Physiological improvements and health benefits during an exercise-based comprehensive rehabilitation program in medically complex patients

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Running title: Therapeutic exercise, aging, and chronic illness

Abstract

Objectives: *To determine the effects of an exercise-based comprehensive rehabilitation program on the physiological, health, and cost benefit in medically complex patients.*
Design: *Case series*
Setting: *Comprehensive rehabilitation centers.*
Participants: *Elderly chronically ill men (n = 39, age = 75.3 ± 1.4) and women (n = 74, age = 76.5 ± 0.9 years)*
Intervention: *Patients participated in individualized physical therapy with therapeutic exercises (stretching, strengthening, endurance, balance, sitting and standing dynamic exercises) three times/week for three months under the supervision of a physician.*
Measurements: *Upper (back) and lower (leg flexors) extremity strength, aerobic power as measured by metabolic equivalents (METS) at 80% of age predicted maximal heart rate (APMHR), physical functioning and mental health as assessed by the Short Form-36 (SF-36) questionnaire, and medical events (falls, physician visits, and hospitalizations) questionnaire was collected at baseline and after three* months of the program.
Results: *Strength measures improved by ~30% (P < 0.05) as well as aerobic power improved by ~25% (P < 0.05) over the three-month period. There were significant improvements in two of the SF-36 Physical Component Scales: Physical Functioning (P < 0.05) and Role Physical (P < 0.05); plus, there were significant improvements in all four of the Mental Component Scales: Vitality (P <*

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0.05), Social Functioning ($P < 0.05$), Role Emotional ($P < 0.05$), and Mental Health ($P < 0.05$). There were significant reductions in fall rate ($P < 0.05$), physician visits ($P < 0.05$), and hospitalizations ($P < 0.05$).
Conclusion: *Patients improve physical capacity, which result in improvements in health status with concurrent reductions in healthcare utilization during a comprehensive rehabilitation program. (Exerc. Immunol. Rev. 12, 2006: 86-96)*

Key words: Exercise; rehabilitation; aging; chronic illness

Introduction

The elderly population in the U.S. is growing rapidly and is currently estimated at ~35 million people over the age 65 [1]. Increases in the aging population pose some severe consequences. Eighty percent of people >65 years is living with a chronic illness (e.g., Parkinson's, balance deficits, chronic pain, coronary artery disease, hypertension, diabetes, etc.) [2]. The chronically ill population suffers from decreased function, endurance, mental health, ability to perform activities of daily living (ADL), independence, and balance, along with an additional myriad of problems.

The increase in the elderly population, with its concurrent elevation in chronic illness and pain and subsequent utilization of health services, will result in an exponential increase of health care expenditures. For example, falls are a foremost health care cost for the over 65 population, presumably due to balance deficits and weakness associated with either aging or secondary to a illness or disease state (e.g., stroke, Parkinson's) [3]. The high incidence of injury from falls can be attributed in part to low bone mass in the elderly (higher occurrence of fractures) [4] and low muscle mass (since soft tissue can attenuate fall impact); furthermore, greater than 90 % of hip fractures may result from falls [5]. Other rising costs include the increased need for hospitalizations, medications, and physician office visits. Therefore, it is important to find ways to counter the decline in health status with advancing age.

The answer to these health problems may lie in the investigation of comprehensive rehabilitation programs that utilize active-based physical therapy protocols involving therapeutic exercise. However, clinical programs, other than cardiac and pulmonary rehabilitation and preventative programs, have been slow to emerge as a standard treatment due to limitations in medical direction and supervision to handle the complex medical problems that those with chronic illnesses present. These patient populations need a carefully planned exercise prescription with regular assessments to monitor modes and intensities of work, medication interaction, disease interaction, and medical events [6]. Many older patients who have an orthopedic malady may have one or more diagnoses of chronic illness. Of all the treatment options, such as hospice care, medications, and surgical intervention, only active treatment options address recovery in terms of function, overall medical status, and future prevention.

Older adults who undergo regular physical training have marked improvements in strength and aerobic power [7]. Physically frail adults who are placed in a physical therapy program focus on improving strength improve functional ability [8]. Older people that exercise on a regular basis are more resistant to chronic illness. As such, there are clear recommendations that the elderly maintain regular physical activity to help offset functional decline and offset risk for illness [9].

