White Paper: Strength Training for the Older Adult

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Exercise to remediate impaired endurance, joint dysfunction, and impaired mobility is a mainstay of physical therapy practice for older adults.[1] Common modes of exercise include aerobic, strengthening, and balance/flexibility programs. In the past 20 years, much has been learned about the benefits of strengthening.[2-5] Muscle weakness, termed sarcopenia[6] and dynapenia[7], is a normal age-related phenomenon, occurring at a rate of 1% to 5% annually from the age of 30.[8] This rate means that given typical patterns of physical activity, a 70-year-old woman could have 50% to 70% less strength than she had at age 30. The rate of strength decline is dependent on age and physical activity. Those who are physically inactive lose muscle mass and strength more quickly than active individuals who participate in strength training.[9] After the age of 60, power decreases even more rapidly at a rate of 3% to 5% annually, affecting the ability to move and react quickly.[10] Diminished power and strength affect function and can be a leading cause of nursing home admission and falls, further reinforcing sedentary habits.[9,11] The vicious cycle of inactivity and diminished power and strength in turn promote further weakness and loss of power causing further functional disability. Critical to keeping older adults independent in the community and avoiding nursing home placement is breaking this cycle of decreased muscle mass/strength/power, inactivity, and functional decline. Therefore, effective strengthening practices must be employed by physical therapy personnel to maintain the highest level of function and achieve optimal aging.

THE MINIMUM STIMULUS: OVERLOAD

Muscle requires an adequate stimulus, or overload, to get stronger.[12] Similar to the cardiovascular system, skeletal muscle requires a workload of approximately 60% of maximum available strength to increase in strength.[13] For some older adults this overload stimulus may be as low as the weight of a grapefruit; for others, overload may be the weight equivalent of a loaded grocery bag. Threshold is most commonly based on a 1 repetition maximum, (1-RM) or the ability to lift or perform a movement 1 time and 1 time only before muscle fatigue prevents lifting of the load or performing movement through full range of motion.[13] Some practitioners use a 3-RM or 8-RM to determine level of overload depending on perceived frailty and safety.

Activities and exercises below the 60% threshold may result in a modest improvement of 5% to 10% on strength tests, but the observed change is likely related to motor learning rather than a biological increase in contractile protein in the muscle.[14] Motor learning alone does not achieve a reversal of muscle atrophy. Without overload, a further decline in function is likely once intervention ceases. This focus on emphasizing motor learning (eg, gait training without muscle overload) often creates the recidivism seen in many therapy settings where a former patient falls or sustains further functional decline requiring additional episodes of PT care.

EXERCISE PRESCRIPTION

Muscle Strength

The American Academy of Sports Medicine, the American Geriatrics Society, the Section on Geriatrics of the American Physical Therapy Association, and others have recommended the use of a 60% or higher of a 1RM strength stimulus to improve strength and function, even for those with pathology such as osteoarthritis or congestive heart failure.[13,15-17] While the exact dosage in terms of intensity, sets, repetitions, and frequency has not been fully determined, solid evidence is available to physical therapists caring for aging adults.[18]

Intensity

Sixty percent of a 1-RM is the *minimal* overload necessary for muscle adaptation in untrained individuals, including older adults.[19] This threshold can be determined using the rate of perceived exertion scale (Table 1) or the maximum number of repetitions the person can perform. The maximum number of repetitions occurs when exercising muscle fatigues, almost reaching failure as indicated by deteriorating form and inability to complete full range during the last 1 to 2 repetitions. Muscle fatigue just before failure indicates a maximal level of exertion and should be achieved for optimal strengthening to occur.[13] A 60% threshold equates to 15 repetitions and a rate of perceived exertion (RPE) of 12-13. Greater strength effects are achieved

Table 1. Rate of Perceived Exertion

<table>
<tr><th>Modified Scale</th><th>Ordinal Scale[1]</th><th>Percent Effort</th><th>Perceived Work Load</th><th>Talk Test</th></tr>
<tr><td></td><td>6</td><td>20%</td><td rowspan="3">Very, very light</td><td rowspan="2">At Rest</td></tr>
<tr><td></td><td>7</td><td>30%</td></tr>
<tr><td></td><td>8</td><td>40%</td><td rowspan="2">Gentle walking or "strolling"</td></tr>
<tr><td>1</td><td>9</td><td>50%</td><td rowspan="2">Very light</td></tr>
<tr><td>2</td><td>10</td><td>55%</td><td rowspan="3">Steady pace, not breathless</td></tr>
<tr><td rowspan="2">3</td><td>11</td><td>60%</td><td rowspan="2">Fairly light</td></tr>
<tr><td>12</td><td>65%</td></tr>
<tr><td rowspan="2">4</td><td>13</td><td>70%</td><td rowspan="2">Moderately hard</td><td rowspan="2">Brisk walking, able to carry on a conversation</td></tr>
<tr><td>14</td><td>75%</td></tr>
<tr><td>5</td><td>15</td><td>80%</td><td rowspan="2">Hard</td><td rowspan="2">Very brisk walking, must take a breath between 4-5 words</td></tr>
<tr><td>6</td><td>16</td><td>85%</td></tr>
<tr><td>7</td><td>17</td><td>90%</td><td rowspan="2">Very hard</td><td rowspan="4">Unable to talk and keep pace</td></tr>
<tr><td>8</td><td>18</td><td>95%</td></tr>
<tr><td>9</td><td>19</td><td>100%</td><td rowspan="2">Very, very hard</td></tr>
<tr><td>10</td><td>20</td><td>Exhaustion</td></tr>
</table>

