this thesis is not only elucidating relationships between exercise habits and potential biological health benefits for the sample population, but also how any associated changes might translate to higher level outcomes. This gives way to questions relating to the individual’s appraisal of their health, which are documented within the MIDUS main study. Questions about how physical activity and biological health might be related to a person’s perceived health and autonomy are covered by hypotheses H.2 and H.4.

Demographic Group

Near the age of 50, most children in the average family will be maturing into adults and do not need the same supervision and guidance that younger children and babies need. Additionally, the individual, in most cases, will likely be well-established in their respective careers, and perhaps thinking more about retirement since they are closer to retirement age than the age at which they may have joined the workforce full-time. This period before the true transitional period is one where the individual will likely be either considering their options, or actively planning them. Within this period, as their required time attending to the needs of children may wane, the parents find themselves with newfound free time that can be filled with any number of activities. Within this pre-transitional stage in their lives, they might seek to employ the remaining physical agency and energy to make changes in their lives they 'never had time' to do. It may be possible to take advantage of this malleable point in their lives to establish good practices that allow them to fully enjoy their later years. Promotion of new activities for aging Americans as they approach the twilight of their careers may offer a benefit to the long-term health and happiness of the aging individual.

Analysis Methodology

Variable groupings

In order to improve clarity, variables what represented independent variables at any point throughout the analysis were divided into groups based on shared characteristics. These groups are referred to in the following forms, or their rough equivalents: Physical activity and controls, biological outcomes, and individual health perceptions. Physical activity and controls are the combination of log of MET minutes, age, sex, race, insurance status, presence of existing chronic conditions, smoking status, diet, BMI, and household income.

The biological outcome grouping includes Neuromuscular function, joint health, chronic disease, vascular health in extremities, bone density, and several blood-based biomarkers. The blood-based biomarkers, as well as the systems they are known to represent are as follows: blood n-telopeptide type 1 collagen (tissue repair), blood amino terminal propeptide type 1 procollagen (tissue repair), Blood creatinine (tissue repair), blood fibrinogen (tissue repair), Urinary cortisol (stress), HOMA-IR (insulin resistance), blood triglycerides (vascular) and LDL cholesterol (vascular), and blood bone specific alkaline phosphatase (bone strengthening). Most of the blood-based tests were chosen as a way to assess effects on tissue repair and recovery, while several of the others were intended to strengthen the assessments of systems where there was a perceived weakness in the main system metrics.

The final grouping of variables was based on the individual's assessment of their health, their influence on their health, their appraisal of how health affects daily activities, and their overall independence. Table 2 contains all variables used within this study, their names in regression results tables, descriptions, and summary statistics for each variable.

Primary Analysis Regression Model

This study considered health as a combination of several contributing input types in the following form (Equation 1):

$$Biological\ Health = \beta_0 + \beta_1 * \ln(Activity) + \beta_2 * Age + \beta_3 * Sex + \beta_4 * Diet + \beta_5 * Income + \beta_7 * Chronic\ Conditions + \beta_8 * BMI + \delta_{insurance} + \delta_{race} + \mu$$

"Biological Health" is used here to represent several dependent variables of interest within the body. In this and all subsequent equations, μ represents the error of the model, and δ represents dummy variables for both race and health insurance status. Based on the literature review, it is believed that with increasing activity levels, the individual has the potential to improve a wide set of dependent variables. This study selected a series of independent variables that were believed to exert a potential impact on overall health, and regressed them versus Neuromuscular function, Joint health, Vascular health, Skeletal strength, Biomarkers related to muscular and bone recovery, presence of chronic conditions, and HOMA-IR insulin resistance index.

Secondary Analysis Regression Models

Secondary regressions were completed after the results were gathered after the results for the primary analyses were gathered. The goal of these regressions was to try to understand the connections between variables existing as part of each discrete grouping. The first of these "group" comparison was that of the initial physical activity model versus variables that reflected the self-appraisal of health and independence of an individual. Specifically, the individual's outlook regarding their health, as well as the individual's assessment of their ability to perform activities of daily living (ADL's). Also was the individual's appraisal of where their health locus of control lies – whether the individual has the ability to impact their own health. or whether health is outside of the control of the individual. The ordinary least squares regression equation for these could be represented as follows (Equation 2):

$$Health\ Outlook = \beta_0 + \beta_1 * \ln(Activity) + \beta_2 * Age + \beta_3 * Sex + \beta_4 * Diet + \beta_5 * Income + \beta_7 * Chronic\ Conditions + \beta_8 * BMI + \delta_{insurance} + \delta_{race} + \mu$$

These are listed as psychological impacts of health because they reflect the health of the respondent by their own appraisal, rather than through measurable biological tests performed. The next series of regressions preformed examined the health outlook of the individual, in the form of self-evaluations, functional autonomy, and locus of control with respect to their impact on health service utilization. This, operating under the premise that a person will be less likely to seek treatment if they do not believe they have health-related problems. Conversely, if a person believes they have health-related problems, they could be expected to seek treatment more often. Ordinary least squares regressions were performed according to the following form (Equation 3):

$$\begin{aligned}Service\ Utilization \\ &= \beta_0 + \beta_1 * Basic\ ADL's + \beta_2 * Intermediate\ ADL's + \beta_3 \\ &* Current\ Evaluation\ of\ health + \beta_4 \\ &* Future\ evaluation\ of\ health + \beta_5 \\ &* Health\ Locus\ of\ control\ is\ self + \beta_6 \\ &* Health\ locus\ of\ control\ is\ external\end{aligned}$$

From a policy perspective, one of the supremely important aspects of improved health is decreases in government spending, and the cost of medicine in general. Thus, regressions were performed comparing biological outcome variables as independent variables and Health service utilization variables as dependent variables. Ordinary least squares regression was used in this comparison as well. The equation for this regression took the following form (Equation 4):

$$Service\ Utilization = \beta_0 + \beta_1 * \ln(Activity) + \beta_2 * Age + \beta_3 * Sex + \beta_4 * Diet + \beta_5 * Income + \beta_7 * Chronic\ Conditions + \beta_8 * BMI + \delta_{insurance} + \delta_{race} + \mu$$

It was believed that by performing all four categories of regression, that any connections or lack thereof would be able to be determined along this pathway, originating with physical activity as the primary independent variable being evaluated. The last set of linear regressions compared the assessed components of biological health versus health outlook and service utilization. The purpose for these was to try to understand whether or not there was some connection between the biological variables studied on both perceptions of health hand service utilization. The following forms were used in these linear regressions (Equations 5 and 6):

$$Health\ Outlook = \beta_0 + \beta_1 * Neuromuscular\ function + \beta_2 * Joint\ health + \beta_3 * Vascular\ health + \beta_4 * Skeletal\ strength + \beta_5 * Ability\ to\ recover\ from\ injury + \beta_6 * Chronic\ conditions + \beta_7 * BMI + \beta_8 * Insulin\ resistance + \mu$$

$$Service\ Utilization = \beta_0 + \beta_1 * Neuromuscular\ function + \beta_2 * Joint\ health + \beta_3 * Vascular\ health + \beta_4 * Skeletal\ strength + \beta_5 * Ability\ to\ recover\ from\ injury + \beta_6 * Chronic\ conditions + \beta_7 * BMI + \beta_8 * Insulin\ resistance + \mu$$

The path of analysis taken considers several different pathways to service utilization, with the goal of understanding the logical progress from each set to the final target, understanding medical service utilization for the population with the highest medical service usage rate. Table 3 provides summary statistics of all variables used in the analysis.

Table 3: Summary of Study Variables

N=287 participants	Mean	std. dev.	min	25%	50%	75%	max
Log of METS	5.43	2.98	0.00	5.04	6.56	7.36	9.75
Age	64.30	8.23	51.00	57.00	62.00	70.00	84.00
Sex	1.49	0.50	1.00	1.00	1.00	2.00	2.00
Protein Consumption-weekly	9.01	2.87	2.50	7.00	9.00	11.50	16.50
Dairy consumption - yearly	922.32	2162.20	0.00	423.00	730.00	1095.00	36291.00
Sugared beverage Consumption - daily	1.40	0.96	1.00	1.00	1.00	1.00	5.00
Fruits and Vegetables - daily	2.80	0.82	1.00	2.00	3.00	3.00	5.00

Whole grains - daily	2.25	0.90	1.00	2.00	2.00	2.00	5.00
Primary Racial Origins: White	0.94	0.23	0.00	1.00	1.00	1.00	1.00
Primary Racial Origins: Black	0.01	0.10	0.00	0.00	0.00	0.00	1.00
Primary Racial Origins: Native	0.01	0.08	0.00	0.00	0.00	0.00	1.00
Total Household Income	69535.47	55449.72	0.00	34000.00	57250.00	89625.00	300000.00
Total Chronic conditions	4.57	2.82	0.00	3.00	4.00	6.00	18.00
Insurance Status	1.07	0.26	1.00	1.00	1.00	1.00	2.00
Smoker status	4.52	3.50	1.00	2.00	2.00	9.00	9.00
Body Mass Index	28.77	5.25	14.99	25.11	27.85	31.69	48.53
Neuromuscular composite score	5.17	6.14	0.00	0.00	0.00	12.17	15.00
Joint Health score	7.47	4.81	1.00	1.00	9.00	9.00	16.50
Blood n-Telopeptide type 1 collagen (nM BCE)	14.74	6.78	2.04	9.96	13.40	17.61	40.70
Blood Bone Specific Alkaline Phosphatase (UL)	28.49	10.23	11.94	21.52	26.49	33.09	77.38
Blood Amino terminal Propeptide type 1 Procollagen (ugL)	55.36	29.31	7.25	33.77	49.23	73.38	177.21
Urine Creatinine (mg/dL)	0.87	0.20	0.50	0.70	0.80	1.00	2.00
Urine Cortisol (ug/dL)	1.08	1.39	0.02	0.46	0.82	1.22	14.50
Blood Fibrinogen (mg/dL)	353.82	84.25	172.00	299.50	342.00	397.00	759.00
HOMA-IR Insulin resistance index	3.70	6.98	0.18	1.40	2.34	4.13	98.00
Blood Triglycerides (mg/dL)	129.81	78.53	37.00	76.00	109.00	153.50	689.00
Blood LDL Cholesterol (mg/dL)	100.59	34.82	16.00	76.00	96.00	121.00	213.00
Vascular Abnormalities	8.99	10.86	0.00	0.00	0.00	24.00	24.00
Total Femur T-score	0.95	0.16	0.60	0.84	0.94	1.04	1.43
Basic Activities of Daily living	1.25	0.59	1.00	1.00	1.00	1.00	4.00
Intermediate Activities of daily living	1.76	0.81	1.00	1.14	1.43	2.29	4.00
Health Locus of Control - self	6.22	0.80	1.25	6.00	6.50	6.75	7.00
Health Locus of Control - others	3.14	1.26	1.00	2.00	3.00	4.00	6.50
Current rating of health (1-10)	7.64	1.35	1.00	7.00	8.00	9.00	10.00

10- years ago rating of health (1-10)	8.31	1.60	3.00	8.00	9.00	9.00	10.00
10- years expected rating of health (1-10)	6.97	1.76	0.00	6.00	7.00	8.00	10.00
Life satisfaction (across domains)	8.01	1.14	3.00	7.50	8.13	8.75	10.00
Self-construal: Independence	5.15	1.08	1.33	4.33	5.00	6.00	7.00
Self-construal: Interdependence	4.68	1.13	1.00	4.00	4.67	5.33	7.00
Number of times seen MD (12 months)	3.55	3.38	0.00	1.00	3.00	5.00	29.00
Total number of medications	6.90	5.22	0.00	3.00	6.00	9.00	45.00

Table 3: Summary statistics of variables included within the study in any capacity. Includes the central metric of interest in the study, METS, all control variables included in the model, biological metric variables, health perception information, and medical service utilization information.

Independent variables

Metabolic Equivalent Task Minutes

Metabolic Equivalent Task (MET) minutes were used for each individual that responded to the activity portion of the biomarker survey as the independent variable of interest. Metabolic Equivalent Tasks are defined by the rate of oxygen consumption that an individual would experience versus normal oxygen consumption during the completion of a task (Jetté 1990). METS accounts for weight and sex in its calculation and is a common method by which people standardize their 'activity level' across different distinct activities. They can be calculated by measuring the oxygen consumed by the body in performing an activity, versus the resting rate of oxygen consumption in the individual (Jetté 1990). After sufficient data collection, it is possible to establish a standard MET value for a given activity for each distinct intensity level. Tables exist within literature outlining MET values for large numbers of common tasks, across several intensity levels (Jetté 1990). METS have been used in similar studies in the past, and MET minutes were constructed within the MIDUS database as a result of individual reporting of specific activities, their intensity, and their duration over the course of a typical week (Adahl 2003, Ostendorf 2018). While there are other metrics for physical activity, it has been noted that there is no single ideal method that can assess every aspect of activity and energy expenditure (Ndahimana 2017). Since this is the only integrated exercise metric calculated within the study, we are forced to assume that the researchers that created the MIDUS database identified it as the metric that best fit their study. This analysis utilized ordinary least squares regression. The initial independent variables include age, sex, number of chronic conditions, diet, race, household income and the natural log weekly metabolic equivalent task (MET) minutes, and BMI. After performing regression with both the linear form and the linearized logarithmic form METs, the log form exhibited a better goodness of fit for the response variable in almost every instance. Because of this, it was retained in the model as the preferred representation of exercise. This decision was also supported by literature, which noted diminishing returns as exercise increased (Wasfy 2016, Young 2016). After combining the two datasets by matching the unique MIDUS ID of each individual, further filtering out individuals who had inapplicable values for the set of examined variables was performed. The total study population had a sample size of n= 287 participants.