The association of mental health and chronic illness is a complex issue, as medical conditions are a risk factor for mental disorders such as depression and conversely depression is a risk factor for medical illness[10]. For example, frequency of negative emotions are a significant predictor of coronary heart disease [11] and depressive symptoms are greater in patients with chronic illness [12]. Physical exercise interventions may lead to improved mental health in chronically ill patients, as evidenced by improved state anxiety scores in cardiac rehabilitation patients [12] and improved mental health, as assessed by the mental health inventory of the Short Form-36 (SF-36) health questionnaire, in chronic low back patients following a 12 week cycle ergometry program [13].

The evidence in the medical literature clearly indicates the utility of active interventions in the chronically ill; furthermore, many patients are afflicted with multiple diagnoses and orthopedic limitations. However, due to the diverse complications with frail elderly, such as of falls, a multidisciplinary team is necessary to address various areas such as gait training, strengthening, and coordination [14]. Therefore, the purpose of the present article is to describe the changes in outcomes following a medically-directed comprehensive rehabilitation program utilizing a team of physicians, physical therapists, and exercise physiologists to supervise therapeutic exercises in medically complex elderly patients. Specifically, our aim is to quantify the changes in both mental and physiological outcomes. Strength and exercise workload, as they relate to health status (physical functioning and mental health status), as measured by the Short Form – 36 questionnaire (SF-36), as well as changes in health care utilization, as measured by fall rates, hospitalizations, and physician visits during the program.

Methods

Subjects:

The following protocol was approved by the Human Research Committee at the University of Colorado - Boulder. Medical data from 113 chronically ill elderly men (n = 39, age = 75.3 ± 1.4) and women (n = 74, age = 76.5 ± 0.9 years) were retrospectively analyzed for changes in response to therapy. Subjects were diagnosed with three or more of the following: hypertension, coronary artery disease (CAD), chronic obstructive pulmonary disease (COPD), type II diabetes, muscle disuse/atrophy, severe deconditioning, osteoporosis, gait abnormality, stroke, obesity, balance deficit, Parkinson's Disease, degenerative joint disease, and/or orthopedic issue. Patients were living independently either in their own home or in independent living communities. Each patient met monthly with a medical doctor (M.D.) to ensure that the patient did not have any serious changes in medical condition that would adversely affect the patient during any therapeutic exercises. The M.D. would also screen for any contraindications to exercise that the patient might have, and give guidelines to address any limitations to ensure patient safety.

Intervention:
All patients underwent three months of therapeutic exercise under the direction of an M.D. and physical therapist, and under the daily direct supervision of the medical doctor, physical therapist, and clinical exercise physiologist in a comprehensive rehabilitation center. The M.D. was available in case of medical emergency and to provide general medical support. The physical therapist would work with the patients who had an orthopedic barrier to perform the therapeutic exercise program. The physiologist would monitor the patient's blood pressure, oxygen saturation, heart rate, and perceived exertion on a daily basis. The physical therapists and physiologists would also monitor the therapeutic exercise progress and modify the daily intensity of the program as needed, as well as monthly following physiological testing.

Therapeutic Exercises:
The subjects performed therapeutic exercises three times/week for 60 minutes per session via a combination of cardiorespiratory equipment, strength equipment, balance training, dynamic stabilization, and functional movements. Strength testing on resistance machines were performed at baseline, then monthly, for the following body parts: knee extensors via leg extension, knee flexors via seated hamstring curl, biceps via seated biceps machine, and back via lat pull down. Testing consisted of a ten repetition maximum test where each patient would progressively have the load increased with each exercise until they could no longer complete ten repetitions (reps) without break in proper biomechanics. Data were recorded as weight in pounds for the ten repetitions.

On strengthening modalities (leg flexion, etc.) patients would complete three sets of ten repetitions of each exercise at 70-90 % of their ten-repetition maximum. Patients were carefully directed to ensure that orthopedic limitations were addressed during the program, as well as other guidelines to ensure safety for other diagnoses (e.g. osteoporosis and hypertension). Functional exercises included working with gym balls, balance activities, therapeutic bands in attempt to increase function with activities of daily living.

All subjects performed work on either a treadmill or cycle ergometer two to three times per week for three months to develop functional endurance and balance. Testing was performed at baseline, repeated each month, and consisted of a graded submaximal exercise to 80 % of age predicted maximal heart rate (APMHR) on treadmill; however, subjects with balance deficits or gait abnormalities were tested on cycle ergometer. Cardiorespiratory fitness was recorded in metabolic equivalents (METS) attained at 80 % of APMHR. Daily sessions would work subjects between 70-90 % of their tested value. Exercise intensity was increased as each testing session demonstrated improvement.