with higher intensities of 80% of a 1-RM (15-17 RPE) even in the very old and frail.[20-22] The 80% threshold equates to 10 repetitions, where form deterioration is observed in the last 1 to 2 repetitions.

To determine the appropriate resistance stimulus for strengthening, a quantitative baseline level of strength must be determined. Estimating the amount of resistance an individual can move based on body weight is one option, especially for the leg press and bench press.[13] For a women over 60 years of age, the 50% percentile for the bilateral leg press is equal to a 1-RM of her body weight.[13] Body weight, then, is an estimate of starting weight for determining appropriate load, and resistance load is increased or until the woman can push the load through the full range only one time (1-RM).

If pain or high joint forces are a concern, the 10-RM method is another option for determining appropriate resistance for strengthening. The 10-RM method uses 80% of a 1-RM as a starting point: the individual is asked to lift 80% of her body weight through full range and with good form as many times as possible. Rather than creating an artificial target by asking for a set number of repetitions, asking for as many repetitions as possible minimizes underestimation of the repetition maximum. If more than 20 repetitions can be completed with good form, the chosen resistance is below the 60% threshold necessary for strengthening and needs to be increased.[13]

Similarly, a functional movement's quantitative baseline can be determined. The aging adult can be asked to perform a step up without using his/her arms. If this is too difficult for an individual to accomplish independently, the task can be modified by using a lower step, or allowing use of the arms (although it will be difficult to determine how much of the load is borne by the legs when arm use is allowed). If more than one step up is possible, load can be increased either by raising step height or using a weighted vest for incremental increases in load, such that 1-RM or 10-RM can be determined and sufficient overload is assured. This method of determining appropriate workload can be applied to many functional activities, including sit to stand transitions, wall slides, and transfers.

The traditional manual muscle test (MMT) does not effectively estimate workload for strengthening because of a profound ceiling effect: a 5/5 MMT grade spans forces from 76 – 675 Newtons.[23] Many therapists are unable to consistently discern the difference in muscle function between a MMT grade of Good (4/5) vs. Normal (5/5): measurement error with MMT may be as high as 50%.[24] In addition, a MMT grade of 5/5 does not accurately reflect strength necessary for functional activities. Eriksrud and Bohannon found the minimum lower extremity strength necessary to rise from a chair without arm assistance is 40% to 47% of a person's body weight, equating to a 5/5 grade for the quadriceps on one side and 4+/5 grade on the other using the MMT scale.[25] If strength is graded as 4/5 and 5/5 or "within functional limits" without examining performance of functional activity, important impairments of muscle performance will not be identified.

When beginning a strengthening program for aging adults with physical and functional frailty, using a load just below the desired threshold for overload will insure good form and allow opportunity for motor learning of the specific movement of the exercise.[18] Between 15 to 20 repetitions with evidence of muscle fatigue just prior to failure is appropriate in teaching the aging adult the exercise protocol in the first week of the program.[26] One week is often sufficient time for consistency in performance to develop; once the routine is mastered, the resistance is increased exercise to load that will stimulate muscle adaptation (ie, a minimum of 60% 1RM).

Sets

The American College of Sports Medicine (ACSM) and others recommend that for untrained individuals, a minimum threshold of 1 set be performed when an adequate strength stimulus is used.[2,13] Greater strength gains are realized when more sets are performed, although risk of injury may increase with multiple sets.[13] In the clinic, use of a single set of each exercise during a physical therapy session allows performance of a variety of exercises and movements, is more interesting to the client, and has lower risk of overuse injury.

Repetitions per Set

The number of repetitions should be determined based on the desired intensity for strengthening (Table 2). The appropriate number of repetitions is determined by the patient's effort and form, rather than an arbitrary target number named by the therapist. Direction to perform 10 repetitions may underestimate what the aging adult is capable of, such that he/she does not reach minimal threshold for strengthening. When the number of repetitions is estimated based on the repetition maximum, the minimum 60% of the individual's 1-RM is more likely to be achieved. Asking the patient/client to perform the movement as many times as possible while observing for signs of deteriorating form will more accurately achieve the appropriate stimulus for strengthening.