Controlling for additional factors

In this analysis, it was necessary to account for other lifestyle factors, so as to avoid bias associated with variables omitted from the model. In order to account for this, each regression was treated as a multivariable regression, with a clearly defined set of included independent variables. This was done in acknowledgement of their potential impact on the input variable that I wanted to measure, and their inclusion was intended to prevent factors from those other inputs being mistaken for impacts caused by the activity variable. While not every input included within the multiple regression for each variable was purely a factor of personal choice, the undeniable differences that exist based on biological factors outside the individual's locus of control needed to be accounted for to ensure rigor of this analysis. Several factors were left out of the analysis that are acknowledged in literature to have a strong bearing on health. These factors were typically the genetic component of health - family history trends for certain diseases as well as non-pathological tendencies (Genetic Alliance 2009). While exclusion of family history from the analysis removes some of the ability to account for genetic factors, there is one glaring problem inherent in including family history in an analysis of health and personal choice - that the choices made by the individual family members, while perhaps sharing similarities to the individual themselves, are unable to be fully accounted for.

While family history of a condition may indicate a higher risk of condition onset for an individual, there is no way to truly delineate between personal choice and the genetic component of health without including the family members in the study.

Diet

An important factor in health, as noted in literature, is the dietary choices of the individual, (Skerrett 2010) In order to perform thorough analysis, it was required that dietary choices of the study participants be taken into account. The MIDUS biomarker sample includes several dietary indicators. One particular point of focus was calcium intake, with the focus on consumption of dairy products. Within the analysis, servings of dairy were integrated into a single whole, which was intended to act as an indicator of calcium consumption. Based on the question setup, it was necessary to extrapolate to use over a whole year period so that consumption habits were appropriately scaled vs one another. The next dietary consideration measured was caffeine consumption, in the form of coffee, caffeinated tea, or other caffeinated beverages. One shortcoming within dietary reporting was the distribution of beverages that were both sugared and caffeinated, versus those that were only sugared in the reporting of 'other' caffeinated beverages. This is a significant oversight when assessing the impact of dietary choices on any variable due to known strong overlap between the two categories, but it is especially troublesome for this analysis, since dietary choices have been noted in literature as having important influences on various aspects of health (HHS 2017). As such it is difficult to get the full picture of the impact on dietary choices. Additionally, there is no separation in reporting of weekly consumption of fruits and vegetables. Despite large nutritional differences between the two food types, their inclusion as a single variable in this database further complicates the ability to accurately include the true dietary contribution (Slavin 2012). In spite of this, nutrition has been noted as being an important component in maximizing the effects of any physical activity (Vuori 2001) and so the exclusion of dietary habits from the regression model was not a feasible option. The final major category within participant dietary choices was protein consumption. Rather than include each individual protein type listed into the regression model, the four types - fatty meats, lean meats, fish, and non-meat protein - were condensed into a single combined value of weekly servings of any recognized protein source. While this may reduce the ability to measure impacts of other nutrients specific to each protein group (iron in beef, certain fats in fish), there is likely an insufficient sample size for micronutrient differences among protein types to exert a significant impact. In the event of this, it becomes better for the sake of simplicity to include one protein consumption variable instead of four.

Age

Age is an undeniable factor in health as an input variable and was added as a control variable in the grouping related to physical activity. (Yashin 2007). Baseline effects of aging tend to accelerate functional decline, and so accounting for health differences that each additional year might bring would be critical in clarifying any effects that the difference in activity level might create.

Gender/sex

There exist considerable biological differences among humans on the basis of sex. Within this, men and women diverge considerably as age advances (Wiacek 2010). An accurate picture of the body systems examined for the effects of physical activity would be an impossibility, especially in areas like skeletal health where bone composition and strength are already a known major difference on the basis of sex but diverge further with age, with osteopenia and osteoporosis disproportionately affecting women (Alswat 2017).

Presence of Chronic Illness

Due to the reporting method of chronic illness within the study, it was not ideal for use as an output variable. The survey questions were framed as "Have you ever had condition X?" Without the same format of questions in the original study, as well as the lack of biomarker information in the original study, there was no way to assess any form of differences in disease onset that may or may not have occurred from differing activity levels. Chronic conditions do, however, represent a valuable input variable in terms of assessing systemic health. Presence of chronic diseases and conditions is a strong indicator that the body would fare worse in various tests, as opposed to the condition-free counterparts. Ultimately, it was used as both a control for the biological outcomes of exercise, but also treated as a biological outcome in and of itself. In order to do this, the activity and control variable group was regressed against number of chronic diseases, while excluding the number of chronic diseases from the list of control variables.

Body Mass Index (BMI)

Like chronic conditions, body mass index represents both a health outcome and a health effector. BMI is measured as the weight of an individual in kilograms divided by the square of their height in meters. This represents an attempt to get a mass per cross-sectional area of the individual. BMI tends to misrepresent people on the higher end of the body fat spectrum who could be categorized as health despite being quite unhealthy, as well as people who are on the lower end of the body fat spectrum who would be categorized as being unhealthy despite being healthy. Both conditions represent outliers. Overall, BMI is generally accepted as a good estimator for what might be a healthy body composition in an individual (Martini 2017). Also, similarly to number of chronic conditions, BMI was used as a control in the activity and controls group to assess biological outcomes, but also as a biological outcome itself. Regression assessing impacts of activity on BMI using the activity and controls group were done with BMI excluded from the control set.

Racial and Economic Factors

In order to reduce the potential for omitted variable bias, race and household income were accounted for as control variables within the analysis. Both factors are known to represent factors contributing to worse health, with the poor and people of color typically seeing worse outcomes (Artiga 2016).

Health insurance

Health insurance is one of the primary methods by which Americans can pay for health services. Lack of insurance can create a significant barrier to medical care. Because of this, it is necessary to include control for any effects that coverage, or lack thereof, might cause.

Smoking

Smoking is viewed as one of the worst things a person can do for their health and represents nearly one out of five deaths annually in the US (CDC 2017). It is typically mentioned in the same breath as alcoholism, which is another significant effector of health problem in the United States. Within this dataset, alcoholism is included within chronic condition, and as such is already accounted for in terms of representation within the statistical analysis. Smoking and tobacco use, however, is not subject to similar representation within the dataset, so it needed to be included separately.

Dependent Variables

Neurological composite

Neuromuscular function was assessed via a physical examination of the study participant. In this, several tests were performed. The first test performed was looking for weakness in extremities. The next set of neuromuscular assessments centered around sensation in the extremities across a number of different sensation types. The final set of neuromuscular tests were reflex tests which assessed magnitude and type of response present for six different common reflex locations on the body. Values were assigned based on whether an individual was normal in each category or whether they showed abnormalities. The 'normal' condition was assigned an arbitrary value, while the 'abnormal' value was assigned a zero. Each subset of the particular group was then assigned a value where the 'normal' assessment was equal to the overall 'normal' divided by the number of subgroups, while the presence of abnormalities was assigned a value of zero. When added across all variables for a particular group, the result was a sliding scale of values where the lack of any abnormalities was assigned the highest possible score, while the presence of a single abnormality in one of the extremities would be the maximum score, minus the value missed due to a zero for an abnormality instead of normal function.

An example of this method exists in the direct neuromuscular component, which assessed motor strength, motor tone, motor volume, touch sensitivity, and presence of muscular spasms. Those who had completely normal functionality were assigned a value of five due to the presence of five subsections, which represented the maximum attainable value in this component of the neurological function composite. Therefore, completely normal functionality in each of the five subsections could have a maximum value of one. Since each subsection assessed the response for all four extremities, each extremity counted for 0.25 towards the final aggregate. A person that experienced spasms in one of their arms, but was otherwise completely normal within the neuromuscular component, therefore, would result in a value of 4.75 for their neuromuscular functionality component of the neurological aggregate. The same process was followed for neurological sensations, which consisted of five subcategories as well: light touch, pin prick, temperature, proprioception, and vibration. Each was weighted in the same manner, resulting in a maximum attainable value of five for the sensation component as well. Reflexes were constructed to match the maximum value of five, but differences in reporting of the variables was necessary. The reflex component was measured in terms of severely reduced response, reduced response, normal response, heightened response, and strongly heightened response, and clonus. Clonus is indicative of neurological damage, so it was given the lowest possible score where present (Boyraz 2015). Reflex tests were performed on biceps, quadriceps, ankles, and for plantar dorsiflexion. They were also performed for left and right sides of all but dorsiflexion, which was only measured for a single foot. Each of the three sections within this neurological function aspect of the physical – neuromuscular function, reflexes, and sensation in extremities – was given equal weight in the overall aggregate. Although the case could certainly be made that one subset of peripheral neurological function might have slightly greater importance versus the other areas, they were given equal weight to try to avoid bias in the results.

Joint health composite

Creation of an overall joint health composite followed a similar form to the construction of the neurological aggregate. After assessing whether joints were normal or showed abnormalities, joints were broken into five subcategories: deformities, crepitation, range of motion problems, swelling, and tenderness. Joint subcategories were divided into based on location: upper central, upper proximal, upper distal, lower central, lower proximal, and lower distal. The combined maximum score was defined as fifteen, with each measured component of joint health contributing a maximum value of three to the total. While these values are somewhat arbitrary in their magnitude, they attempt to represent a total body picture, versus analysis of each individual joint, which would not be possible within the limits of the selected data. The whole-body approach mirrors that of using Metabolic Equivalent Tasks (METS) as a measure of physical activity. METS loses location specific information of how each individual exercise may have affected a particular region, but it standardizes the effects of each activity across the entire body in terms of overall impact. Construction of composites in this analysis sought to achieve the same end – the regional effects were eschewed in favor of assessment of whole-body effects in both joint health and neurological function.

Vascular Health in Extremities

The physical examination portion of the dataset assessed several indicators of vascular health in extremities. These were: presence of varicosities, indicators of venous stasis, edema, and unilateral clubbing. Each of these were given equal weight and added based on whether or not they were present. An individual with none of the conditions would result in a value of four, while an individual with all of the indicators present would have a value of zero in their assessment of vascular health in extremities. Body Mass Index. Body mass index represents the one of the simplest measures of body composition. It assumes that the person being measured is roughly average in terms of body fat percentage, and effectively standardizes weight against height. Higher BMI values are typically associated with a number of health-related problems, so it was necessary to view it as a target indicative of biological health.

Chronic disease

Chronic disease represents both an effector and an outcome in terms of biological health. Limitations on functional capacity arising from chronic disease can reverberate across other body systems, resulting in worse outcomes in areas that on a surface level may follow separate pathways. An example that might better illustrate this is that a person with chronic kidney failure could be expected to experience a degree of edema in the extremities. The excess fluid in the form of edema can alter vascular function by exerting additional pressure inward on blood vessels, and lead to poor circulation in the extremities, leading to reduced overall tissue health as a result of reduced vascular function.

Blood-based biomarkers

Blood testing offers considerable insight into the inner workings of the body. Selected biomarkers were chosen based on identification as being important to one or more of the body systems identified within the literature review. The reasoning behind these choices was, therefore, that changes in biomarkers might be noticeable as a result of exercise, even if higher level results might not be seen.

Bone Density and T-Score

Bone density and T-score represent the same attribute – the strength of an individual's bones in terms of their mineral composition. The only difference between the two is that T-score represents bone density standardized to that of a healthy, same-sex 30-year old. A particularly low T-score, being less than -2.5, is used as a direct diagnostic method for osteoporosis.

Activities of Daily Living

Translational outcomes were represented in the form of Activities of Daily living composites (ADL), which were divided into several subcategories - Basic ADL's and Intermediate ADL's. Basic ADL's were comprised of dressing oneself, climbing a flight of stairs, and walking one block (MIDUS Constructed Variables Documentation). Intermediate ADL's encompassed a larger set of activities, including carrying groceries, bending over, climbing several flights of stairs, walking several blocks, walking more than a mile, performing vigorous activity such as running or lifting heavy objects, and moderate activity such as bowling and vacuuming (MIDUS Constructed Variables Documentation).