Assessment of physical functioning and mental health:
The SF-36 questionnaire is a widely used and previously validated [15] health questionnaire and was utilized to assess physical functioning and mental health. All subjects completed the SF-36 health questionnaire at baseline and

repeated at three months. Forms contain 36 questions that consist of four categories pertaining to physical functioning and the remaining pertaining to mental health. The forms were then scored using the standard SF-36 formula, with 0 being the lowest score and 100 being the best score for each category.

Medical Events:
All patients completed a medical events questionnaire at the initial visit and at three months. The number of hospitalizations, falls, and M.D. visits for the prior three month period were recorded for each individual patient. Visits to the M.D. or hospitalization for any reason was included (e.g., pre-planned visits, procedures, etc.).

Statistics:
Strength and cardiorespiratory data were analyzed using repeated measures ANOVA with gender as an independent variable ($P < 0.05$). Gender groups were pooled for SF-36 and health care utilization analysis to increase the power for subjective questionnaires and were analyzed using repeated measures ANOVA ($P < 0.05$).

	Age (years)	Height (in)	Weight (lbs)
Men (n=39)	75.3 ± 1.4	67.6 ± 0.3	193.7 ± 8.6
Women (n = 74)	76.5 ± 0.9	62.9 ± 0.3	157.0 ± 4.6

Table 1. Subject Characteristics
Mean ± Standard Error of Measurement (SEM)

Diagnosis	% of Patients
Back Pain	18%
Balance Deficits	36%
Coronary Artery Disease	15%
Neck Pain	6%
Chronic pain	13%
Congestive Heart Failure	4%
Chronic Obstructive Pulmonary Disease	7%
Stroke	6%
Degenerative Joint Disease	20%
Gait abnormalities	7%
Hypertension	39%
Multiple Sclerosis	2%
Muscle Disuse	33%
Osteoarthritis	4%
Osteoporosis	11%
Parkinson's Disease	2%
Severe Deconditioning	58%
Morbid Obesity	4%
Type-I Diabetes	3%
Type-II Diabetes	7%
Other	21%

Table 2. Subject Problem List
All subjects were diagnosed with a minimum of three diagnoses

Results

Subjects
Select subject characteristics are in Table 1. No adverse events were reported in subjects in conjunction with this exercise program. Percentage of subjects with primary diagnoses are presented in Table 2.

Strength
Both male and female subjects had a significant increase in leg flexor strength [$F(1,110) = 165.87$; $P < 0.0001$; Fig. 1A] and back strength [$F(1,111) = 108.54$; $P < 0.0001$ Fig. 2A] over time. There was a difference in strength between men and women for leg flexors [$F(1,110) = 19.14$; $P < 0.0001$) and back strength [$F(1, 111) = 26.07$; $P < 0.0001$].

Figure 1 A

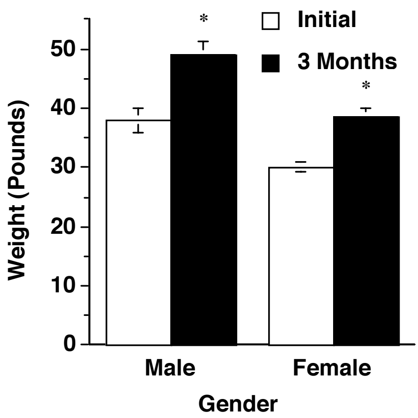

Figure 1 B

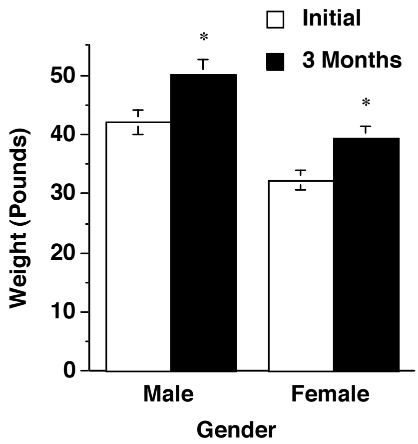

Figure 1 Improvements in Leg Strength Both male and female patients had significant improvements in lower (1A) and upper (1B) extremity strength over a three-month period. *P < 0.05 compared to baseline.

