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Power of lower extremities and age were the main determinants on the Agility Test for Adults in a cohort of men aged 66-91 years

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ABSTRACT

Study Design: Cross-sectional study.

Objective: To evaluate the relationship between agility and personal factors, muscle strength and power, mobility, self-reported balance and physical activity among older men.

Methods: Agility was measured by using the Agility Test for Adults (ATA). We studied 100 Finnish male former elite athletes (endurance n = 50; power n = 50) and 50 matched controls aged 66 to 91 years (mean age 75.5 years). The associations between agility and other variables were similar between three groups; thus, multiple linear regression analyses were done by using the pooled data of the participants.

Results: On the basis of multiple linear regression analyses, combination of age ($p = .02$), self-reported Activities-specific Balance Confidence scale (ABC scale), jumping height ($p = .001$) and self-rated health explained 26% of the variance in execution time of ATA ($R^2 = 0.26$; $p = .000002$) among elderly men.

Conclusion: Power of lower extremities and age were the main determinants of the results of ATA in a cohort of men aged 66-91 years. From a clinical point of view, power of lower extremities measured by test demanding explosive power plays an important role to maintain or enhance capacity of agility.

KEYWORDS: Ageing; countermovement jump; feasibility; motor skills; physical functioning

Introduction

Relationships between balance, mobility, muscle strength/power of lower extremities, or physical activity have been studied in older people [1-4] while there is a little research on the relationship between agility and those factors among older adults [5]. The evaluation of agility would be useful because it could help trainees to identify at risk individuals who show decline in these neuromuscular functions and would help them to develop exercise programs improving or maintaining the capacity of agility among elderly.

The physical capacity represents physical functioning that is needed to perform independently and safely activities of daily living. The ageing process tends to impair physical capacity as agility, balance, muscle strength and power, and causes difficulties in daily activities and physical functioning of older adults [3, 6-8]. The capacity of agility has been described as a versatile skill consisting of a variety of body functions including power, balance and cognitive functions [9-11]. Based on data from previous cross-sectional studies, weak relationships have been reported between agility and power of lower extremities in young physically active people because cognitive functions appear to have a stronger influence on agility than muscle power qualities [10, 12, 13]. Furthermore, one previous study has shown that balance and coordination would be the physical key qualities that are most strongly associated with agility [14]. These findings are in line with conclusions drawn by Liefeith et al. [15] suggesting that the capacity of agility requires the dynamic integration of balance, coordination, decision making, and dexterity, contraction of a muscle, mobility, perceptual awareness and speed depending on a physical task.

The relationships between agility, balance and power of lower extremities have been reported among young athletes, but limited information is available on explanatory factors determining agility in older persons after their athletic career. Therefore, we aimed to study the relationship between Agility Test for Adults (ATA) and a wide selection of known and potential determinants: personal factors, body mass index (BMI), jumping height, hand grip strength, static balance, walking speed, chair stand, self-reported Activities-specific Balance Confidence scale (ABC scale) [16] and self-reported leisure time physical activity (LTPA) among elderly men. In addition, participant group allowed evaluating the feasibility of ATA for people over sixty years old having high mean age and still with a large age variation. Based on previous cross-sectional studies conducted in untrained adults [17] and in young athletes [14, 18], it was hypothesized that the explosive power of lower extremities would be related to agility among former elite athletes and their controls. However, age may have a diminished influence on the capacity of agility because one previous study has reported decline of agility already beyond the age of 40 [19].

Materials and methods

Participants

Detailed descriptions of the participants and the criteria for inclusion and exclusion have been previously reported [20, 21]. Briefly, a questionnaire-based study consisting of Finnish male former elite athletes (*n* = 2424) and their age- and area-matched healthy controls (*n* = 1712) was initiated in the year 1985. Participants were mailed identical questionnaires in 1995 and 2001. In 2008, all surviving cohort members (*n* = 1183) who had answered at least one of the previous questionnaires, were recruited to the Health Study 2008. Of them, 599 (50.6%) agreed to participate. A flowchart describing the participants and non-participants of the study is presented in Figure 1.