Health Locus of Control

Health locus of control represents an individual's belief in the influence they have over their health, as described in MIDUS documentation. The purpose of including locus of control in an evaluation of a person's perception of their health can be useful in examining relationships between how they appraise their health, and what they do to improve it if they evaluate it negatively. This is represented in terms of scales that assess whether the participant believed that they could exert a major impact on their health as well as their belief that outside forces could exert a major impact on their health. These two are not necessarily mutually exclusive.

Self-evaluation of health

Self-evaluation of health has been shown to be a good predictor of actual health (Gordon 1991). It also represents a motive for medical service utilization. A person who evaluates their health as poor, irrespective of actual function, would express a greater need for medical care, while a person who rates their health as good could be similarly expected to seek lesser medical care (Scheunermann 2011).

Independence and Interdependence

Self-construal of independence and interdependence were viewed as high-level health outcomes. While these include mental aspects along with physical aspects, they are important in terms of an individual's assessment of their autonomy. Perceived independence is highly valued by aging individuals (Monin 2014), so a baseline health plan for aging individuals would likely include actions that promote retention of independence.

Variable correlations

With the selected variables a correlation matrix was constructed to assess for potential collinearities between independent and dependent variables. The correlation matrix of the variables found several that were highly correlated, as was expected due to the subject matter of the study itself. While every attempt was made to avoid co-linear variables within the regression models, it was not entirely unavoidable (Table 4). One such example was the correlation between number of chronic conditions and number of medications (Table 4). Since diagnosis with a chronic disease is typically done as part of a visit with a physician and any associated testing, it stands to reason that such instances would lead to the prescription of some form of medications for condition management more often than not.

Table 4: Correlation Matrix of Variables Used in the Study (Part 1 of 2):

	METS	Age	Sex	Dietary Protein	Dietary Dairy	Daily SSB	Dietary Fruit & Veg.	Dietary Whole Grains	Race: White	Race: Black	Race: Native	Income	Number of chronic conditions	Health Insurance Status	Smoking Status	BMI	Neuro Function	Joint Function	Blood n-Telopeptide Type 1 collagen	Bone Specific Blood Alkaline Phosphatase	Blood Amino terminal Propeptide Type 1 Procollagen
METS	1	0.08	-0.03	0.01	0.02	0.05	0.16	0.13	0.06	-0.11	0.08	0.08	-0.12	0.04	0.08	-0.19	-0.02	0.02	0.09	0.09	0.07
Age	0.08	1	-0.05	-0.07	0.11	-0.1	0.09	0.12	0.05	0.03	-0.04	-0.27	0.28	-0.17	0.04	-0.08	-0.06	0.15	-0.07	0.04	-0.13
Sex	-0.03	-0.05	1	-0.12	0.07	-0.09	0.18	0.02	-0.07	0.11	0.09	-0.17	0.11	0.1	0.04	-0.16	0.01	0.06	0.01	0.04	0.15
Dietary Protein	0.01	-0.07	-0.12	1	-0.01	0.08	0.21	0.11	0.06	-0.05	-0.06	-0.03	-0.09	-0.05	0.15	0.14	0.04	-0.02	0.06	0.06	0.03
Dietary Dairy	0.02	0.11	0.07	-0.01	1	-0.02	0.13	-0.06	0.01	0.02	-0.01	-0.07	0.08	-0.01	0.09	-0.06	0.09	-0.08	-0.07	0.01	-0.1
Daily SSB	0.05	-0.1	-0.09	0.08	-0.02	1	0.04	0.16	-0.09	0.03	0.01	0	0	-0.02	0.13	0.13	-0.1	0.05	-0.01	-0.05	0.01
Dietary Fruit & Veg.	0.16	0.09	0.18	0.21	0.13	0.04	1	0.26	0.09	-0.06	-0.08	-0.07	0.18	-0.08	0.12	0.03	0.16	-0.01	-0.01	0.05	-0.07
Dietary Whole Grains	0.13	0.12	0.02	0.11	-0.06	0.16	0.26	1	0.07	-0.03	-0.02	-0.05	0.14	-0.09	0.14	0.02	-0.06	0.1	-0.01	0.11	0
Race: White	0.06	0.05	-0.07	0.06	0.01	-0.09	0.09	0.07	1	-0.42	-0.34	0.05	0.09	-0.11	-0.03	-0.03	0.09	-0.07	0.06	0.05	-0.12
Race: Black	-0.11	0.03	0.11	-0.05	0.02	0.03	-0.06	-0.03	-0.42	1	-0.01	0	0.04	-0.03	0.06	0.07	-0.02	-0.02	-0.09	-0.1	0.04
Race: Native	0.08	-0.04	0.09	-0.06	-0.01	0.01	-0.08	-0.02	-0.34	-0.01	1	-0.06	-0.09	0.3	-0.06	-0.11	0.02	-0.04	0.01	0	0.06
Income	0.08	-0.27	-0.17	-0.03	-0.07	0	-0.07	-0.05	0.05	0	-0.06	1	-0.09	-0.15	0.03	0	-0.1	0.02	0	-0.06	0.02
Number of chronic conditions	-0.12	0.28	0.11	-0.09	0.08	0	0.18	0.14	0.09	0.04	-0.09	-0.09	1	-0.1	-0.08	0.12	-0.05	0.11	-0.06	-0.07	-0.06
Health Insurance Status	0.04	-0.17	0.1	-0.05	-0.01	-0.02	-0.08	-0.09	-0.11	-0.03	0.3	-0.15	-0.1	1	-0.12	0.06	0.01	-0.02	0.03	0.09	0.01
Smoking Status	0.08	0.04	0.04	0.15	0.09	0.13	0.12	0.14	-0.03	0.06	-0.06	0.03	-0.08	-0.12	1	-0.02	0	-0.04	0	0.02	-0.02
BMI	-0.19	-0.08	-0.16	0.14	-0.06	0.13	0.03	0.02	-0.03	0.07	-0.11	0	0.12	0.06	-0.02	1	0.02	0.02	-0.09	0.08	-0.05
Neuro Composite	-0.02	-0.06	0.01	0.04	0.09	-0.1	0.16	-0.06	0.09	-0.02	0.02	-0.1	-0.05	0.01	0	0.02	1	-0.42	-0.04	-0.09	-0.07
Joint Composite	0.02	0.15	0.06	-0.02	-0.08	0.05	-0.01	0.1	-0.07	-0.02	-0.04	0.02	0.11	-0.02	-0.04	0.02	-0.42	1	0.01	0	0.08
Blood n-Telopeptide type 1 collagen	0.09	-0.07	0.01	0.06	-0.07	-0.01	-0.01	-0.01	0.06	-0.09	0.01	0	-0.06	0.03	0	-0.09	-0.04	0.01	1	0.41	0.47
Bone Specific Blood Alkaline Phosphatase	0.09	0.04	0.04	0.06	0.01	-0.05	0.05	0.11	0.05	-0.1	0	-0.06	-0.07	0.09	0.02	0.08	-0.09	0	0.41	1	0.41
Blood Amino terminal Propeptide type 1 Procollagen	0.07	-0.13	0.15	0.03	-0.1	0.01	-0.07	0	-0.12	0.04	0.06	0.02	-0.06	0.01	-0.02	-0.05	-0.07	0.08	0.47	0.41	1
Blood Creatinine	-0.03	0.13	-0.51	0.05	0.03	0.18	-0.03	0.01	0	-0.02	-0.07	0.12	0.01	-0.04	-0.05	0.13	-0.01	0.01	0.04	-0.12	-0.08
Urinary Cortisol	0.1	0.04	-0.1	0.08	-0.06	-0.02	-0.08	-0.06	0.08	-0.06	-0.01	0	-0.11	-0.02	0.1	0.01	0.05	-0.07	0.09	0.23	-0.02
Blood Fibrinogen	-0.07	0.03	0.19	-0.07	0	-0.04	-0.05	0.04	0.05	0.02	-0.07	-0.07	0.02	0.16	-0.11	0.09	-0.16	-0.11	0.05	0.19	0.11
HOMA-IR	-0.03	-0.05	-0.04	0.05	-0.02	-0.02	-0.07	-0.03	0.01	0.01	-0.02	0.03	0.02	-0.02	-0.04	0.1	0.07	-0.14	0.08	0.1	0.09
Blood Triglycerides	-0.13	-0.06	-0.13	0.08	-0.04	0.04	-0.08	-0.02	0.02	-0.01	-0.04	-0.11	0.14	0.07	0.04	0.36	0.08	0.07	-0.05	-0.01	-0.11
LDL Cholesterol	0.04	-0.2	0.18	-0.06	0	-0.07	-0.09	0.02	0	-0.06	0.1	-0.12	-0.15	0.14	-0.03	-0.07	0.01	0.03	0.13	0.1	0.12
Vascular Composite	-0.04	-0.06	0.01	0.07	0.06	-0.09	0.14	-0.05	0.08	-0.01	0.02	-0.11	-0.09	-0.01	0	0.01	0.97	-0.41	-0.06	-0.1	-0.08
Bone T-score	-0.03	-0.06	-0.52	0.17	-0.03	0.2	0.01	0.01	0	0.02	-0.13	0.18	-0.12	-0.05	0.03	0.42	0.06	-0.07	-0.18	-0.05	-0.13
Basic ADL	-0.16	-0.01	0.1	0.04	0.13	0.06	0.03	0	-0.02	-0.04	-0.04	-0.11	0.24	0.05	-0.11	0.21	-0.13	0.15	0.09	0.03	0.07
Intermediate ADL	-0.2	0.14	0.14	0.01	-0.01	0.05	-0.02	0.06	0.02	-0.05	0.02	-0.13	0.35	0.08	-0.1	0.22	-0.1	0.16	0.07	0.01	0.03
Health LOC : Self	0.22	0.08	0.15	-0.1	0.05	-0.01	0.14	0.06	-0.01	-0.01	0.02	0.06	-0.11	-0.06	0.15	-0.22	-0.12	0.15	0.02	0.13	0.04
Health LOC: Others	0.01	-0.01	0.06	-0.16	0.03	-0.04	0	-0.01	-0.05	-0.07	0.07	-0.19	0.02	0.19	-0.05	-0.02	-0.04	0.07	0.01	0.08	0.01
Rating: current health	0.03	0.09	0.06	-0.02	-0.05	-0.05	-0.01	0.1	-0.12	0.13	0.05	0.04	-0.19	-0.1	0.2	-0.13	0.04	-0.04	0	-0.01	0.05
Rating: health 10 years ago	0.06	0.19	0	0.01	0.03	0.03	-0.02	0.06	-0.11	0.09	0.04	0.01	0	0	0.07	-0.06	-0.04	-0.05	0.1	0.05	0.09
Rating: Health in 10 years	0.03	-0.1	0.09	0.01	-0.08	0.05	0.03	0.03	-0.1	0.08	0.03	0.16	-0.19	-0.04	0.16	-0.04	0	-0.05	0.01	-0.03	0.03
Life Satisfaction	0.04	0.23	0.04	-0.03	-0.09	-0.02	0.02	0.09	-0.06	0.04	0.03	0.01	-0.1	-0.15	0.18	-0.1	-0.08	-0.08	-0.01	0.03	0.02
Rating: Independence	0.01	0.09	0.09	-0.02	0.09	0	0.12	0.04	-0.01	0.08	0.01	-0.1	0.08	0.1	-0.1	0.1	-0.01	0.08	-0.05	0.1	-0.02
Rating: Interdependence	-0.08	-0.02	0.02	0	0.05	0.03	-0.01	0	-0.06	0.02	-0.04	-0.03	-0.04	-0.04	0	0.02	-0.08	0.03	-0.01	0.04	0.09
Physician Visits	-0.05	0.14	0.05	0.01	0.06	-0.07	0.05	0.05	0	-0.01	-0.06	-0.12	0.21	-0.09	-0.11	0	0.02	-0.04	0.09	0.03	0.14
Number of Medications	-0.06	0.17	0.2	-0.09	0.04	-0.04	0.11	0.08	-0.01	0.09	-0.06	0.06	0.53	-0.14	0.05	-0.01	-0.11	0.1	0	-0.03	0.03

Table 4: Correlation Matrix of Variables Used in the Study (Part 2 of 2):