Frequency

The recommended frequency of exercise performance is based on muscle recovery. When intensity to promote muscle strength (60% or more of 1RM) is used, recommended frequency is 2-3x/week, allowing 24 to 48 hours of rest in between sessions of the *same* muscle group.[13,26] If a patient receives physical therapy care more than once daily over 5-7 days/week, focusing on different muscle groups in each session is necessary to allow adequate muscle rest (ie, upper extremities are challenged one day, lower extremities are challenged the next day). An example of a weekly schedule incorporating recommended rest for muscle recovery is found in Table 3.

Long lasting and significant change in strength occurs over a 12 to 16 week period; however in most instances, aging adults are discharged from physical therapy care in hospital and rehabilitation settings before such gains can be realized. For this reason, home exercise programs and/or community based exercises are necessary if goals of gaining and maintaining strength are to be successfully met.

Where home exercise programs (HEP) are used, specific strengthening exercises performed in the clinic are adapted to make muscle challenge realistic. Milk jugs filled with water, sand filled containers, and elastic bands such as Theraband(R) etc. can provide sufficient stimulus to continue strengthening begun in the clinical setting. Each HEP should be designed to include adequate time for muscle recovery, similar to the way

Table 2a. How to Determine Intensity with 1-RM as the Starting Value

Desired Baseline	% of 1-RM
1-RM	100
2-RM	95
3-RM	93
4-RM	90
5-RM	87
6-RM	85
7-RM	83
8-RM	80
9-RM	77
10-RM	75

RM = repetition maximum

Table 2b. How to Choose a Weight or Machine Value Given a 1-RM of 100 Pounds

Desired Baseline	Load (in pounds)	Repetitions
1-RM	100	1
2-RM	95	2
3-RM	93	3
4-RM	90	4
5-RM	87	5
6-RM	85	6
7-RM	83	7
8-RM	80	8
9-RM	77	9
10-RM	75	10

Table 2c. Appropriate Loads (in pounds) for a Variety of 1-RM Values

1-RM	2-RM	3-RM	4-RM	5-RM	6-RM	7-RM	8-RM	9-RM	10-RM
10	10	9	9	9	9	8	8	8	8
20	19	19	18	17	17	17	16	15	15
30	29	29	27	26	26	25	24	23	23
50	48	47	45	44	43	42	40	39	38
70	67	65	63	61	60	58	56	54	53
120	115	112	108	105	103	100	96	93	91
150	143	140	135	131	128	125	120	116	113

Example: If a 78-year old man can leg press 120 pounds (1-RM) and the desired training intensity is 60% of 1-RM for the first two weeks of exercise, his maximum load would be .60 x 120= 72 lbs. One repetition of this load would be appropriate to lift for 60% of 1-RM. If ten repetitions are desired, the load would be 60 pounds.

Table 3. Example of Exercise Schema to Incorporate Appropriate Intensity and Rest in the Inpatient Environment

Exercise:	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Strengthening High Intensity	Dorsiflexors Quadriceps Gluteus maximus Gluteus medius Gastrocnemius	Abdominals Erector spinae	Dorsiflexors Quadriceps Gluteus maximus Gluteus medius Gastrocnemius	Abdominals Erector spinae • Measure 10-RM or RPE	Dorsiflexors Quadriceps Gluteus maximus Gluteus medius Gastrocnemius • Measure 10-RM or RPE
Endurance Ambulation	Work on gait speed • Measure Gait Speed	Gait tolerance • Measure endurance (i.e. 6MWT)	Work on gait speed	Gait tolerance	Work on gait speed
Postural Control & Balance	Static balance Dynamic Balance Stability Ball	Dynamic gait: Head turning, obstacle course, uneven and compliant surfaces	Static balance Dynamic Balance Stability Ball • Measure Balance (i.e. BBS)	Dynamic gait: Head turning, obstacle course, uneven and compliant surfaces	Static balance Dynamic Balance Stability Ball
Task-specific Activity High Intensity	ADLs, transfers, bed mobility, wheel chair mobility; timed or weighted	Reaching, squatting, bending, lifting, rotation, etc; timed or weighted	ADLs, transfers, bed mobility, wheel chair mobility; timed or weighted	Reaching, squatting, bending, lifting, rotation, etc; timed or weighted	ADLs, transfers, bed mobility, wheel chair mobility; timed or weighted

(Footnotes)
1 Adapted from Borg Perceived Level of Exertion

exercises are designed in the clinical setting. Performing the same strengthening exercises at an intensity of 60% of 1-RM twice a day is not appropriate based on muscle physiology. To provide adequate muscle rest, the HEP might also include motor learning activities and/or aerobic activity.

