THE EFFECTS OF AGING ON MUSCLE STRENGTH AND FUNCTIONAL ABILITY OF HEALTHY SAUDI ARABIAN MALES

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Background: Loss of muscle strength as a result of normal aging is reported to impair functional ability in various communities. The purpose of this study was to determine the age at which loss of muscle strength and functional ability begins, and to establish a preliminary baseline for the pattern of changes in muscle strength and functional ability of aging in adult healthy Saudi Arabian males.

Subjects and Methods: A sample of 160 healthy Saudi Arabian males aged 20-89 years participated in this study. The subjects were divided into seven age groups, each representing a decade. Maximum isometric "make" strength of bilateral quadriceps muscles were measured using a hand-held dynamometer. Functional ability tests that included stair walking, timed-up-and-go and balance tests were also performed and timed using a digital stopwatch.

Results: Muscle strength and functional ability remained unchanged in the 20- and 30-year-old age groups. Around the age of 40, muscle strength and functional ability began to gradually decline. Muscle strength of males in their twenties was 380±62N and 330±60N in the right (RT) and left (LT) quadriceps, respectively. A decline with aging is represented by 190±40N and 110±30N in the RT and LT quadriceps muscles, respectively, by the eighth decade of life. Stair-walking, timed up-and-go and balance tests in the second decade were 4±1 sec, 8±2 sec and 130±20 sec, respectively, against 15±4 sec, 26±7 sec and 15±5 sec in the eighth decade. One-way ANOVA test showed that muscle strength and functional ability differed ($P<0.01$) among decades, except between the second and third decades ($P<0.31$). Age, muscle strength and functional ability displayed a significant relationship ($P<0.001$).

Conclusion: Loss of muscle strength and functional ability seem to begin in the fourth decade of life. The changes in muscle strength and functional ability have a significant relationship to aging. Clinically, these results may provide clinicians with a guide to the strength level of normal quadriceps and the functional ability of adult healthy Saudi Arabian males in relation to the normal aging process.

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Key Words: Muscle strength, functional performance, aging.

Muscle strength is known to indicate habitual and cultural physical activity.[1,2] It has a strong association with changes in the body systems, i.e., the cardiovascular system, the nervous system, the musculoskeletal system, and the endocrine system, as well as with the nature of psychosocial activities.[3-7]

Loss of muscle strength as a result of normal aging is reported to impair functional ability in various communities.[4,8-11] There is controversy in the literature as to when loss of muscle strength and the pattern of changes in strength and functional ability as it corresponds to aging begin.[4,11,12] Such a controversy necessitates the establishment of a database on muscle strength and functional ability loss for any given population. This information can provide clinicians with accurate guidelines for the normal changes in muscle strength and functional ability throughout aging. This study aims to establish a preliminary baseline for the effects of aging on muscle strength and functional ability of healthy adult Saudi Arabian males.

Subjects and Methods

Subjects

A sample of 160 Saudi Arabian males aged 20-89 years volunteered to participate in this study. All were Riyadh residents, originally from different parts of Saudi Arabia. To collect this number of participants, several verbal announcements were made to the students at King Saud University in Riyadh to encourage them to bring their male relatives for general functional ability testing. The subjects were healthy, and claimed no known musculoskeletal, neuromuscular or cardiovascular pathology affecting their functional ability. None were engaged in active sports for

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TABLE 1. *Characteristics of subjects grouped by decade (mean±SD; n=number of subjects).*

Decade	Age (yr)	Weight (kg)	Height (cm)
20s (n=30)	24±4	58±8	160±10
30s (n=20)	32±6	62±10	167±6
40s (n=29)	47±8	70±7	162±10
50s (n=26)	59±4	66±15	164±20
60s (n=19)	64±9	65±20	159±22
70s (n=20)	72±5	58±15	160±23
80s (n=16)	81±6	61±18	158±26

TABLE 2. *Mean±SD of muscle strength and functional ability tests of different age groups.*

Decade (yr)	Muscle strength (N)		Stair walking (sec.)	Timed up-and-go	Balance
	Rt	Lt			
20s	380±62	330±60	4±1	8±2	130±20
30s	379±35	333±30	4±1	8±3	135±24
40s	313±29	294±16	6±2	11±3	90±19
50s	284±20	255±20	8±3	15±4	60±10
60s	235±15	206±20	11±3	18±5	40±10
70s	215±30	186±15	13±4	22±5	30±8
80s	190±40	110±30	15±4	26±7	15±5

more than two hours per week. They were aware of the purpose of the tests and were not paid for their participation. All were able to follow instructions. The age, height and weight of subjects were recorded (Table 1).