	Blood Creatinine	Urinary Cortisol	Blood Fibrinogen	HOMA-IR	Blood Triglyc-erides	LDL Cholest-erol	Vascular Composite	Bone T-score	Basic ADL	Interm-ediate ADL	Health LOC: Self	Health LOC: Others	Rating: current health	Rating: health 10 years ago	Rating: Health in 10 years	Life Satisfaction composite	Rating: Indepe-ndence	Rating: Interdep-endence	Physician Visits	Number of Medications
METS	-0.03	0.1	-0.07	-0.03	-0.13	0.04	-0.04	-0.03	-0.16	-0.2	0.22	0.01	0.03	0.06	0.03	0.04	0.01	-0.08	-0.05	-0.06
Age	0.13	0.04	0.03	-0.05	-0.06	-0.2	-0.06	-0.06	-0.01	0.14	0.08	-0.01	0.09	0.19	-0.1	0.23	0.09	-0.02	0.14	0.17
Sex	-0.51	-0.1	0.19	-0.04	-0.13	0.18	0.01	-0.52	0.1	0.14	0.15	0.06	0.06	0	0.09	0.04	0.09	0.02	0.05	0.2
Dietary Protein	0.05	0.08	-0.07	0.05	0.08	-0.06	0.07	0.17	0.04	0.01	-0.1	-0.16	-0.02	0.01	0.01	-0.03	-0.02	0	0.01	-0.09
Dietary Dairy	0.03	-0.06	0	-0.02	-0.04	0	0.06	-0.03	0.13	-0.01	0.05	0.03	-0.05	0.03	-0.08	-0.09	0.09	0.05	0.06	0.04
Daily SSB	0.18	-0.02	-0.04	-0.02	0.04	-0.07	-0.09	0.2	0.06	0.05	-0.01	-0.04	-0.05	0.03	0.05	-0.02	0	0.03	-0.07	-0.04
Dietary Fruit & Veg.	-0.03	-0.08	-0.05	-0.07	-0.08	-0.09	0.14	0.01	0.03	-0.02	0.14	0	-0.01	-0.02	0.03	0.02	0.12	-0.01	0.05	0.11
Dietary Whole Grains	0.01	-0.06	0.04	-0.03	-0.02	0.02	-0.05	0.01	0	0.06	0.06	-0.01	0.1	0.06	0.03	0.09	0.04	0	0.05	0.08
Race: White	0	0.08	0.05	0.01	0.02	0	0.08	0	-0.02	0.02	-0.01	-0.05	-0.12	-0.11	-0.1	-0.06	-0.01	-0.06	0	-0.01
Race: Black	-0.02	-0.06	0.02	0.01	-0.01	-0.06	-0.01	0.02	-0.04	-0.05	-0.01	-0.07	0.13	0.09	0.08	0.04	0.08	0.02	-0.01	0.09
Race: Native	-0.07	-0.01	-0.07	-0.02	-0.04	0.1	0.02	-0.13	-0.04	0.02	0.02	0.07	0.05	0.04	0.03	0.03	0.01	-0.04	-0.06	-0.06
Income	0.12	0	-0.07	0.03	-0.11	-0.12	-0.11	0.18	-0.11	-0.13	0.06	-0.19	0.04	0.01	0.16	0.01	-0.1	-0.03	-0.12	0.06
Number of chronic conditions	0.01	-0.11	0.02	0.02	0.14	-0.15	-0.09	-0.12	0.24	0.35	-0.11	0.02	-0.19	0	-0.19	-0.1	0.08	-0.04	0.21	0.53
Health Insurance Status	-0.04	-0.02	0.16	-0.02	0.07	0.14	-0.01	-0.05	0.05	0.08	-0.06	0.19	-0.1	0	-0.04	-0.15	0.1	-0.04	-0.09	-0.14
Smoking Status	-0.05	0.1	-0.11	-0.04	0.04	-0.03	0	0.03	-0.11	-0.1	0.15	-0.05	0.2	0.07	0.16	0.18	-0.1	0	-0.11	0.05
BMI	0.13	0.01	0.09	0.1	0.36	-0.07	0.01	0.42	0.21	0.22	-0.22	-0.02	-0.13	-0.06	-0.04	-0.1	0.1	0.02	0	-0.01
Neuro Composite	-0.01	0.05	-0.16	0.07	0.08	0.01	0.97	0.06	-0.13	-0.1	-0.12	-0.04	0.04	-0.04	0	-0.08	-0.01	-0.08	0.02	-0.11
Joint Composite	0.01	-0.07	-0.11	-0.14	0.07	0.03	-0.41	-0.07	0.15	0.16	0.15	0.07	-0.04	-0.05	-0.05	-0.08	0.08	0.03	-0.04	0.1
Blood n-Telopeptide type 1 collagen	0.04	0.09	0.05	0.08	-0.05	0.13	-0.06	-0.18	0.09	0.07	0.02	0.01	0	0.1	0.01	-0.01	-0.05	-0.01	0.09	0
Bone Specific Blood Alkaline Phosphatase	-0.12	0.23	0.19	0.1	-0.01	0.1	-0.1	-0.05	0.03	0.01	0.13	0.08	-0.01	0.05	-0.03	0.03	0.1	0.04	0.03	-0.03
Blood Amino terminal Propeptide type 1 Procollagen	-0.08	-0.02	0.11	0.09	-0.11	0.12	-0.08	-0.13	0.07	0.03	0.04	0.01	0.05	0.09	0.03	0.02	-0.02	0.09	0.14	0.03
Blood Creatinine	1	-0.12	-0.08	-0.01	0.06	-0.11	-0.01	0.31	0.02	-0.02	-0.16	-0.03	-0.06	0.12	-0.11	-0.09	-0.03	0.03	0.05	0
Urinary Cortisol	-0.12	1	0.05	-0.03	-0.01	0.05	0.05	0.03	0.04	-0.03	0.06	0	0.07	-0.01	0.03	0.08	-0.05	-0.04	-0.12	-0.04
Blood Fibrinogen	-0.08	0.05	1	0.05	-0.02	0.09	-0.15	-0.07	0.15	0.17	-0.01	0.15	-0.01	0.07	-0.06	0.01	0.08	-0.06	0.13	0.01
HOMA-IR	-0.01	-0.03	0.05	1	0.1	0.01	0.04	0	0.04	0	-0.02	0.04	-0.05	-0.01	-0.08	0.02	-0.03	0.03	0.13	-0.02
Blood Triglycerides	0.06	-0.01	-0.02	0.1	1	0.06	0.08	0.21	0.19	0.19	-0.21	0.02	-0.07	-0.06	-0.09	-0.1	0.02	-0.03	-0.01	-0.05
LDL Cholesterol	-0.11	0.05	0.09	0.01	0.06	1	0	-0.23	-0.04	-0.09	0.08	0.07	0.07	0.01	0.01	-0.04	0.04	0.09	0.01	-0.18
Vascular Composite	-0.01	0.05	-0.15	0.04	0.08	0	1	0.07	-0.12	-0.09	-0.14	-0.04	0.04	-0.04	0.01	-0.07	-0.01	-0.08	0.03	-0.11
Bone T-score	0.31	0.03	-0.07	0	0.21	-0.23	0.07	1	-0.01	-0.06	-0.13	-0.03	-0.02	-0.01	0.02	-0.04	0	-0.02	-0.05	-0.15
Basic ADL	0.02	0.04	0.15	0.04	0.19	-0.04	-0.12	-0.01	1	0.74	0.02	0.16	-0.39	-0.07	-0.4	-0.21	0.09	0.07	0.18	0.2
Intermediate ADL	-0.02	-0.03	0.17	0	0.19	-0.09	-0.09	-0.06	0.74	1	-0.13	0.12	-0.42	-0.08	-0.48	-0.23	0.05	0.05	0.14	0.22
Health LOC : Self	-0.16	0.06	-0.01	-0.02	-0.21	0.08	-0.14	-0.13	0.02	-0.13	1	0.07	0.21	-0.01	0.19	0.3	0.1	0.03	-0.12	0.05
Health LOC: Others	-0.03	0	0.15	0.04	0.02	0.07	-0.04	-0.03	0.16	0.12	0.07	1	-0.22	-0.05	-0.28	-0.18	0.08	0.07	-0.06	-0.1
Rating: current health	-0.06	0.07	-0.01	-0.05	-0.07	0.07	0.04	-0.02	-0.39	-0.42	0.21	-0.22	1	0.2	0.73	0.69	0.06	-0.01	-0.04	-0.06
Rating: health 10 years ago	0.12	-0.01	0.07	-0.01	-0.06	0.01	-0.04	-0.01	-0.07	-0.08	-0.01	-0.05	0.2	1	0.05	0.15	0.08	0.02	0.11	0
Rating: Health in 10 years	-0.11	0.03	-0.06	-0.08	-0.09	0.01	0.01	0.02	-0.4	-0.48	0.19	-0.28	0.73	0.05	1	0.52	0.05	-0.06	-0.05	-0.01
Life Satisfaction	-0.09	0.08	0.01	0.02	-0.1	-0.04	-0.07	-0.04	-0.21	-0.23	0.3	-0.18	0.69	0.15	0.52	1	0.14	0.04	0.03	-0.02
Rating: Independence	-0.03	-0.05	0.08	-0.03	0.02	0.04	-0.01	0	0.09	0.05	0.1	0.08	0.06	0.08	0.05	0.14	1	-0.01	0.05	0.09
Rating: Interdependence	0.03	-0.04	-0.06	0.03	-0.03	0.09	-0.08	-0.02	0.07	0.05	0.03	0.07	-0.01	0.02	-0.06	0.04	-0.01	1	0.02	-0.06
Physician Visits	0.05	-0.12	0.13	0.13	-0.01	0.01	0.03	-0.05	0.18	0.14	-0.12	-0.06	-0.04	0.11	-0.05	0.03	0.05	0.02	1	0.17
Number of Medications	0	-0.04	0.01	-0.02	-0.05	-0.18	-0.11	-0.15	0.2	0.22	0.05	-0.1	-0.06	0	-0.01	-0.02	0.09	-0.06	0.17	1

Table 4: Correlation matrix of variables used in the study with associated correlation values. Increasingly red cells indicate positive correlations of increasing strength, and increasingly blue cells indicate negative correlations of increasing strength.

Secondary Analyses

As a follow-up to the initial analysis model which tried to quantify the effects of general activity on the health of several biological systems, several follow-ups were performed using the same ordinary least squares regression methods. The inconclusive results of the initial phase of the analysis led to additional comparisons, attempting to find whether the results of the biological effects assessment would be mirrored in terms of the higher-level translational target effects of interest. Confirmation of positive biological outcomes was expected based on the literature review, and the presence of very few significantly correlated variables gave rise to several additional questions. Addressing questions became the basis for what we believe to be the most meaningful results of this study (Figure 2).

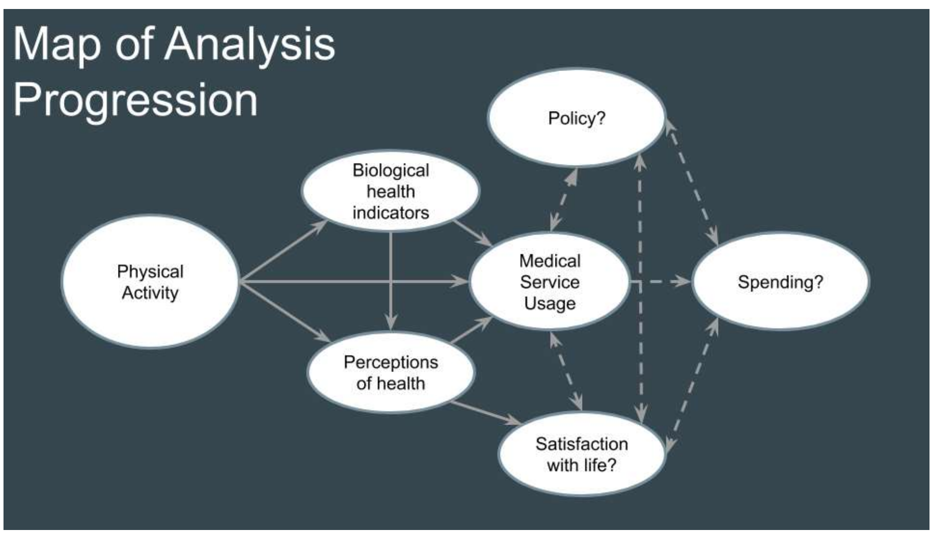

Figure 2: Map highlighting progression of analysis. This shows the progression of primary and secondary analyses throughout out the study. The dashed arrows represent

Activity and Controls versus Self-assessed health

After failing to provide clear evidence of health benefit through most of the biological aspect of the study, the psychological aspects of the first-stage independent variables were regressed against the respondents' personal appraisal of their health for the purpose of addressing any psychological effects that may be present in relation to health. This analysis was in search of correlations that might be indicative of whether the individuals had a very firm grasp on their health, as well as shedding some light into how a layperson's evaluation of their health might differ from biological metrics, which are used overwhelmingly in medical diagnostics to identify notable conditions.

Biological health versus Self-assessed health

Along the same lines of the individual's evaluation of health, an important step was identifying whether or not there was a statistically significant relationship between actual biological indicators of health, and the individual's assessment of their health. This analysis became necessary once a disconnect became apparent between the perceived health of the individual as a result of maintaining an active lifestyle and the impacts on their actual biological health that maintaining activity imparted. Once again, this attempt at connecting the two utilized ordinary least squares regression to assess the impact that biological function, as defined by the output variables from the primary analysis, might have on individual perceptions of overall health and autonomy.

Activity and Controls versus Health Service utilization

For the sake of thoroughness, the activity and controls variable group was regressed against the selected service utilization variables. Several of the control variables within the activity-focused variable grouping are known to be tied to service utilization based on previous work. It was not hypothesized that increasing general activity levels would be directly correlated to decreases in service utilization.