In 2008-2010, clinical examinations including measurements of personal factors and physical functioning were carried out in a subgroup, which was randomly selected from the 2008 cohort of former elite athletes and controls. The subgroup included 50 endurance athletes (aged 76.2 ± 5.2 years), 50 power athletes (aged 74.9 ± 5.1 years) and 50 controls (aged 75.4 ± 5.0 years) [21]. The selection of the study cohort was made by using the GMATCH macro [22] using age and area as matching criteria to select and form the groups. The participants were excluded from the study if they were unable to execute the measurements of physical functioning and/or to complete the questionnaires. Of the 150 participants, 14 (9.3%) were unwilling to participate in the second test session (agility, static balance and jumping height) due to personal reasons. Altogether 34 (22.7%, mean age 78.7 years) participants were not able to execute ATA by reasons of declined function of lower extremities and various neurological diseases. Detailed reasons are described in Figure 1. Data on LTPA were missing for five (3.3%) participants. Overall data from 97 (64.7%, mean age 75.7 years) participants were available for regression analysis.

The study was approved by the ethics committee of the Hospital District of Helsinki and Uusimaa. All participants were informed of the purpose, benefits and risks of the study prior to signing their written informed consent document to participate in the study.

Procedure

All participants underwent clinical examinations including assessment of acute disorders of lower extremities, cardiovascular and neurological diseases by a trained physician. In addition, information on chronic medication was obtained from national registers [23]. Two individual physical functioning test sessions were carried out between noon and 4 p.m. The first session included the following tasks: chair stand, hand grip strength and walking speed. On the second test session, participants executed ATA, static balance, and jumping height, as well as completed the ABC scale questionnaire. All participants received identical instructions on tests that were conducted barefooted in light clothes (t-shirt and shorts). At the beginning of each session, the participants performed warm-up with exercise bicycle for 3-5 minutes and with a standardized battery of dynamic stretches. After warm-up, an experienced physiotherapist demonstrated the test and participants were allowed to practice each test once. The same physiotherapist, who was blinded to the athletic history of the participant, carried out all measurements.