Figure 2

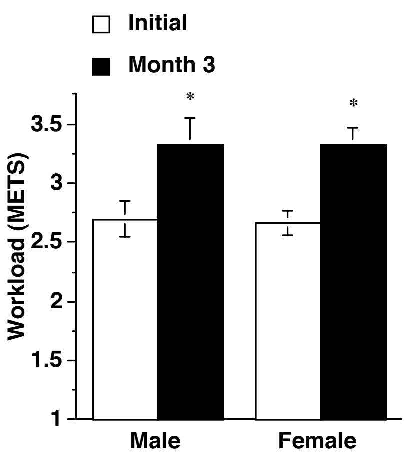

Figure 2 Improvement in Workload Both male and female patients had significant improvements in workload attained at 80 % of APMHR over a three-month period. *P < 0.05 compared to baseline.

Aerobic Capacity

Both male and female subjects had significant increase in METs at 80 % of APMHR from baseline [F(1,99) = 96.96; $P < 0.0001$; Fig. 2]. However, there were no differences between men and women [F(1,99) = 0.0054; $P = 0.09418$].

SF-36 Questionnaire

There was an improvement in two of the physical components of the SF-36 questionnaire over time (Table 3): Physical Functioning [F (1,107) = 6.84; $P < 0.05$] and Role Physical [F(1,105) = 8.0035; $P < 0.01$]. However, there were no differences in Bodily Pain [F(1,108) = 1.7410; $P = 0.1898$] and General Health [F(1,106) = 0.7753; $P = 0.3806$].

There was an improvement in all mental components of the SF-36 questionnaire over time: Mental Health [F (1,105) = 4.8339; $P < 0.05$], Role Emotional [F(1,102) = 6.56; $P < 0.05$] Social Functioning [F(1,107) = 12.3756; $P < 0.001$], and Vitality [F (1,105) = 12.5013; $P < 0.001$].

SF-36 Category	Initial	Month 3
Physical Component Scales:		
Physical Functioning	41.4 ± 2.3	45.7 ± 2.4*
Role Physical	26.2 ± 3.3	34.5 ± 3.5*
Bodily Pain	55.7 ± 2.3	58.1 ± 2.2
General Health	57.8 ± 1.8	59.1 ± 1.8
Mental Component Scales:		
Vitality	43.2 ± 2.0	49.3 ± 2.0*
Social Functioning	66.8 ± 2.6	75.2 ± 2.5*
Role Emotional	59.2 ± 4.2	69.1 ± 3.7*
Mental Health	72.0 ± 1.7	75.2 ± 1.6*

Table 3. SF-36 Scores
Mean ± SEM. *Denotes significantly different than baseline (P < 0.05)

Medical Events

There were significant reductions in hospitalization rate [F (1, 94) = 4.1814; *P* < 0.05; Fig. 3A], fall rate [F (1, 98) = 16.0353; *P* < 0.001; Fig. 3B], and physician visits [F (1, 90) = 13.3043; *P* < 0.001; Fig. 3C].

Figure 3 A

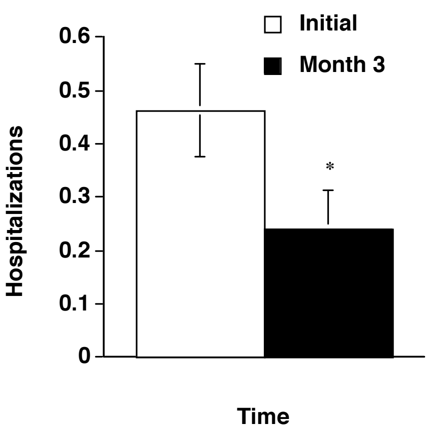

Figure 3 B

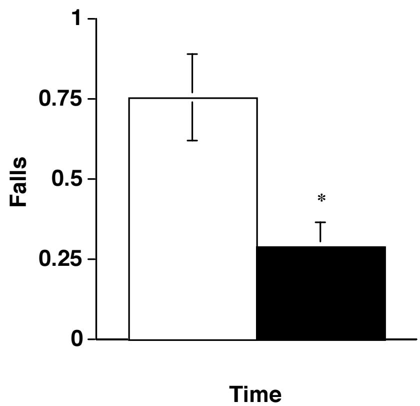

Figure 3 C

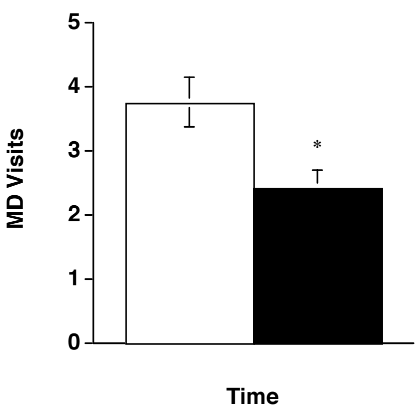

Figure 3 Reduction of medical event
During the program, patients significantly decreased the rate of hospitalizations (3A), falls (3B), and physician office visits (3C) as assessed by number of events over the prior three-month period. *P < 0.05 compared to baseline.