Self-assessed health versus Health Service Utilization

This set of regressions attempts to connect the prior regression results to the core public policy relevance of this study – the effects that maintaining a physically active lifestyle as the person ages may impart on usage of medical services and, as a result, medical spending in the elderly. This was done with the goal of gaining a better understanding on how a person's perception of their health in terms of their ability to function in day-to-day life might affect how often they express a need for medical services.

Biological Health versus Health Service Utilization

The purpose of this set of regressions was to identify any apparent trends existing between biological health and use of medical services. Here, biological health was represented by the set of constructed variables and biomarker information that acted as dependent variables in the primary analysis. This was done to see if there were any apparent trends within the sample population between biological health, as measured through medical tests, had a significant bearing on whether a person used medication or saw a doctor. Previous studies had shown that despite not knowing any of their measurable health-related attributes, that individuals had some general awareness of their overall health. After other analyses within this study found a disconnect between the biological and self-assessed health of the individuals within the study, it became of interest to further clarify the impact that the gap between health perception and reality might hold.

Chapter 3: Results

Primary Analysis Results

Activity and Controls versus Biological health Indicators

This study found that within the sample population studies and the age group in question, that increasing general activity levels, as measured by weekly Metabolic Equivalent Task minutes, had no statistically significant effect on most of the biological systems that were examined. Dependent variables that correlated with increasing activity were number of chronic conditions and BMI (Table 5). Examining neuromuscular function, joint function, bone density, vascular health, and several biomarkers related to muscular recovery found that within the sample studies, that increasing activity levels lacked a statistically significant correlation in all cases. Overall, physical activity offered very little in terms of correlations to biological benefits for the study cohort (Table 5).

Table 5: Activity and Controls vs. Biological Indicators

Description	Joint Health composite	Neuromuscular health composite	Bone T-score	Vascular composite	Blood Triglycerides	LDL Cholesterol	Blood n--Telopeptide type 1 collagen	Blood Bone-specific Alkaline phosphatase	Blood Amino terminal Propeptide type 1 procollagen	Blood Creatinine	Urinary Cortisol	Blood Fibrinogen	HOMA-IR insulin resistance	Total Chronic conditions	BMI
Log of METS	0.0438 (0.101)	-0.0703 (0.129)	-0.0009 (0.003)	-0.2097 (0.228)	-0.6253 (1.549)	0.6368 (0.711)	0.1707 (0.146)	0.2636 (0.217)	1.0144 (0.617)	-0.0048 (0.004)	0.0484 (0.03)	-1.3373 (1.741)	0.0531 (0.152)	-0.1256 (0.055)**	-0.3012 (0.105)***
Age	0.1101 (0.039)***	-0.0833 (0.05)*	0.0002 (0.001)	-0.1275 (0.088)	-1.0845 (0.598)*	-0.9127 (0.274)***	-0.0578 (0.057)	0.077 (0.084)	-0.3809 (0.238)	0.004 (0.001)***	0.0098 (0.011)	0.8952 (0.672)	-0.0423 (0.059)	0.0929 (0.021)***	-0.0536 (0.041)
Sex	1.1815 (0.616)*	-0.7143 (0.784)	-0.1398 (0.016)***	-1.1108 (1.389)	-17.483 (9.426)*	11.0897 (4.327)**	0.2258 (0.891)	1.4227 (1.324)	10.8046 (3.759)***	-0.1995 (0.023)***	-0.1403 (0.18)	37.7227 (10.596)***	-0.1638 (0.923)	0.6778 (0.3350**	-1.9211 (0.637)***
Protein Consumption - weekly	0.0329 (0.105)	-0.0334 (0.133)	0.0019 (0.003)	0.0448 (0.236)	1.0338 (1.601)	-0.5371 (0.735)	0.1579 (0.151)	0.1398 (0.225)	0.8168 (0.638)	-0.0009 (0.004)	0.0353 (0.031	-1.0673 (1.8)	0.1372 (0.157)	-0.1042 (0.057)*	0.2133 (0.109)*
Dairy consumption - yearly	-0.0002 (0.0013)	0.0002 (00083)	0.000001548 (0.00000345)	0.0002 (0.00043)	-0.0008 (0.002)	0.0004 (0.000547)	-0.0002 (00018)	0.0001 (0.00026)	-0.0011 (0.001)	0.000004759 (0.0000049)	-0.00004038 (0.0000388)	0.0007 (0.002)	0.000000356 9 (.0018)	0.00007005 (0.0000728)	-0.0001 (.00011)
Sugared beverage Consumption - daily	0.3112 (0.306)	-0.6927 (0.389)*	0.0185 (0.008)**	-1.1149 (0.69)	-2.3024 (4.68)	-2.6894 (2.148)	-0.0465 (0.442)	-0.8514 (0.657)	-0.0555 (1.866)	0.0337 (0.011)***	-0.045 (0.089)	-1.4867 5.26)	-0.2225 (0.458)	0.0932 (0.167)	0.5585 (0.320*
Fruits and Vegetables - daily	-0.4158 (0.387)	1.4905 (0.493)***	0.0186 (0.01)*	2.412 (0.872)***	-10.1966 (5.92)*	-4.7745 (2.717)*	-0.1605 (0.560	-0.1438 (0.831)	-3.9577 (2.36)**	0.0159 (0.014)	-0.1489 (0.113)	-8.9624 (6.654)	-0.713 (0.58)	0.4766 (0.21)**	0.381 (0.406)
Whole grains - daily	0.4447 (0.337)	-0.5228 (0.429)	-0.0009 (0.009)	-0.7912 (0.76)	-1.6765 (5.156)	3.3464 (2.367)	-0.1307 (0.487)	1.3582 (0.724)*	0.5942 (2.056)	-0.0018 (0.012)	-0.1125 (0.098)	9.0069 (5.795)	-0.1115 (0.505)	0.3154 (0.183)*	-0.005 (0.354)
Primary Racial Origins: White	-3.3477 (1.476)**	3.4759 (1.881)*	-0.0121 (0.038)	5.9963 (3.33)*	9.4961 (22.598)	6.3586 (10.373)	1.2241 (2.136)	0.2764 (3.174)	-14.5031 (9.01)	-0.0301 (0.054)	0.4833 (0.431)	16.167 (25.401)	0.2492 (2.213)	1.0177 (0.806)	-0.8887 (1.552)
Primary Racial Origins: Black	-5.1307 (3.134)	3.2243 (3.992)	0.0624 (0.081)	6.2824 (7.07)	-21.8193 (47.974)	-14.0857 (22.02)	-3.6659 (4.535)	-9.2731 (6.738)	-1.8495 (19.128)	0.013 (0.115)	-0.2976 (0.914)	4.5883 (53.9240)	0.8625 (4.697)	1.0776 (1.715)	3.2476 (3.2910
Primary Racial Origins: Native	-5.8535 (3.839)	5.9478 (4.891)	-0.1014 (0.1)	11.3451 (8.661)	6.6667 (58.772)	19.0912 (26.976)	-0.1483 (5.556)	-2.6046 (8.254)	-2.4011 (23.433)	-0.0906 (0.1410	0.2636 (1.12)	-122.2165 (66.062)*	-0.2359 (5.754)	-0.5304 (2.102)	-7.136 (4.0160*
Total Household Income	0.000008055 (0.00000554)	-0.0000156 (0.00000705) **	0.000000304 (0.000000144)**	-0.00002952 (0.0000125)* *	-0.0002 (0.0000848)* *	-0.0001 (0000389)**	-0.000002959 (0.00000801)	-0.00000565 (0.0000119)	0.00000391 (0.0000338)	0.000000380 2 (0.000000304)*	-0.00000063 (0.00000162)	0.000008442 (0.0000953)	0.000000357 4 (0.0000083)	0.000000837 2 (0.00000303)	- 0.000000744 1 (0.00000583)
Total Chronic conditions	0.1104 (0.111)	-0.1635 (0.141)	-0.007 (0.003)**	-0.4429 (0.25)*	4.6754 (1.698)**	-1.2774 (0.779)	-0.0055 (0.161)	-0.3867 (0.238)	-0.0572 (0.677)	0.00001576 (0.004)	-0.0362 (0.032)	-1.7263 (1.908)	0.1075 (0.166)	--	2.6184 (1.2350**
Insurance Status	0.3308 (1.184)	-0.7041 (1.508)	0.004 (0.031)	-2.4316 (2.671)	12.2512 (18.124)	4.5934 (8.319)	0.6012 (1.713)	3.0965 (2.545)	-5.5996 (7.227)	0.0464 (0.044)	-0.0721 (0.345)	56.2164 (20.372)***	-1.0442 (1.775)	-0.6078 (0.647)	-0.0174 (0.089)
Smoker status	-0.0839 (0.084)	0.0093 (0.107)	0.0003 (0.002)	0.0028 (0.19	2.1443 (1.29)*	-0.0599 (0.592)	0.0155 (0.122)	0.0225 (0.181)	-0.2847 (0.514)	-0.0036 (0.003)	0.0431 (0.025)*	-2.351 (1.450	-0.058 (0.126)	-0.0892 (0.046)*	0.2887 (0.115)**
Body Mass Index	0.0284 (0.058)	0.0322 (0.074)	0.0101 (0.001)***	0.0401 (0.13)	4.6606 (0.224)***	-0.0975 (0.406)	-0.1106 (0.084)	0.2536 (0.124)**	-0.1343 (0.352)	0.0009 (0.002)	0.0095 (0.017)	1.8893 (0.993)*	0.1272 (0.087)	0.0782 (0.0320**	--

N= 287 **Standard errors in parentheses ***p<0.001, **p<0.05, *p<0.1.**

Table 5: Primary regression analysis results. This compared the constructed model with the METS included versus comprehensive physical exam and blood test findings.

Secondary Analysis Results

Activity and Controls versus Self-assessed health

While offering minimal correlations between activity levels and measurable biological differences, there were more numerous statistically significant correlations present between activity levels and the individual's outlook on their health. People that spent more time physically active over the course of the week were correlated with having a higher degree of belief that their health is affected by things they do (Table 6). More active people also correlated with lesser reporting of health as a barrier preventing them from performing intermediate level mobility tasks (Table 6).

Table 6: Activity and Controls vs. Individual Health Outlook

Description	Life Satisfaction composite	Health LOC – Self	Health LOC – Others	Basic ADL	Intermediate ADL	Self-construal: Independence	Self-construal: Interdependence	Rating: Current Health	Rating: Health 10 years ago	Rating: health in 10 years
Log of METS	-0.0121 (0.023)	0.037 (0.016)**	0.0074 (0.026)	-0.0171 (0.012)	-0.0353 (0.015)**	0.0077 (0.023)	-0.0267 (0.024)	-0.0159 (0.027u)	0.0134 (0.034)	-0.0099 (0.037)
Age	0.0384 (0.009)***	0.0097 (0.006)	-0.009 (0.01)	-0.0032 (0.005)	0.0125 (0.006)**	0.0116 (0.009)	-0.0022 (0.009)	0.0232 (0.011)**	0.044 (0.013)***	-0.0004 (0.014)
Sex	0.1635 (0.141)	0.2061 (0.098)**	-0.0472 (0.161)	0.1264 (0.072)*	0.287 (0.094)***	0.1555 (0.139)	0.0539 (0.149)	0.1865 (0.166)	0.063 (0.206)	0.4365 (0.222)*
Protein Consumption - weekly	-0.0145 (0.024)	-0.032 (0.017)*	-0.0755 (0.027)***	0.0123 (0.012)	0.0171 (0.016)	-0.0062 (0.024)	-0.0047 (0.025)	-0.0169 (0.028)	0.0223 (0.035)	-0.0093 (0.038)
Dairy consumption - yearly	-0.00006522 (0.0000305)	0.00000286 (0.0000212)	0.00001316 (0.0000348)	0.00003627 (0.0000156)**	-0.000006899 (0.0000203)	0.00003962 (0.0000301)	0.00002952 (0.0000322)	-0.00003691 (0.000036)	0.00001508 (0.0000446)	-0.00006912 (0.0000481)
Sugared beverage Consumption - daily	-0.0252 (0.07)	0.0043 (0.049)	-0.053 (0.08)	0.0351 (0.036)	0.0541 (0.047)	0.0159 (0.069)	0.0347 (0.074)	-0.0929 (0.083)	0.0545 (0.102)	0.0667 (0.11)
Fruits and Vegetables - daily	0.0175 (0.089)	0.1246 (0.062)**	0.0426 (0.101)	-0.0286 (0.045)	-0.1122 (0.059)*	0.1292 (0.087)	-0.0086 (0.094)	-0.0134 (0.105)	-0.1069 (0.13)	0.1159 (0.14)
Whole grains - daily	0.0791 (0.077)	0.0154 (0.054)	0.0198 (0.088)	0.0007 (0.039)	0.0316 (0.051)	0.0295 (0.076)	0.0237 (0.082)	0.1742 (0.091)*	0.0881 (0.113)	0.0476 (0.122)
Primary Racial Origins: White	-0.258 (0.338)	-0.0978 (0.235)	-0.325 (0.385)	-0.2124 (0.173)	-0.0277 (0.226)	0.1617 (0.334)	-0.4246 (0.357)	-0.3925 (0.399)	-0.6565 (0.495)	-0.4946 (0.533)
Primary Racial Origins: Black	0.0714 (0.718)	-0.083 (0.499)	-1.0858 (0.818)	-0.6775 (0.366)*	-0.9274 (0.479)*	0.9996 (0.709)	-0.33 (0.759)	1.2195 (0.847)	0.7052 (1.05)	0.7088 (1.132)
Primary Racial Origins: Native	0.6531 (0.879)	-0.106 (0.611)	-0.1276 (1.002)	-0.3531 (0.449)	0.2633 (0.587)	0.074 (0.869)	-0.7973 (0.93)	0.7362 (1.038)	-0.0898 (1.286)	0.1469 (1.386)
Total Household Income	0.000001255 (0.00000127)	0.000001219 (0.000000882)	-0.000004176 (0.00000145)* **	-0.0000006091 (0.000000647)	-0.0000002901 (0.000000846)	-0.0000007149 (0.00000125)	-0.0000006256 (0.00000134)	0.000001473 (0.0000015)	0.000002178 (0.00000186)	0.000004952 (0.000002)**
Total Chronic conditions	-0.0719 (0.025)***	-0.0403 (0.018)**	0.0086 (0.029)	0.0441 (0.013)***	0.0829 (0.017)***	-0.0007 (0.025)	-0.0228 (0.027)	-0.1092 (0.03)***	-0.0215 (0.037)	-0.1148 (0.03)***
Insurance Status	-0.4983 (0.271)	-0.1246 (0.189)	0.6851 (0.309)**	0.0732 (0.138)	0.2433 (0.181)	0.3827 (0.268)	-0.2038 (0.287)	-0.4654 (0.32)	0.2537 (0.397)	-0.2437 (0.428)
Smoker status	0.0482 (0.019)**	0.0233 (0.013)*	0.0012 (0.022)	-0.0165 (0.01)*	-0.0157 (0.013)	-0.0377 (0.019)**	-0.0041 (0.02)	0.0622 (0.023) ***	0.0175 (0.028)	0.0629 (0.03)**
Body Mass Index	-0.009 (0.013)	-0.0195 (0.009)**	-0.0004 (0.015)	0.0192 (0.007)***	0.0289 (0.009)***	0.0224 (0.013)*	0.0022 (0.014)	-0.0188 (0.016)	-0.0144 (0.019)	-0.0045 (0.021)