Quadriceps Strength Testing

Isometric quadriceps strength was measured bilaterally, using a Nicholas hand-held dynamometer. Subjects sat upright in a test chair with hips and knees flexed at approximately 90 degrees. A restraining belt was strapped across the waist to minimize unwanted hip, pelvic girdle and lower trunk movements. The subjects' hands were positioned across their chests. The hand-held dynamometer was then fixed just proximal to the malleoli. The quadriceps strength was measured using isometric "make" tests. The subjects were asked to build force to a maximum over a 2-second period and maintain the maximum effort for approximately 5 seconds. The subjects were then requested to stop. This procedure has been shown to be reliable and adequate to measure the maximum isometric quadriceps strength.[12,13] Isometric quadriceps force was measured in the late morning after an hour of resting in the laboratory. The peak force (in Newton 'N') of three readings was recorded and averaged from each side to characterize the strength of the quadriceps. Two minutes of rest were allowed between repeated readings. All strength measurements were obtained by a 30-year-old male physical therapist, whose weight was 90 kg (882N), with a hand grip of 630N. He was familiar with the hand-held dynamometer and was physically healthy. His strength was sufficient to fix the dynamometer against the forces produced by all subjects. The hand-held dynamometer has an upper limit of 199.9 kg (1959 N) and measures force to the nearest tenth of a kilogram.

Functional Ability Testing

Functional ability tests, which included stair walking,[14] timed up-and-go,[15] and balance,[16] were performed and timed in seconds (sec.), using a digital stopwatch. One practice run was carried out before the actual trial was recorded for each test. Reliability of these procedures was established in our laboratory for healthy adults (r=0.77-0.86). These are quick and practical tests of basic mobility that form part of a functional ability in different age groups.[9,17]

Stair Walking Test

Each subject stood in front of a small wooden staircase consisting of three steps of 20 cm up and three steps of 15 cm down. They were instructed on the command "Go" to walk up and down the staircase at a comfortable pace. They were not allowed to stop or to use the handrail as support. The task was timed.

Timed Up-and-Go Test

The subjects were seated in a chair with arm rests and instructed on the command "Go" to rise from the chair without using the arms for support, walk three meters along a level corridor, turn, return to the chair, and sit down at their own comfortable speed. The task was timed.

Balance Test

The subjects were asked to stand on their preferred leg with their eyes open. The task was timed from the moment the leg was lifted off the floor until balance was lost or the foot was placed on the floor again.

Data Analyses

One-way ANOVA was used to determine the difference among the age groups. If a statistical difference existed, Bonferroni *post-hoc* test was used to determine which group was different from the other groups, with alpha level set at 0.05. Multiple regression analysis was also used to determine the nature and degree of the relationship between muscle strength, functional ability tests and age. The SPSS software statistical program was used to analyze the data.

Results

The quadriceps strength and functional ability remained level throughout the second and third decades of life. A gradual decline started in the fourth decade. A summary of the quadriceps strength and functional ability measurements for each age group is presented in Table 2.

The isometric quadriceps strength in the second decade were 380±62N and 330±60N in the right (RT) and left (LT) quadriceps, respectively. A stable pattern of isometric quadriceps strength continued throughout the third decade of life (379±35N in the RT leg and 333±30N in the LT leg). A gradual decline in the quadriceps strength continued to the eighth decade (190±40N in the RT leg and 110±30N in the LT leg). By the eighth decade, there was an approximate quadriceps strength loss of 33%-50%. One-way analysis of variance test showed no significant difference between the muscle strength in the second and third decade ($P<0.18$). In contrast, a significant difference was found in muscle strength among the age groups ($P<0.001$).