Muscle Power

The ability to accelerate and to move quickly is an important component of muscle performance that is often compromised in older adults.[27] Adequate power is necessary to cross the street, to climb stairs, and to quickly rise from a chair. Diminished ability to respond quickly to loss of balance, related to diminished power, has been implicated as a cause of falls.[28] Because improving power can reduce falls and function,[29] improving power is a necessary element of a strengthening program. Once an older adult achieves 2 sets of an exercise/movement with good form and no pain, it is appropriate to incorporate training to increase power resources in their exercise program.[26,30] The goal is to move as quickly as possible through the concentric phase of the exercise, followed by a slow and controlled lowering of the load through the eccentric phase back to starting position.[29] Initial loads of 20% of 1RM are progressed as tolerated (indicated by good form and no pain), increasing toward 60% of 1RM.[26,30]

SPECIFICITY AND FUNCTIONAL STRENGTH TRAINING

Strengthening occurs in the specific way that muscle is trained. Sale et al found that closed chain training on a leg press did not increase strength in open-chain knee extension performance and vice versa.[14] In designing exercise programs for aging adults, consideration must be given to salient activities and tasks, especially if there is limited functional reserve or little desire to exercise. Tasks that can be compromised by inadequate strength include transfers, stair climbing, mobility, and activities of daily living that tax dynamic balance. Interventions focusing on developing strength enough to safely and efficiently do these tasks receive priority. Because these tasks involve weight bearing in multiple planes, activities that promote stepping, weight shifting and multi-planar movements should be emphasized. Examples include rising from surfaces of different heights, foot tapping various height steps and progressing to stepping up and over steps and stair climbing, stooping, kneeling, and reaching. Once these tasks can be accomplished with good form, adding a weighted vest to increase load or increasing speed of movement will provide the necessary overload to continue building strength in ways specific to the task.

For frail individuals, task specificity may be the critical parameter to improve function, rather than intensity, because of diminished reserve and increased bodily fatigue.[31] De Vreede,[32] Bean,[33] and Manini[34] have demonstrated that when frail individuals perform task specific exercise, their strength is increased, similar to the effects of resistance exercise. The performance of certain ADL and household tasks in frail individuals may require enough effort to achieve the threshold required for muscle strengthening, thus combining overload with motor learning to achieve functional improvements. Task-specific training for frail men and women may achieve functional gains better than resistance exercise alone.[32]

Progression

It has been our experience that older adults, who are inexperienced exercisers, rapidly increase their ability to progress to successively higher loads, especially on isotonic machines. Therefore it is necessary to continually reassess the patient/client's baseline strength to assure an adequate strengthening stimulus. Progression can be accomplished in several ways. Repetitions can be increased to the desired intensity or the resistive load is increased and the repetitions decreased. For example, when the patient/client can move the initial load more than 12 to 15 repetitions, the load should be increased 2% to 10% and the number of repetitions the patient can do safely, with good form and with maximum muscle fatigue just prior to failure should be re-established.[26] Other ways of progressively increasing the stimulus is to perform more sets or multiple exercises for the same muscle group.

Injury

Many authors have demonstrated the safety of high intensity exercise.[5,35,36] However, some authors have suggested that the potential for injury indicates the need for supervision by trained personnel.[37,38] It is our opinion that using high intensity resistance requires one-on-one supervision to observe form and muscle fatigue. Additionally, adverse cardiac events have not been reported in patients undergoing high intensity training.[39-41] In fact, cardiac benefits are more likely to occur. For example, Martel et al reported decreases in blood pressure in older adults with high normal blood pressures after performing high intensity exercise training.[42] Delayed onset muscle soreness (DOMS) is a common effect of high intensity strength training and should be expected. The therapist can minimize the effects of DOMS by preparing the patient/client for its effect, specifically identifying the location of the expected muscle soreness and differentiating muscle soreness from joint pain. Encouraging the patient/client to move through the DOMS will reduce the duration of DOMS.

Clinical Significance

Muscle weakness is related to decreased physical function and falls and is a compelling reason for physical therapy intervention. However, inadequate resistance is too often seen in the clinic where 2lb weights are commonly used and an arbitrary number of repetitions to perform is given, *without a quantitative baseline assessment of strength*. Strengthening without rationale or adequate stimulus is tantamount to malpractice.

SUMMARY

The aim of this White Paper was to review the current recommendations for strength training of older adults, to promote physical therapist best practice and achieve optimal functional outcomes. A secondary intent was to encourage prospective researchers to use published guidelines to establish an adequate strength stimulus for patients in their research, rather than perpetuating "usual or traditional" care.

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