N= 287 Standard errors in parentheses ***p<0.001, **p<0.05, *p<0.1.

Table 6: Secondary analysis results. This regression was done in search of significant correlations between increased activity and differences in health self-assessment.

Biological Health versus Self-assessed health

Biological indicators were shown to have significant effects in terms of the individual's self-evaluated health (Table 7). This suggests that irrespective of medical knowledge, a person may have, at the very least, a baseline understanding of their health. Whether the person is able to perceive biological differences that may be affecting their health is unlikely, but translational effects that correspond with differing quantities of blood-based compounds could very likely be perceived as a change from the individual's baseline.

Table 7: Biological Indicators vs. Individual Health Outlook

Description	Basic ADL	Intermediate ADL	Health LOC - Self	Health LOC - others	Rating: Current health	Rating: Health 10 years ago	Rating: health in 10 years	Life Satisfaction Composite	Self-construal: Independence	Self-construal: Interdependence
Neuromuscular composite score	-0.0373 (.0.022)*	-0.0464 (0.029)	0.0579 (0.031)*	0.0247 (0.051)	0.0252 (0.054)	-0.0236 (0.064)	0.0225 (0.07)	-0.0457 (0.046)	-0.0041 (0.044)	0.0118 (0.046)
Joint Health score	0.0131 (0.008)*	0.0224 (0.01)**	0.0247 (0.011)**	0.0263 (0.018)	-0.0036 (0.019)	-0.0265 (0.023)	-0.0234 (0.025	-0.0305 (0.016)*	0.0232 (0.015)	-0.007 (0.016)
Total Chronic conditions	0.0456 (0.012)***	0.0892 (0.016)***	-0.0321 (0.017)*	0.0022 (0.028)	-0.0813 (0.03)***	0.0067 (0.036)	-0.1076 (0.039)***	-0.0374 (0.026)	0.0313 (0.024)	-0.0124 (0.025)
Blood n-Telopeptide type 1 collagen (nM BCE)	0.008 (0.006)	0.0126 (0.007)*	-0.0017 (0.008)	-0.0007 (0.013)	-0.007 (0.014)	0.0152 (0.016)	0.0009 (0.018)	-0.0052 (0.012)	-0.0051 (0.011)	-0.0117 (0.012)
Blood Bone Specific Alkaline Phosphatase (UL)	-0.0024 (0.001)*	-0.0015 (0.002)	0.0007 (0.002)	0.0036 (0.003)	-0.0026 (0.003)	-0.0031 (0.004)	-0.0032 (0.004)	-0.0023 (0.003)	0.0055 (0.003)**	-0.004 (0.003)
Blood Amino terminal Propeptide type 1 Procollagen (ugL)	0.0013 (0.001)	0.0003 (0.002)	-0.0017 (0.002)	-0.0021 (0.003)	0.0029 (0.003)	0.0033 (0.004)	0.003 (0.004)	0.001 (0.003)	-0.0028 (0.003)	0.0039 (0.003)
Urine Creatinine (mg/dL)	0.0651 (0.173)	-0.0979 (0.229)	-0.5075 (0.238)**	-0.1043 (0.397)	-0.2818 (0.421)	1.0864 (0.050)**	-1.122 (0.545)**	-0.4114 (0.356)	-0.1739 (0.339)	0.2645 (0.354)
Urine Cortisol (ug/dL)	0.0313 (0.024)	-0.0004 (0.032)	0.0269 (0.034)	-0.0111 (0.056)	0.0529 (0.06)	0.0019 (0.071)	0.005 (0.077)	0.0554 (0.05)	-0.0516 (0.048)	-0.0142 (0.05)
Blood Fibrinogen (mg/dL)	0.001 (04.04E-4)**	0.0018 (0.00054)***	-0.0002 (0.001)	0.0023 (0.001)**	-0.0002 (0.001)	0.001 (0.001)	-0.0015 (0.001)	-0.0004 (0.001)	0.0013 (0.001)	-0.0012 (0.001)
HOMA-IR Insulin resistance index	0.0035 (.005)	-0.0004 (0.006)	0.0003 (0.007)	0.0061 (0.011)	-0.0093 (0.012)	-0.0048 (0.014)	-0.0194 (0.015)	0.0036 (0.01)	-0.0052 (0.01)	0.0041 (0.01)
Blood Triglycerides (mg/dL)	0.0013 (4.479E-4)***	0.0017 (0.00061)***	-0.002 (0.0006)***	0.00001023 (0.001)	-0.0006 (0.001)	-0.0009 (0.001)	-0.001 (0.001)	-0.0007 (0.001)	-0.0002 (0.001)	-0.0002 (0.001)
Blood LDL Cholesterol (mg/dL)	-0.0008 (.001)	-0.0024 (0.0013)*	0.0012 (0.0014)	0.0018 (0.002)	0.0015 (0.002)	0.0003 (0.003)	-0.0007 (0.003)	-0.0019 (0.002)	0.0019 (0.002)	0.0031 (0.002)
Vascular health in extremities	0.018 (0.013)	0.0269 (0.017)	-0.038 (0.017)**	-0.0111 (0.029)	-0.0108 (0.031)	0.0056 (0.036)	-0.0194 (0.04)	0.011 (0.026)	0.0078 (0.025)	-0.0177 (0.026)
Total Femur T-score	-0.0263 (0.237)	-0.1883 (0.314)	-0.2102 (0.327)	-0.0084 (0.545)	-0.0859 (0.578)	-0.2549 (0.687)	0.4919 (0.748)	-0.3143 (0.489)	0.2798 (0.466)	-0.1165 (0.486)

N= 287 Standard errors in parentheses ***p<0.001, **p<0.05, *p<0.1.

Table 7: Secondary analysis results. This regression was done in search of significant correlations between physical exam findings and blood test results, and differences in health self-assessment.

Activity and Controls versus Health Service utilization

Notably in this part of the analysis, physical activity di not correlate significantly with either form of medical service compared. Number of medications was significantly correlated with sex, consumption of sugar sweetened beverages, household income, and number of chronic conditions (Table 8). Frequency of physicians was correlated with number of chronic conditions, as well as whether the individual smoked regularly or not (Table 8). The strongest correlations existed between Income and number of medications (p<.01) and number of chronic conditions and number of medications used (p<.01).

Table 8: Activity and Controls vs. Health Service Use

Description	Number of medications taken	Times Seen doctor, past 12 months
Log of METS	-0.0323 (0.093)	-0.0117 (0.071)
Age	0.0385 (0.0360	0.0212 (0.027)
Sex	1.6471 (0.568)**	0.2316 (0.433)
Protein Consumption (weekly)	-0.0284 (0.096)	0.0554
Dairy consumption (yearly)	-0.00004619 (0.00012285904)	0.00007979 (0.0000936)
Sugared Beverage Consumption - daily	-0.1645 (0.282)*	-0.1979 (0.215)
Fruits and Vegetables - daily	-0.0011 (0.356)	-0.0561 (0.272)
Whole grains - daily	0.0321 (0.31)	0.1579 (0.237)
Primary Racial Origins: White	-1.2988 (1.361)	-0.9335 (1.038)
Primary Racial Origins: Black	1.3612 (2.889)	-1.2512 (2.203)
Primary Racial Origins: Native	-1.1537 (3.539)	-2.27 (2.699)
Total Household Income	0.00001362 (0.0000051)***	-5.119E-6 (3.89E-6)
Total Chronic conditions	0.9478 (0.102)***	0.1958 (0.078)**
Insurance Status	-1.2201 (1.091)	-1.0712 (0.832)
Smoker status	0.1059 (0.078)	-0.1127 (0.059)**
Body Mass Index	-0.0413 (0.053)	-0.0074 (0.041)

N= 287 Standard errors in parentheses ***p<0.001, **p<0.05, *p<0.1.

Table 8: Secondary analysis results. This regression was done in search of significant correlations between activity, and differences in selected health service utilization variables.

Biological Health versus Health Service Utilization

A considerable number of biologically-rooted variables showed significant relationships with service utilization in some form. With respect to number of medications taken, number of chronic diseases and symptoms, LDL cholesterol, and femur T-score showed statistically significant correlations (Table 9). Frequency of physician visits showed significant correlations with number of chronic diseases and symptoms, blood bone specific alkaline phosphatase concentration, blood amino terminal propeptide type 1 procollagen concentration, blood fibrinogen concentration, and HOMA-IR insulin resistance index (Table 9). The only biological health variable within this set that correlated with both forms of service utilization was chronic disease, which was very strongly correlated with both (p<.01).

Table 9: Biological Indicators vs. Health Service Use

Description	Number of medications taken	Times Seen MD (12 months)
Combined Reflex, Muscular, and Sensation aggregates, equal weights	-0.2512 (0.177)	-0.1234 (0.131)
Sum of all other scores for joint health attributes, equal weights	0.022 (0.062)	-0.0207 (0.046)
All chronic diseases and apparent symptoms	0.9669 (0.098)***	0.2738 (0.073)***
Blood n-Telopeptide type 1 collagen (nM BCE)	-0.0004 (0.045)	0.0325 (0.033)
Blood Bone Specific Alkaline Phosphatase (UL)	-0.0143 (0.011)	-0.0194 (0.008)**
Blood Amino terminal Propeptide type 1 Procollagen (ugL)	0.0123 (0.011)	0.0138 (0.008)*
Blood creatinine	0.6774 (1.372)	0.9682 (1.017)
Urinary Cortisol - stress hormone	0.1615 (0.194)	-0.2095 (0.144)
Blood Fibrinogen	-0.0002 (0.003)	0.0051 (0.002)**
HOMA-IR -- Insulin resistance index	-0.0096 (0.039)	0.053 (0.029)*
Blood Triglyceride levels	-0.0055 (0.004)	-0.0017 (0.003)
LDL Cholesterol	-0.0184 (0.008)**	0.0027 (0.006)
Combination of all noted abnormalities in extremities	0.1191 (0.1)	0.0877 (0.074)
Bone T-score, combined from lunar and hologic body scan information	-3.4498 (1.885)*	0.0926 (1.397)

N= 287 **Standard errors in parentheses ***p<0.001, **p<0.05, *p<0.1.**

Table 9: Secondary analysis results. This regression was done in search of significant correlations between physical exam findings and blood test results, and differences in health service utilization variables.