The time required for subjects in their eighth decade to complete the stair walking test was more than three-fold (15±4 sec) of that required for subjects in the second decade of life (4±1 sec). It also took more than thrice the time (26±7 sec) for the subjects in the eighth decade to complete the timed up-and-go test, compared to the subjects in their second decade (8±2 sec). These differences among the age groups were statistically significant ($P<0.01$). The difference between the second and third decade was not statistically significant ($P<0.31$).

In the balance test, the subjects in the second decade balanced themselves for 130±20 sec. Subjects in the eighth decade maintained balance for 15±5 sec. These differences among the age groups were statistically significant ($P<0.01$). The difference between the second and third decade was not statistically significant ($P<0.26$).

Regression analysis showed that age is significantly ($P<0.001$) associated with muscle strength ($r^2=0.54$ to 0.62), stair walking test ($r^2=0.77$), timed up-and-go test ($r^2=0.64$), and balance test ($r^2=0.77$) (Table 3). Muscle strength also showed significant association ($P<0.001$) with stair walking test ($r^2=0.31$ to 0.33), timed up-and-go test ($r^2=0.20$ to 0.24) and balance test ($r^2=0.76$ to 0.79).

TABLE 3. *Regression analysis between age, muscle strength and functional ability.*

	Age		Muscle strength			
			Right		Left	
Decade (yr)	R	R^2	R	R^2	R	R^2
Muscle strength						
Right	0.79	0.62	–	–	–	–
Left	0.74	0.54	–	–	–	–
Stair walking	0.88	0.77	0.58	0.33	0.55	0.31
Timed up-and-go	0.80	0.64	0.49	0.24	0.45	0.20
Balance	0.88	0.77	0.89	0.79	0.87	0.76

$P<0.001$.

Discussion

In this study, the isometric quadriceps strength and functional ability remained fairly stable throughout the second and third decade of life. A gradual significant loss started at the fourth decade in these groups of subjects. It is not clear if the reduction in muscle strength and functional ability during the fourth decade was due to age-related changes or from a sedentary lifestyle, or a combination of both. However, the significant correlation between age and muscle strength and functional ability suggests that age-related changes may be used as a predictor for such reduction. The sedentary aspects of living were not measured in this study. It was, therefore, difficult to determine its effect on muscle strength and functional ability among the subjects in their fourth decade. Researchers may be encouraged by this study to review the relationship between the muscle morphology and biochemistry, sensory input and the impact of lifestyle on muscle strength and physical performance of people in their forties. Whatever the causes of declining muscle strength and functional ability, the fourth decade is considered a turning point for muscle strength and physical performance.

The gradual decline in muscle strength and functional ability as a result of aging have also been reported in various communities.[2,5,9,18] This decline is related to various normal aging processes,[9,11,19] lifestyle, vocation, behavioral, cultural and physical activities.[1,2] However, the degree and pattern of decline differ from one community to another. These studies cannot be compared with our study because of differences in equipment and procedures used in measuring muscle strength and/or functional ability. Also, specific comparisons are difficult because of the inconsistent grouping of the subjects in various studies.

The results of this study, like those of others,[4,8-11,18] demonstrate a relationship between age, lower extremity muscle strength and functional ability. It has also been observed that increases in gait speed are associated with a higher level of muscle activity.[18,20] Thus, muscle strength generation is essential to ambulation.

The speed of the tested functional activity is important because of its implications for community ambulation[21,22] and because of its relationship with independent living,[23] risk for falls,[24] and muscle strength.[12,13]

In this study, isometric quadriceps strength for all age groups was less than reported by previous studies.[12,13] The loss of strength in the isometric quadriceps began during the fourth decade of life in this study. In another study, isometric quadriceps strength began to decline in the fifth decade.[12] The awareness of losing muscle strength and endurance was also reported to occur at about age 50.[25] These variations may be due to different anthropometric characteristics and habitual level of functional activity of the participants in the various studies.[12,13,25] Differences in equipment and procedures used to measure muscle strength may also contribute to the variations. Body weight and height have been shown to correlate with quadriceps strength.[12,26] Habitual level of physical activity and the degree of physical effort have been reported to affect muscle strength.[1,2] Exceeding 350N is possible, but for the average examiner, this is too high for a careful measurement.[27] Furthermore, the quadriceps strength recorded in this study cannot be considered subnormal because subjects with quadriceps strength below 160N and body weight >40 kg are considered to have subnormal strength.[28]

This study confirms the extreme importance of quadriceps muscle strength for activities of daily living, including standing up, sitting down, and stair climbing.[8,9,18] A regular quadriceps muscle strengthening program may be helpful in maintaining functional activity involving the lower extremity.[29-32] People who exercise regularly are stronger, have faster reaction times and are more physically stable than people who do not exercise regularly.[33]

Muscle strength has an integral role in the structure and function of joints[34] and bone mass.[35] The degree to which muscle strength loss in the fourth decade of life will affect the structure and function of joints and bone mass in the elderly is a question that needs to be answered.