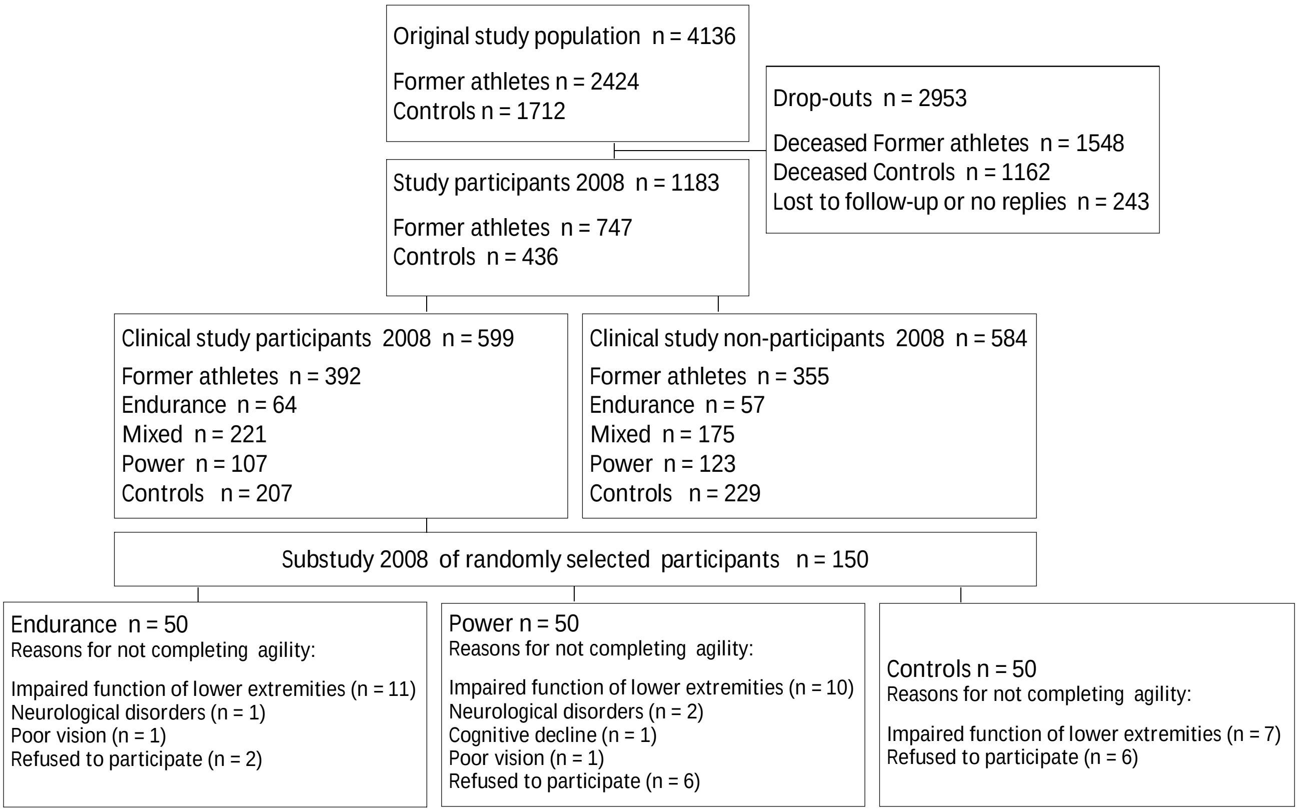

Figure 1. Flowchart of participation through the study.

In this study, the International Classification of Functioning, Disability and Health (ICF) is used as a framework for the physical capacity and performance [24]. Physical functioning of former elite athletes and their controls encompasses measurements of body functions and structures, activities and participation on two component levels of the ICF: 1) ‘body functions’ describes e.g. proprioceptive function (e.g. agility), muscle power functions (e.g. countermovement jump) and weight maintenance functions (e.g. BMI), and 2) ‘activities and participation’ include capacity for activities (e.g. agility and chair stand); and performance for participation is evaluated by ABC scale and LTPA [25]. Figure 2 outlines measurements in the ICF domains.