Self-assessed health versus Health Service Utilization

When compared with medical service utilization in the form of visits and consultation with physicians, there existed as significant correlation between belief that individual health depends on thins that the individual can do, prior assessments of health, and ability to perform basic ADL's with respect to physician consultations (Table 10) No other variables from the self-assessed health group exhibited significant correlations with physician visits. Ability to perform intermediate ADL's and belief that health is in the hands of others both had significant correlations with the number of medications in use by the individual (Table 10).

Table 10: Individual Health outlook vs. Health Service Use

Description	Number of medications	Times Seen MD (12 months)
"Health restricts basic ADL's"	0.7662 (0.789)	1.2183 (0.515)**
"Health restricts Intermediate ADL's"	1.3523 (0.593)**	-0.0568 (0.387)
Health Locus of control is self	0.516 (0.408)	-0.6354 (0.266)**
Health Locus of control is others	-0.5621 (0.251) **	-0.1802 (0.164)
Rate current health 1-10 (10 best)	-0.3402 (0.399)	-0.1796 (0.260)
Rate health 10 years ago, 1-10 (10 best)	0.0957 (0.194)	0.2313 (0.127)*
Rate expected health in 10 years, 1-10 (10 best)	0.4241 (0.267)	0.0253 (0.172)
Satisfaction with life composite	-0.0951 (0.379)	0.382 (0.248)
Self-Construed independence	0.3572 (0.283)	0.1023 (0.185)
Self-construed interdependence	-0.2835 (0.267)	0.0235 (0.175)

N = 287 **Standard errors in parentheses ***p<0.001, **p<0.05, *p<0.1.**

Table 10: Secondary analysis results. This regression was done in search of significant correlations between health outlook variables, and differences in health service utilization variables.

Chapter 4: Discussion

Assessment Versus Hypothesis

Given the nature of H.1, the hypothesis tested in this analysis (Table 1) it was necessary to establish criteria for having met the hypothesis in satisfactory manner. Since the hypothesis had several subsets identified based on biomarkers and composite variables constructed for each system, effectively meeting the criteria for rejection of the null hypothesis relied on fulfilling greater than half of the subsets of H.1. While highly desirable that all be fulfilled, this is in acknowledgement of the critical importance that each system holds, and improvements therein could be expected to manifest in the form of improvements in top level function versus those who did not see individual system benefit. This was expected to have been fulfilled based on literature review indications that there would be statistically significant differences between those who were more active versus those who were less active. Such an expectation, however, was not met in either the initial constructed model. Of the H.1 subsets that were covered within the regression, Only H.1c and H.1d showed any significant correlations. Among those, however, there was slight overlap in terms of the variables themselves, as obesity, which is defines as a BMI greater than 30, was included within the study as a chronic condition. Thus, any action that correlated with improvements in BMI would also have a high likelihood of correlating with reductions in total number of chronic conditions. Since there were no clear correlations found which would meet the criteria for acceptance, we cannot reject the null hypothesis in this study (Table 11).

Table 11: Assessment vs. Hypothesis

Number	Hypothesis	Importance	Supported?
H.1	Physical activity has a significant impact on maintaining health in old age.	n/a	No
H.1a	Physical activity improves musculoskeletal function	Maintain Functional independence	No
H.1b	Physical activity improves vascular health.	Blood distribution throughout body.	No

H.1c	Physical activity has a positive impact on body composition.	Strain on body increases likelihood of injury.	Yes
H.1d	Physical activity reduces onset of chronic diseases.	Many of the most prevalent chronic diseases in the US are preventable.	Yes
H.1e	Physical activity improves peripheral neurological function.	Maintaining functional independence.	No

Table 11: Table showing whether H.1 and its subsets a-e were deemed to be accepted based on the analysis performed.

Preventable Chronic Disease

After accounting for diet, age, and sex, it was found that there is a significant relationship between increasing metabolic activity and number of chronic conditions. One unclear result from this is which variable is affecting the other. Could increasing activity levels exhibit reduced incidence of chronic disease, or is chronic disease imparting a significant negative effect on the activity level of the study participant? A literature search seeking clarification on this found results that supported both - meta analyses found that increasing activity levels trended with reductions in incidence of chronic disease (Kujala 2004, Pedersen 2006), and presence of chronic disease has shown to have a significant bearing on activity levels in adults (Durstine 2013). These sets of analyses conflicted somewhat with each other, but due to the phrasing and format of the survey question, it became clearer that without a similar longitudinal sample including the same biomarker dataset, it would not be possible to assess disease onset over the reporting period as a function of activity levels. The Midlife in the US data series implemented the first biomarker project in the 2004-2006 time period, and there does exist a second biomarker dataset for which coding is not yet complete, but it utilizes a 'refresher' cohort and not the same cohort as the first two iterations of the main study and the first iteration of the biomarker project. In this, it was decided that preventable chronic disease would be better included as an effector variable on other health variables; their expected effects were controlled for in assessing the outcomes of physical activity rather than as a target itself. Considering this, the other regressions were re-run to account for presence of chronic conditions as an "independent" input variable rather than an outcome in and of itself.

BMI and body composition

This analysis found a significant correlation between increasing activity levels and lower BMI. This is a somewhat unsurprising result, as there already exists an extensive body of work relating to the influence of activity on maintaining a healthy BMI. Within this analysis, BMI exhibited a relatively large number of strong correlations with health variables, and translational outcomes. This might suggest that BMI represents an intermediary step between activity and other forms of health, and that BMI should likely be treated as the sum of dietary choices, physical activity rates, and genetic heritance and not necessarily compared alongside what would amount to its inputs.

Exercise and Bone Mineral Density

Maintaining skeletal structural integrity in older age is of the utmost importance. Weakening bones coupled with declining motor function can increase the chance of serious injury in day-to-day life, turning something as simple as a fall into a potentially life-threatening situation. Hip fractures are rarely viewed as an issue for young people, and it often takes extenuating circumstances for them to occur in younger populations, but a hip fracture in an elderly individual likely means permanent loss of mobility and institutionalization (Ungar 2013). Other factors such as staving off neuromuscular decline may reduce the chance of falls but maintaining a strong skeleton can reduce the likelihood that falls lead to injury. An individual who has an interest in preventing such adverse events in the future, then, would ideally target both events for preventive maintenance. This analysis found a lack of a clear correlation between increased general activity levels and bone composition (Table 4). While this runs counter to the findings of the literature review, it may be able to be accounted for due to the focus on general activity levels, rather than specific training regimens like those performed in several of the studies listed in the review. This appears to reinforce the idea that being generally active may not be enough to achieve better outcomes. Rather, there needs to be deliberate action taken to force usage of bone-building pathways, which typically would involve applying a loading force on the bone or joint (Martini 2017).

Neuromuscular function

It was believed initially that a measure of neuromuscular function would see positive effects, as it the underlying theory would claim that the continued repetition of coordinated tasks would exert a positive effect, serving to reduce or negate the detrimental effects that have been observed with aging in literature (Hunter 2016). While previous literature detailed measurable physiological impacts, any purported gains in neuromuscular abilities were not apparent within this study. It was noted previously that there is a lack of good information on how improvements in neurological metrics can translate into changes in functional performance tasks (Hunter 2016). This study had minor overlap in that area but was ultimately unable to assess due to insufficient sample size.

Vascular Health

Based on the literature review, it was expected that there would be noticeable differences in the selected indicators of vascular health that would correlate with increased physical activity. This analysis found that for the selected group of individuals and controlling for numerous external factors, that increasing activity levels had no significant correlation with improved vascular function in older adults.

Biomarkers

Within the cohort studied, there was no significant correlational differences in biomarker values that could be attributed to increased activity levels. This was somewhat surprising, as the selected biomarkers were believed based on literature to exert anabolic effects throughout the body that would be intended to counter the breakdown associated with heightened activity levels.

Biological Health differences and perceived health

This analysis found that there were several strong correlations that existed between the individual's perception of their health and biological metrics. This finding matches that previous studies, which found that despite lack of medical knowledge, a person can typically assess their actual health somewhat accurately in terms of mortality rate (Mossey 1982).

Intermediate Vs. Basic ADL's

An important result from the regression analysis was the correlation between increased active time and increased ability to perform intermediate activities of daily living. This was important in light of the lesser significance of active lifestyles on basic activities of daily living. ADL's encompass a set of activities that a person should be able to do if they to be considered capable of independent living. Basic ADL's typically include ability to maintain hygiene, carrying groceries, having enough mobility and physical capability to move around a living space without assistance from another person. In the case of elderly people, they may need to use a walker, cane, or other assist device, but they are still mobile enough to complete any necessary tasks for the day without fear of falling and injuring themselves. Fall-based injuries are especially dangerous to older people. While they may not pose the same threat level to younger parts of the selected cohort, the more elderly ones are far more subject to serious injury, such as broken bones after a fall that would lead to being institutionalized (cite fall statistics here). Once institutionalized, the health of the individual typically sees a marked change in the rate of deterioration; Institutionalization in the elderly appears to hasten the process of dying and loss of agency that the elderly unfortunately reports fearing more than death itself. The ability to perform ADL's that go beyond the baseline represents several things in the elderly. Health-wise, maintaining higher levels of physical mastery in old age can decrease the risk of injury doing daily tasks, partially as a result of decreasing the likelihood of adverse events like falls, and partially through a stronger body that is more resistant to injury from this particular type of accident (Arnold 2008). In addition to decreasing the risk of injury - and thereby the risk of major health deterioration that can occur as a result - the ability to perform higher level tasks in old age grants greater independence to the individual, and allows them to pursue activities that those with lesser capabilities would no longer able to participate in. The additional freedom that physical mastery grants the individual, therefore, was expected to be reflected in improved quality of life, since the theoretical individual would be able to continue to perform hobbies and other activities that either enhance or maintain quality of life. This is represented the secondary analysis, where the ability to perform intermediate ADL's has a significant relationship to the natural logarithm of weekly Metabolic Equivalent Task (MET) minutes. While there is not a statistically significant direct link between weekly MET minutes and increased satisfaction with life, may be an indirect path present with regards to increased ability to perform ADL's and maintain at the bare minimum the belief in one's autonomy. Alternatively, the any benefits to ADL's that correlate with increased physical activity could be purely psychological. An improved appraisal of functional capability independent of biology is supported by the lack of biological performance correlations within this study. This would be indicative of a person's reduced belief of in health as a limiting factor and would not necessarily represent actual biological improvements versus less active individuals.

Why focus on autonomy?

The ability to remain autonomous and independence in later stages of life has strong predictor of well-being in later stages of life. When things within the body are generally working well and do not impact a person's life negatively, a person could be expected to express lesser desire to utilize medical services they may not perceive as a need (Tkatch, 2016). Along this trend, the better a person perceives their health to be, it could be expected that they would visit the physician less frequently. Based on the results comparing the self-evaluation of health variable group and the selected service utilization variables, there is a correlation evident between an individual's self-assessed health and the frequency at which they express a need for medical services. Increasing the ability of aging and elderly individuals to live autonomously can translate into fewer visits to the physician's office. Since in this scenario no medical services would be rendered, the money that would have been spent - be it through out of pocket expense, frequent insurance usage raising rates, meeting a deductible (also out of pocket) or some combination of those - would instead be saved by the individual and presumably spent elsewhere.

Service Utilization

While connections with service utilization were outside the scope of the primary analysis, the secondary analyses addressed connections between variable groupings and service utilization indicators. This study offers a pathway towards potential reductions in service utilization. Based on regression results through the pathway this particular study took, it is believed that increasing general levels of physical activity may be able to be realized in terms of reductions in medical service use. It did not, however, follow the hypothesized path in terms of eliciting biological responses which then led to better physical mastery. Rather, it would be better represented in its correlation to better individual health outlook, in spite of the lack of significant correlations to biological benefit experienced by the study cohort (Figure 3). Subsequent linear regression of self-assessed health and functionality versus two types of medical services agreed with the literature-supported conclusion that when a person believes they are healthier, they are less likely to utilize medical services (Lee 2017) (Figure 3). Less service utilization roughly equates to, at least in the short term, a reduction in cost.