Discussion

The present findings of this paper demonstrate marked improvements in strength, workload, SF-36 measures (physical functioning and mental health), and importantly a concurrent reduction in medical utilization and events. The goal of this program was aimed at optimizing gains in function and health status. Both cardiorespiratory and strengthening modes of exercise were utilized since concurrent training optimizes many aspects of functional fitness [16]. Furthermore, therapeutic exercises, aimed at improving balance and function, were also utilized.

The ~30 % improvement in strength found in this patient population translates to improved functional capacity. Our results are in agreement with Fiatarone et al. [17] who demonstrated that severe weakness in older adults is reversed through exercise training over a ten-week period. This would indicate that frailty is in part due to the muscle inactivity associated with chronic illness, pain, and/or bedrest, and this frailty is treatable. Brown et al. [18] demonstrated that elderly subjects who performed strengthening exercises for the elbow flexors had a significant gain in muscle strength (48 %) and muscle cross sectional area (30.2 %), demonstrating the ability for elders to overcome muscle atrophy. In addition, elderly subjects improve treadmill endurance, dynamic strength, and peak cycle workloads in a resistance training only program, indicating that improved strength is a key factor for improving function[19].

The improvement in workload as measured by a ~25 % increase in METs in our patients may be functionally significant as others have demonstrated that a 15 % improvement in aerobic capacity is of functional importance [20]. In addition to increased workload, cardiorespiratory exercises lead to positive adaptations in nervous and endocrine system regulation, metabolic and functional economy, functional stability, and has anti-atherosclerotic effects [21]. Improvements in workload in these patients may be of further importance, as achieved workload (METs) during exercise testing provides prognostic value for predicting mortality in the elderly [22, 23].

The SF-36 questionnaire indicated that the patients had a concurrent improvement in two out of four on the physical functioning and four out of four on the mental health components. The SF-36 has been used extensively as a quality of life measure to assess health [24, 25] and is an indicator of physical performance in older adults [26]. As such, our results reinforce the self-perception of health with these patients with actual objective improvements in workloads attained during the intervention. Improvement in mental health or psychological affect following the intervention is of particular importance in the medically complex patient population as depressed mood state serves as a predictor of strength decline in the elderly [27].

The reductions in fall, physician visits, and hospitalization rates in response to the program may be significant. For example, fall-related injuries result in an average of $19,440/fall in healthcare costs [28] and falls are now the eighth leading cause of death in the elderly [29]. The high susceptibility to injury and mortality with falling may be attributed to decrements in strength. Both muscle strength (grip strength) [30] and muscle mass (corrected arm muscle area) [31], are important predictors of mortality in the elderly, as well as muscle strength serves as a predictor of mortality following a bone fracture in older people [32]. Others have been successful in reducing the risk of falling with multidimensional exercise programs [33]. While we did not measure the risk of falling per se we did demonstrate a ~60 % reduction in the rate of falls during the program, presumably due to the improvement in strength in the patients.

Clearly, the medical community supports the use of active interventions to address the needs of the chronically ill population. For instance, clear guidelines are presented for both heart disease and cardiopulmonary disease by the American Heart Association [34] and the American Thoracic Society/American College of Chest Physicians [35]. The U.S. Preventive Task Force recommends that high fall risk elderly patients receive multi-factorial interventions where adequate resources are available [36]. This is important, as it should be noted that many of the chronically ill have multiple diagnoses including orthopedic maladies; therefore, careful restrictions and goals must be outlined for each individual patient to provide proper intervention prescription. In the present study, a team of physicians, physical therapists, and clinical exercise physiologists treated the patients to address the multiple problems presented.

Conclusion

The results of the current study apply previous research in individual chronic disease states (e.g., heart disease, cancer, etc.) to a genuine clinical setting and in a large number of medically complex (multiple diagnoses) patients. Strong functional outcomes are imperative in the medically complex populations as there is a robust relationship between functional health status and mortality [37]. Paffenbarger et al. [38] demonstrated that all-cause mortality was significantly lower among physically active subjects, suggesting that physical activity is an important factor for longevity. The present study works to apply these functional and exercise principles to chronically ill patients. In conclusion, integrated therapy interventions that aim to increase the functional strength and functional capacity result in an improvement in ability to perform activities of daily living, psychological state, and a reduction in health care utilization.

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