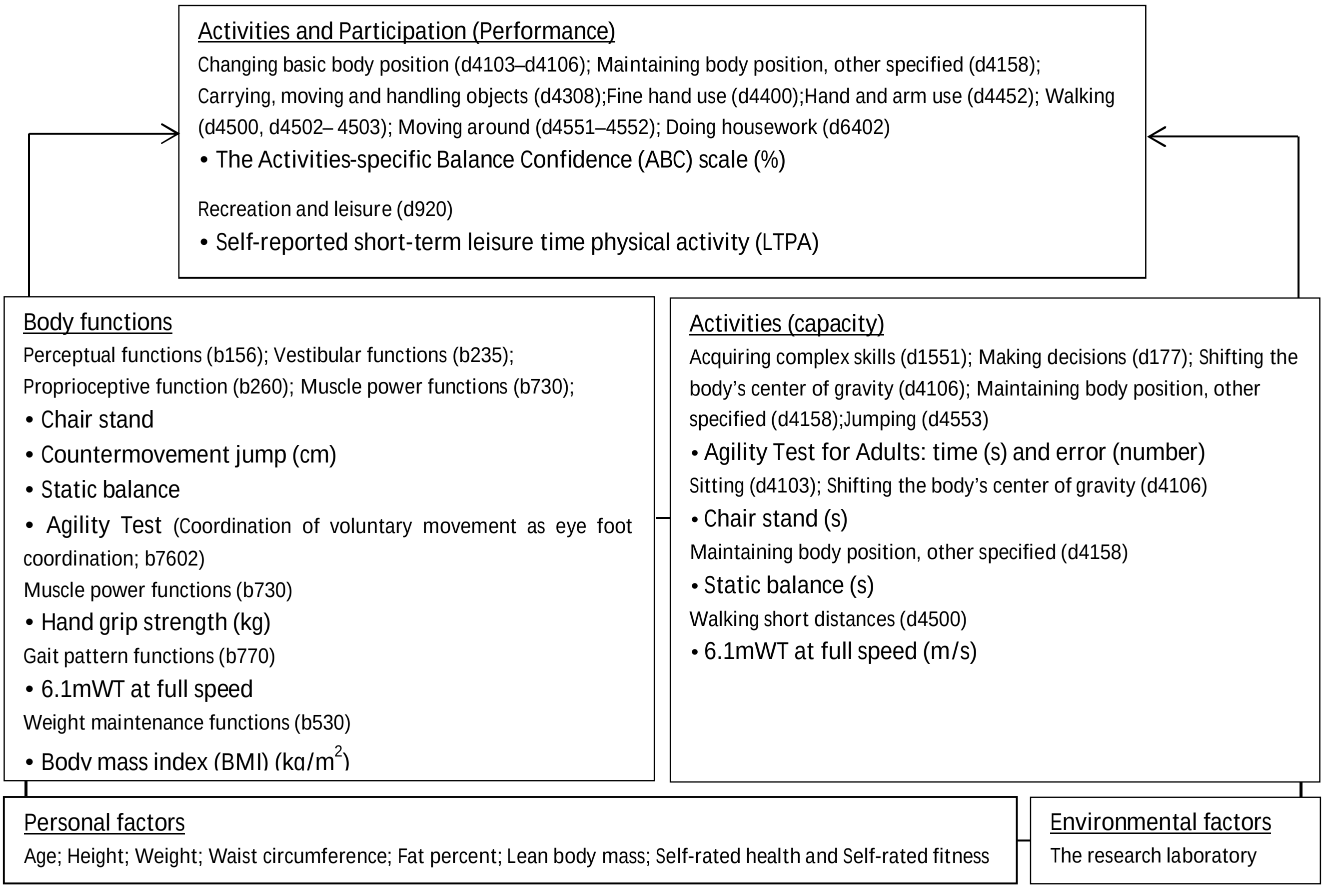

Figure 2. Health condition and measurements of physical functioning in male former elite athletes and their controls on the basis of the ICF categorization [25].

Personal factors

A trained study nurse performed the physical examinations including assessment of *height* and *weight*, as well as blood sampling. Height was measured barefooted with a stadiometer using an accuracy of 0.1 centimetres. Body weight with an accuracy of 0.1 kg was determined with a digital scale (Seca Delta Model 707 patient scale, Seca, Hamburg, Germany) in light clothing and barefoot. *Waist circumference* was measured midway between the anterior superior iliac spine and lower edge of the rib cage in a relaxed standing posture. *Body fat per cent* was calculated as fat mass (kg) divided by body weight (kg) converted to percent. *Lean body mass* with an accuracy of 0.1 kg was assessed by electrical bio impedance (In Body 3.0, Biospace, Soul, South Korea). *Self-rated health (SRH) and fitness (SRF)* were evaluated by a five-point Likert Scale (very good, fairly good, average, fairly poor and poor) [26]. For the analyses, response scores 3-5 were unified as 'average or fairly poor' in variables SRH and SRF (no responses in score 5 and very few ones in score 4). Table 1 shows detailed personal factors of the participants. BMI was calculated as measured weight divided by height squared (kg/m^2) (Table 1).

Leisure-time physical activity

LTPA was evaluated by a validated questionnaire that included information on average intensity, duration and frequency of physical activity [27, 28] during the previous three months (Table 1). Intensity of LTPA was asked by the following question “Is your physical activity (physical exercise) during leisure time about as tiring (intensive) on average as? 1 = walking (4 metabolic equivalent [MET]), 2 = walking and jogging alternately (6 MET), 3 = jogging (10 MET), 4 = running (13 MET)”. Duration of LTPA was asked by the question “What is the mean duration of your average physical exercise session? 1 = < 15 minutes, 2 = 15−29 minutes, 3 = 30−59 minutes, 4 = 1−2 hours, 5 = > 2 hours”. Frequency of LTPA was asked by the question “How many times per month do you participate in physical exercise? 1 = < once a month, 2 = 1−2 times / month, 3 = 3−5 times / month, 4 = 6−10 times / month, 5 = 11−19 time / month, 6 = > 20 times / month”. For each of intensity category a MET value (MET value, 1 MET = 3.5 ml VO_2 / kg / min or 1 kcal / kg / h) [29] was determined. The volume of LTPA was expressed in MET hours (METh), which was calculated by multiplying the intensity (MET), duration and frequency.