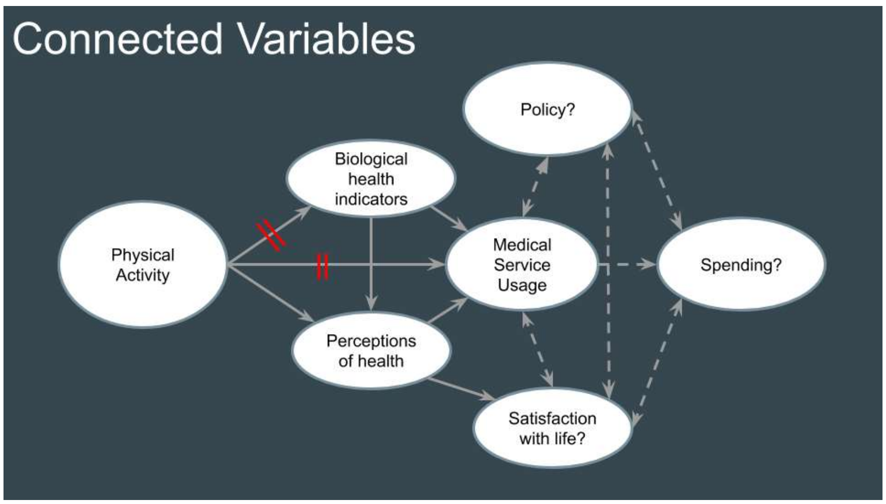

Figure 3: Interconnection map of variable groups in analysis. This is meant to show the associations made between the variable type groupings within this study. While some controls showed effects in various areas of biological effects and medical service use, physical activity failed to make the connection with biological indicators of health and service utilization. Activity was associated with improvements for several important indicators relating to the individual's perception of their health. Similar to figure 2, the dashed arrows represent the flow of the study itself with respect to regressions performed, and the dashed arrows represent discussion-based connections of the linear regressions performed. The red marks represent areas where there was a lack of a meaningful connection made.

Additional Health Considerations

A person's belief that they are healthier than they actually are can lead to longer term challenges. The best way to avoid life-threatening conditions is early diagnostics (Ecder 2013, Birnbaum 2018). This analysis found that a higher self-evaluation of one's health, especially in terms of health as a limitation on physical activity has been correlated within this analysis to decreased use of medical services, as represented by doctors' visits and use of medication (Table 7) . This result is supported in literature as well (Taber 2015). Considering that higher levels of physical activity correlated with a better outlook on health despite the lack of significant biological differences within the over-50 age group, should the benefits be advertised to seniors the same way for the sake of reducing costs? Is the act of reducing costs the only goal ultimately? Financially, *something* needs to be done, as the deadline for government—supported medical care to run out of money looms large. Based on these regression results of this study, increases in general physical activity in the aging population may only represent a small piece of the puzzle. Another point of consideration from this analysis is the effect that a person's view of health holds on their life satisfaction. A person may not actually be in better health, which could result in worse health in the long term, but a person who rates their health highly might see improvements in quality-adjusted life years (Prieto 2003). This is an area that exists outside the scope of this analysis but might be beneficial in terms of additional study in relation to the effects of exercise in populations of older Americans. Even if retaining a certain level of general activity may not lead to actual improvements in health, it may lead to an increase in QALYs in populations that are more active, and retain its worth in that manner. Until further study is performed along this vein, it would be difficult to make the assertion that any gains in terms of long-term medical costs would outweigh the improvements realized in terms of a happier aging process. This, especially in light of prior research finding that the elderly tend to fear the process of aging and dying more than the actual act of dying itself (Sinoff, 2017). Perhaps the overstatement of the benefits of remaining "active" late in life would could be tempered and clarified to maximize any potential benefits.

Policy recommendations

Reassessment

While it was not possible to identify direct biological changes within the sample population, likely a result of the large amount of variability within human biology where the systems still 'works,' a correlation was found between increasing physical activities and ability to retain functional autonomy, measured by the ability to continue to perform activities of daily living. With the current state of medicine being highly reactive, this analysis concluded that people who were able to perform higher level functionality correlated with lower medical service usage, and a correlated with higher likelihood of assessing themselves as being in good health. This may not actually mean, however, that they are necessarily in better health biologically. This study found minimal connections between time spent exercising and improvements in health outcomes in older adults. In this, it may be more apparent the power that the brain itself holds on health - higher levels of happiness at the perception of being in more control, healthier, etc. may have significant psychological effects on health that contribute to reductions in medical costs. The mindset of 'If I believe I can, I can." is clearly apparent here, and may be the result of other physiological process that were not measured within the dataset. Promotion of active participation in health via an active lifestyle is a worthwhile endeavor, although other methods may serve to better promote biological health. While increasing exercise did not present the robust biological effects that were hypothesized, the increased repetitions of coordinated activities utilizing numerous musculoskeletal interactions may keep a person 'sharp' through practice and help reduce physical deconditioning. In conclusion, policy promoting the benefits of 'activity' as a direct facilitator of greater health outcomes should be re-examined. Analysis of this cohort failed to produce a clear, positive correlation between increasing activity levels as measured through METS and baseline biological outcomes. Nevertheless, secondary analysis suggested that higher activity levels exhibited a positive correlation with ability to perform activities of daily living, which was subsequently correlated to lower medical service utilization rates.

Clarification and Education

Based on the vast volume of work pointing towards the benefits of being active, the lack of applicability to the sample population when viewed through a more general measurement of activity is somewhat concerning, especially with respect to a commonly employed method for measuring activity and a population that needs health benefits arguably more than any other group. The average layperson who decides to be more active because it is purportedly good for them could search endlessly and not be able to properly dispel truth from fiction, a potentially problematic development that could discourage due to *too much* information. Improvements in ease of access, as well as allowing variable levels of complexity and specificity for people of all levels could help to filter fact from fiction.

Additional Lines of Communication

Historically, there is been minimal relationships between medical professionals and physical fitness experts. One of the main bridges in this gap exists in physical therapy (PT), but this has several shortcomings. PT is designed to rehabilitate damaged systems, but a further relationship between care providers and fitness experts might help achieve the goal of targeted exercise for improvement. In this situation, a physician might prescribe exercise to the patient for a specific condition, and the trainer could act as a liaison between the specific body systems the physician identifies as needing work, and the patient who needs to 'exercise more.' While it would incorporate an additional intermediary into an already expensive and convoluted process, the addition of professionals has the potential to increase effectiveness by helping to guide the patient rather than leaving them solely to their own devices.

Context within National discourse

If the political winds continue in the same direction as they have been, nationalized healthcare may someday become a reality. Before that could find success though, it would be necessary to address the great many pitfalls associated with such as system. One of the chief concerns with such a system, especially in the United States, is healthcare rationing. It is politically difficult to tell a person they cannot consume as much as they want of any particular good or service within the current prevailing culture, and health care is certainly no exception. The presence of those who consume in excess without any concern for, and without addressing any of the factors that led to their overconsumption in the first place represent a danger to a system that is already struggling to address higher volumes of patients who are becoming progressively sicker. Medical management of patient conditions can only go so far and may be meaningless overall if the patient is uncooperative with treatment plans and does nothing else to promote their own health. Because of this, part of the solution to the American healthcare puzzle lies within reducing the need for services; ensuring that American stay healthier and have less of a need for medical care so that the cost of a single program does not drive the federal government bankrupt. An alternative policy to this would be state-level programs. There is no policy within the federal government that forbids states from enacting such policies, and they would stand a better chance against attempts to overturn such laws within the court systems. Furthermore, state-based solutions could serve not only as a slower roll-out but could also help test for efficacy of a program without being destructive on a national level in the event of failure. Another ideal characteristic of states versus federal level legislation would be that states generally represent people who share a common culture. One of the defining characteristics of the Nordic states that are held as shining examples of social democrat policies are the confluence of both relatively small; populations (those closer to a US state in size) and cultural homogeneity. Socially, it is easier to accept and buy into a policy if there is a belief that the person affected by it is part of the individual's *gemeinschaft*. The diametric opposition of principles existing among states makes the implementation of national policies, especially those relating to healthcare, exceedingly difficult on a national level, whereas the California and New York State legislatures have shown that similar policies can be passed at the state level with wide acceptance.

Study Limitations

Cardiovascular bias

In the assessment of physical activities, there is a general bias toward activities that might be aerobic in nature, as opposed to those that might fall more under the resistance-based exercise umbrella. Because of this bias towards aerobic exercise over resistance-based activities, certain relationships between strength-building activities and health may not be represented, and the effects noted within other literature may appear to lack statistical significance when analysis is performed for this study.

Weaknesses of METS

One of the major weaknesses of using METS to measure overall activity is the loss of activity-specific characteristics that differentiate them from other activity types. Important features lost by measuring activity might include resistance type metrics and stress on skeleton, muscles, and joints. These stresses can lead to additional physiological signaling that leads to biological changes (reference bone building and muscular repair here). While MET minutes reflect the additional energy expenditure by the body, standardizing based on MET minutes loses resistance characteristics present in a unique activity. The loss of resistance data reduces the ability of METS to give a complete picture of how activities impact the body. Within this analysis, it would not have been feasible to include a calculated resistance rate for activities, since those would include analysis of joint and bone-specific stresses of each activity, standardized across the different areas of the musculoskeletal system, and then combined into a weighted composite whole, similar to the way METS reflect total body energy expenditure. While increasing METS correlated with a significant, positive effect on one of the main measures of structural strength in bone density, it is believed that if activities that included additional loading-based characteristics had been accountable for within the metric, that it might exert a more significant impact, both statistically and in terms of magnitude.

Circularity of body systems, interdependencies

One major challenge in this analysis is the circularities and interdependencies of input variables on one another, as well as the response variables. Variables that are included as inputs have two main roles. The primary role of the variable is to be examined as an effector. The secondary role of input variable inclusion is to remove it as a potential confounding factor by including it. Conceptualized as a signal, the response signal is the result of the convolution of a number of signals into a single result stream. Therefore, in order to characterize a single component, it becomes necessary to remove other known components. This is the understood relationship between BMI and the response variable, despite the known impacts of activity levels and diet on BMI; obesity, which is defined as a BMI over 30, is known to be a strong effector of a number of chronic conditions as well as representing a chronic condition in and of itself. Therefore, to be able to more clearly understand the nature of the impact of higher activity on prevalence of chronic activity, known effectors need to be filtered out of the 'signal.'

Sampling Limitations

Filtering out inapplicable results, excluding individuals who did not participate in both studies, and also restricting by age made significant impacts on the usable sample size. This might introduce bias within this study based on lack of ethnically representative samples, as well as uneven distributions across income. A surface level assessment of racial and income-based differences within the included sample found that the sample population with data for all examined values was overwhelmingly white, with 94% of the population sample listing Caucasian or European as their racial origins. In addition to this, after filtering out groups that did not complete all portions of the testing the demographic group saw zero participants that were Asian or pacific islanders, and so those variables were removed from the model. The lack of racial diversity in the sample eliminates the ability to assess correlations across racial lines. The general "white-ness" of science has been gaining more attention as a problem of late, especially within the medical field. Many new technologies are developed and tested with white middle-aged males in mind, and as such miss out on any differences in response across racial lines. The study was performed with these considerations in mind, but the required matching across several aspects of the database severely hampered any efforts to avoid known issues within the sample population with respect to ethnic representation.

Common criticisms

One major hurdle in producing work on this topic is the volume of previous work relating to healthy aging. This makes it difficult to justify and produce original work in the field, and also makes literary searches ensuring that work will be original far more difficult to achieve. Within the literature review process, most of the work focused on the effects of exercise on a single body system over an established time period, generally less than two years. At the end of the time period, physiological measurements are taken to assess the function of the system in question. In nearly all cases, discussions and conclusions steer clear of any larger implications of the work, beyond any direct impact of the improvements associated with the particular system of study. Any mention of effects on the patient experience beyond the measured outcomes is glossed over, since they are largely outside the scope of the studies themselves. This thesis attempted to combine biological systems into a more complete picture of overall health and examine the effect that leading an active lifestyle might have in older populations. While the combination of the MIDUS main study and the biomarker dataset represent a considerable portion of bodily system function, it is not exhaustive. One system in particular that has very minimal representation within the dataset is the immune system. One of the major challenges seniors face as they age is decline in immune function. This makes it riskier to participate in certain leisure activities for fear of injury and infection, as well as reduced immune responses to vaccines (Montecino-Rodriguez 2013). The literature review showed evidence that exercise may lead to improved immune function, however translational effects on this system are not testable in this analysis due to lack of availability of data within the datasets.

Conclusions

This study attempted to provide incorporate a biological basis into activity-driven health outcomes in the selected sample. It found that there were minimal correlations between increasing general activity, as measured by METS, and biologically-rooted health outcomes We believe that this may be the result of another 'layer' existing in the chain between exercise and any apparent health outcomes, in the form of its correlation with reductions in BMI. Elevated BMI showed connections to several negative health outcomes in addition to being well-connected to generally poorer evaluations of individual health. In terms of Individual health, however, there was what appeared to be an overstated belief in the benefits of health-positive effort - more activity for a study participant correlated with lesser perception of health as a limiting factor. In this, the participants appeared to over-evaluate any health-positive effects that their active lifestyle might grant them. There was also a correlation present between physical functionality and self-assessed health with respect to use of medical services. As the individual believed they were less healthy, or that their health limited their functional capacity more, these conditions correlated with higher frequency of doctor visits, as well as greater numbers of medications in use. This study was limited by demographic samples, as well as the general circularity of body systems. In several cases, it could not be determined which variable was exerting the effect on the other. Additional studies might attempt to compare how potential overstatement of positive effects of maintaining a physically active lifestyle could translate to differing medical outcomes, with respect to expected lifespan. This would be an important step in assessing the impact that an over-evaluation of health-positive action can have in terms of real outcomes.

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