Health care expenditures increase when subjects begin to lose their functional ability.[29] This could imply that people aged 40 and older in Saudi Arabia may spend more money on health care than the younger population. Consequently, to lower health care expenditure for people aged 40 and over, it is necessary to find a proper solution to reduce the reported loss in functional ability. Regular physical exercises, such as balancing, strength training, low-impact aerobic exercise, body flexibility exercise and functional exercise, and health promotion in the workplace, have been documented to improve functional ability and self-reported health status in various communities.[29-33] These exercises and health promotion in the workplace could also be used in Saudi Arabia to reduce declining functional ability.

The reduction in balance ability between the fourth and the eighth decades of life could indicate an increased risk of falling. This is in agreement with the reported increased incidence of falls in elderly subjects.[24] Falls are the most important reason for elderly people being admitted to the hospital[36] and apprehension about falling is a source of distress in 25% to 50% of community-dwelling elderly people.[24,37] Quadriceps weakness has been associated with an increased incidence of falls in elderly subjects.[24,38] In nursing homes, dwellers with a history of falls only had 62% of the quadriceps strength of fellow residents not experiencing falls, and 37% of community dwellers.[39] An intervention program of muscle strength and balance exercises has been suggested to prevent falls.[14]

In summary, isometric quadriceps strength is able to determine the level of physical activities that can be performed during the aging process. Subjects in their fourth decade of life and above are at increased risk for a variety of physical and functional limitations. The figures produced in this study can provide therapists with a guide to normal isometric quadriceps strength level and functional ability of a healthy and active population.

References

1. Cooper C, Barker DJP, Wickham C. Physical activity, muscle strength and calcium intake in fracture of the proximal femur in Britain. BMJ 1988;297:1443-8.
2. Ringsberg K. Muscle strength differences in urban and rural population in Sweden. Arch Phys Med Rehab 1993;74:1315-8.
3. Lung M, Hartsell H, Vandervoort A. Effects of ageing on joint stiffness: implications for exercise. Physiother Can 1996;48:96-106.
4. Vandervoort AA. Effects of ageing on human neuromuscular function: implications for exercise. Can J Sport Sci 1992;17:178-84.
5. Marks R. The effect of ageing and strength training on skeletal muscle. Aust Physiother 1992;38:9-19.
6. Reynolds P. Characteristics of ageing skeletal muscle. Physiother Theory Pract 1991;7:157-62.
7. Snow-Harter C, Bouxsein M, Lewis B, Charette S, Weinstein P, Marcus R. Muscle strength as a predictor of bone mineral density in young women. J Bone Miner Res 1990;5:589-95.
8. Bohannon R. Comfortable and maximum walking speed of adults aged 20-79 years: reference values and determinants. Age Ageing 1997; 26:15-9.
9. Hurley M, Rees J, Newham D. Quadriceps function, proprioceptive acuity and functional performance in healthy young, middle-aged and elderly subjects. Age Ageing 1998;27:55-62.
10. Rantanen T, Era P, Heikkinen E. Maximal isometric knee extension strength and stair-mounting ability in 75- and 80-year old men and women. Scand J Rehab Med 1996;28:89-93.
11. Larsson L, Grimby G, Karlsson J. Muscle strength and speed of movement in relation to age and muscle morphology. J Appl Physiol 1979;46:451-6.
12. Bohannon R. Reference values for extremity muscle strength obtained by hand-held dynamometry from adults aged 20 to 79 years. Arch Phys Med Rehab 1997;78:26-32.
13. Andrews AW, Thomas MW, Bohannon RW. Normative values for isometric muscle force measurements obtained with hand-held dynamometers. Phys Ther 1996;76:248-59.
14. Skelton DA, McLaughlin AW. Training functional ability in old age. Physiotherapy 1996;82:159-67.
15. Podsiadlo D, Richardson S. The timed “up and go”: a test of basic functional mobility of frail elderly persons. J Am Geriatr Soc 1991;39:142-8.
16. Iverson BD, Gossman MR, Shaddean SA, Turner ME. Balance performance, force production and activity level in non-institutionalized men 60-90 years of age. Phys Ther 1990;70:348-55.
17. Simmonds M, Olson S, Jones S, Hussein T, Lee E, Radwan H, et al. Physical performance tests: are they psychometrically sound and clinically useful for patients with low back pain? Spine. In press.
18. Brown M, Sinacore D, Host H. The relationship of strength to function in the older adult. J Gerontol 1995;50:55-9.
19. Wilmore J. The aging of bone and muscle. Clin Sports Med 1991;10:231-44.
20. Miyashita M, Matsui H, Miura M. The relation between electrical activity in muscle and speed of walking and running. Med Sport 1971;6:192-6.
21. Nelson P, Hughes S, Virjee S, Beresford H, Murray C, Watson E, et al. Walking speed as a measure of disability. Care Elderly 1991;3:125-6.
22. Robinett C, Vondran M. Functional ambulation velocity and distance requirements in rural and urban communities. Phys Ther 1988;68:1371-3.
23. Cunningham D, Paterson D, Himann J, Rechnitzer P. Determinants of independence in the elderly. Can J Appl Physiol 1993;18:243-54.
24. Tinetti M, Speechly M, Ginter S. Risk factors for falls among elderly persons living in the community. N Engl J Med 1988;319:1701-7.
25. Tseng B, Marsh D, Hamilton M, Booth F. Strength and aerobic training attenuate muscle wasting and improve resistance to the development of disability with aging. J Gerontol 1995;50:113-9.
26. Nordstrom P, Thorsen K, Nordstrom G, Bergstrom E, Lorentzon R. Bone mass, muscle strength and different body constitutional parameters