Table 1. Mean (SD) of personal factors and BMI, percentage (%) of self-rated health and fitness, and LTPA for the participants[‡].

	ndurance = 50		Power n = 50		Control n = 50	
Age (years)	76.2	(5.2)	74.9	(5.1)	75.4	(5.0)
Height (cm)	173.7	(6.1)	173.5	(9.9)	173.3	(5.9)
Weight (kg)	75.3	(11.7)	84.8	(16.4)	77.8	(11.5)
Waist circumference (cm)	94.1	(10.2)	99.6	(11.9)	97.4	(9.7)
Fat percent (%)	23.7	(6.2)	26.6	(5.4)	24.7	(6.0)
Lean body mass (kg)	56.8	(5.6)	61.4	(9.3)	58.0	(5.3)
Self-rated health (%)						
very good	12.0		8.2		4.0	
fairly good	60.0		51.0		46.0	
average or fairly poor	28.0		40.8		50.0	
Self-rated fitness (%)						
very good	18.0		8.3		6.0	
fairly good	48.0		52.1		50.0	
average or fairly poor	34.0		39.6		44.0	
BMI (kg/m^2)	24.9	(3.5)	28.0	(3.7)	25.9	(3.4)
LTPA volume (METh/week)	43.2	(34.5)	26.1	(23.9)	18.9	(15.1)

[‡] BMI: body mass index; LTPA: leisure-time physical activity; METh/week: metabolic equivalent hour per week.

Agility

The ATA has been developed to evaluate the capacity of agility comprehensively. ATA and its test-retest reliability have been reported in detail previously [9]. Our study described ATA performance as side-stepping movements including multi-choice cognitive tasks. Initially, the participant stood barefoot behind the starting line. After getting permission, he had to jump on all the twenty-five marks (11 cross marks and 14 square marks) as fast as possible without errors over the finish line.

The error was counted when the participant jumped with the wrong foot on the cross mark, or with one leg on the square, or the foot did not hit the mark. The fastest time (s) of three attempts was recorded.

The execution of ATA has been suggested to demand quick perception and decision making to choose target movement between 3 types of jumping on the marks while quickly processing visual, vestibular and sensomotoric information and connecting that with the neuromuscular system [9]. The essentials of ATA execution are speed and accuracy. The basis of our study is that errors should be taken into account when evaluating the execution in versatile ATA test. In our study, execution time has been increased by 1% per error based on our calculations (data not shown).

Static balance

In the balance test [30], the participants stood both in a tandem (one foot after the other) and in one-leg positions on firm and soft platforms in both positions with open eyes and closed eyes. He was asked to stand in each position for as long as possible but for a maximum of 20 s. The subtest, standing with one leg on firm platform with closed eyes, was selected in further analysis because it discriminated the study groups best (p = .049; data not shown). The execution time was recorded in seconds (s) [21].

Walking speed

Walking speed was measured over a distance of 6.1 meters [31] using a stopwatch. The participant was asked to walk the distance as fast as he could, starting from a standstill behind the starting line continuing at full speed over the finish line. He was allowed to use walking aids if he normally uses them when walking. We recorded number of steps and speed in meter per second (m/s) [21].

Chair stand

The chair stand test [32] was used for evaluating mobility. The participant was asked to sit down in a standard chair with no arm rests, with hands across their chest. He was asked to get up and sit down five times as quickly as possible, still without using his hands. Execution time was measured in seconds with one decimal using a stopwatch [21]. It was also recorded whether the participant was able to get up from the chair five times in a row with or without using his hands. The test-retest reliability of the 5-repetition sit-to-stand test has been reported as good to very good [33].

Activities-specific Balance Confidence scale (ABC scale)

The ABC scale [16] was used to measure a person's balance confidence and ability to perform daily activities without falling; this scale has been designed especially for evaluating older adults

[34]. The questionnaire contains 16 activities-specific items scored on a range from 0% to 100% (0 indicating no confidence and 100 indicating full confidence) [21].

Power of lower extremities

Countermovement jump (CMJ) was used to measure power of lower extremities using a contact mat (Newtest Powertimer®, Newtest Oy, Finland) [35, 36]. The participant was barefoot keeping his body in straight position with his hands on his pelvis. He was instructed to perform a quick countermovement with knees flexed to 90 degrees before jumping and to jump as high as possible. Participant had three attempts in CMJ, with 1-3 minutes rest between the attempts. The flight time (s) was transformed to centimetres (cm) as $9.81 \times \text{flight time}^2/8$ [35]. The highest value of three jumps was used [21].

Hand grip strength

Hand grip strength was measured with a dominant hand, elbow flexed at 110° angle, wrist in a neutral position, and the interphalangeal joint of the index finger at 90° angle against the handle [37]. The participant was instructed to grip the handle and keep on with maximal effort for 3−5 s (Good Strength, IGS01, Metitur Oy, Jyväskylä, Finland). Each participant had three attempts with the dominant hand separated by 30 s' rest. The highest value was used in the analysis [21]. Test-retest correlation coefficient of more than 0.95 has been shown for hand grip strength in older people aged 65-85 years [38].

Statistical analyses

Basic data is presented as means, standard deviations (SD), or percentages (%). Execution of ATA has expressed as means and standard deviations as well as means and 95% confidence intervals (CI) for differences (Δ). Between groups comparison of personal factors, strength, and mobility variables were performed with analysis of variance. Correlations between the agility and independent variables were expressed with Pearson's product moment correlation coefficients (r). The strength of the correlation coefficient was interpreted based on the definition by Hopkins [39], where 0−0.09 = trivial, 0.10−0.29 = small, 0.30−0.49 = moderate, 0.50−0.69 = large, 0.70−0.89 = very large, 0.90−0.99 = nearly perfect and 1 = perfect. The between-groups comparisons of correlation coefficients was analysed using a multiple regression analyses with correlation coefficients transformed with Fisher's z-method. In order to test whether the associations between agility and independent variables were similar between the three groups, the interaction term was applied in linear regression analysis by the independent variable. The multiple linear regression analyses were done using pooled data of the participants (n = 97) in order to compute variance in agility explained by personal factors and LTPA (Model 1), muscle strength (Model 2), or mobility (Model 3). All the statistically significant independent variables from the Models 1-3 were included in a combined model. All continuous independent variables were standardized before the analysis. Statistical analyses were carried out with the Stata/SE 13.1 and 14.2 (Stata corp., 4905 Lakeway Dr, College Station, TX 77845, USA). The level of statistical significance was set at $p < .05$.

Results

Personal factors, BMI and LTPA of the participants are presented in Table 1. Power athletes had a higher BMI than endurance athletes or the controls. No significant difference was found between the groups for SRH or SRF. Endurance athletes reported higher volume of LTPA compared to the other groups. The descriptive data of mobility, muscle strength and power, and ABC scale and LTPA is presented by the groups in previous study [21]. Table 2 shows the results of ATA among groups of athletes and controls. We evaluated the feasibility of ATA by comparing participants who were able to execute ATA with those participants who were unable to execute it but were able to execute other mobility tests in the current study. Participants, who had not execution time of ATA, had significantly weaker results with larger standard deviations in mobility tests and in the ABC scale than participants who executed ATA (Table 3).

The correlation coefficients between ATA result and each predictor variable are shown in Table 4. Jumping height was significantly correlated with agility in all groups, whereas age was only with that in the control group. Moreover, agility was significantly correlated with hand grip strength in the power group and with ABC scale in the control group. When comparing the groups, no significant differences in correlation coefficients were found between ATA results, CMJ, hand grip strength, static balance, walking speed, chair stand, ABC scale, age, BMI, fat%, lean body mass, or LTPA (data not shown).

The associations between results of ATA and personal factors, BMI, muscle strength and power, and mobility were similar between the endurance, power and control groups (p for interaction > .07, data not shown). Therefore, all groups were pooled into multiple regression analyses. After entering z-scores of age, ABC scale, jumping height and SRH into the combined model, it explained 26.4% ($p = .000002$) of the total variance in executed times of ATA. An increase of SD by one unit in the age was associated with an increase of 0.26 SD in agility (95% CI, 0.05: 0.47, $p = .02$) while in jumping height it was associated with a decrease of -0.36 SD in agility (95% CI,-0.56: -0.15, $p = .001$) (Table 5).

Table 2. Agility in male former elite athletes and their matched controls[‡].

	Endurance n = 50				Power n = 50				Controls n = 50				Endurance vs Power		Endurance vs Controls		Power vs Controls	
	n	Mean	±	SD	n	Mean	±	SD	n	Mean	±	SD	Δ Mean	95% CI	Δ Mean	95% CI	Δ Mean	95% CI
Agility (s)	35	21.3	±	7.9	30	19.3	±	3.9	37	22.1	±	5.8	-2.7	-6.6, 1.2	-0.9	-4.4, 2.7	-3.6	-6.3, -0.8

[‡] Execution of agility has presented as means and standard deviations (SD) as well as means and 95% confidence intervals (CI) for differences (Δ).