in adolescent boys with a low or moderate exercise level. Bone 1995;17:351-6.
27. Wiles C, Karni Y. The measurement of muscle strength in patients with peripheral neuromuscular disorders. J Neurol Neurosurg Psychiatr 1983;46:1006-13.
28. Ploeg R, Fidler V, Oosterhuis H. Hand-held myometry: reference values. J Neurol Neurosurg Psychiatr 1991;54:244-7.
29. Cochrane T, Munro J, Davey R, Nicholl J. Exercise, physical function and health perceptions of older people. Physiotherapy 1998;84:598-602.
30. Pert V. Exercise for health. Physiotherapy 1997;83:453-60.
31. Province M, Hadley E, Hornbrook M, et al. The effects of exercise on falls in elderly patients: a preplanned meta-analysis of the FICSIT trials. J Am Med Assoc 1995;273:1341-7.
32. Preventing falls and subsequent injury in older people. Effective Health Care Bulletin 1996;2(4).
33. Lord S, Caplan G, Ward J. Balance, reaction time and muscle strength in exercising and non-exercising older women: a pilot study. Arch Phys Med Rehab 1993;74:837-9
34. O'Reilly S, Jones A, Doherty M. Muscle weakness in osteoarthritis. Curr Opin Rheumatol 1997;9:259-62.
35. Marcus R. Relationship of age-related decreases in muscle mass and strength to skeletal status. J Gerontol 1995;50:86-7.
36. Cryer C, Davidson L, Styles C. Injury epidemiology in the South East: identifying priorities for action. Prepared by South East Institute of Public Health, South Thames Regional Health Authority, 1993.
37. Tinetti M, Baker D, McAvay G, Claus E, Garrett P, Gottschalk M, et al. A multifactorial intervention to reduce the risk of falling among elderly people living in the community. N Engl J Med 1994;331:822-7.
38. Hyatt R, Whitelaw M, Bhat A, Scott S, Maxwell J. Association of muscle strength and functional status in elderly people. Age Ageing 1990;19:330-6
39. Whipple R, Wolfson L, Amerman P. The relationship of knee and ankle weakness to falls in nursing home residents: an isokinetic study. J Am Geriatr Soc 1987;35:13-20.