Table 3. Mean (SD) and range of age, mobility tests and ABC scale among participants who were not able to execute ATA and among those who were able to execute that [‡].

	n	Participants not able to execute ATA		n	Participants able to execute ATA	
Age (years)	53	77.4 (6.0)	66 - 91	97	74.5 (4.3)	66 - 85
Chair Stand (s)	52	13.9 (4.0)	8.6 - 25.8	97	11.5 (2.5)	7.4 - 20.6
Walking speed (s)	53	4.8 (2.5)	2.6 - 19.4	97	3.5 (0.6)	2.3 - 5.2
Static balance (s)	18	3.1 (3.5)	0.0 - 11.3	95	4.9 (3.2)	0.0 - 20.0
ABC scale (%)	53	76.3(20.6)	10.0 - 100.0	97	89.1 (10.9)	34.4 - 100.0

[‡] ABC scale: Activities-specific Balance Confidence scale.

Table 4. Pearson's correlation coefficients between agility, muscle strength and power, mobility, ABC scale, personal factors, BMI and LTPA for the participants[‡].

	Control			Endurance			Power		
	r	95% CI	p	r	95% CI	p	r	95% CI	p
CMJ	-0.404	(-0.63 – -0.06)	.02	-0.545	(-0.73 – -0.23)	.001	-0.427	(-0.67 – -0.04)	.02
Hand grip	0.089	(-0.25 – 0.40)	.60	-0.314	(-0.57 – 0.04)	.07	-0.403	(-0.65 – -0.02)	.03
Static balance	-0.242	(-0.52 – 0.11)	.16	-0.240	(-0.52 – 0.12)	.17	0.304	(-0.08 – 0.59)	.10
Walking speed	-0.076	(-0.39 – 0.25)	.66	-0.023	(-0.35 – 0.31)	.90	-0.333	(-0.60 – 0.05)	.07
Chair stand	0.030	(-0.30 – 0.35)	.86	-0.079	(-0.40 – 0.27)	.65	0.229	(-0.16 – 0.53)	.22
ABC scale	-0.352	(-0.60 – -0.01)	.03	-0.227	(-0.51 – 0.13)	.19	-0.277	(-0.57 – 0.11)	.14
Age	0.468	(0.14 – 0.67)	.004	0.321	(-0.03 – 0.58)	.06	0.368	(-0.02 – 0.63)	.05
Height	-0.150	(-0.45 – 0.19)	.38	-0.336	(-0.59 – 0.02)	.05	-0.298	(-0.58 – 0.09)	.11
Weight	0.011	(-0.32 – 0.33)	.95	0.139	(-0.21 – 0.44)	.43	-0.195	(-0.51 – 0.19)	.30
Fat%	0.075	(-0.26 – 0.39)	.67	0.250	(-0.11 – 0.53)	.15	0.125	(-0.26 – 0.46)	.52
Lean body mass	-0.036	(-0.35 – 0.29)	.83	-0.058	(-0.39 – 0.29)	.75	-0.300	(-0.59 – 0.10)	.11
BMI	0.098	(-0.24 – 0.40)	.57	0.305	(-0.05 – 0.57)	.06	-0.057	(-0.41 – 0.31)	.77
LTPA	-0.150	(-0.45 – 0.20)	.39	0.068	(-0.28 – 0.39)	.70	-0.093	(-0.44 – 0.29)	.63

[‡] CMJ: countermovement jump; ABC scale: Activities-specific Balance Confidence scale; BMI: body mass index; LTPA: leisure-time physical activity. Statistically significant p-values are in bold ($p < .05$).

Table 5. Multiple linear regression models showing potential determinants of agility in pooled participant group (n = 97) ‡.

	Beta	(95% CI)	p	Adjusted R^2
Model 1			.0009	0.172
†Age	0.396	(0.175 – 0.616)	.001	
†Height	-0.139	(-0.342 – 0.064)	.18	
†BMI	0.182	(-0.011 – 0.374)	.06	
Self-rated health	0.439	(0.041 – 0.836)	.03	
Self-rated fitness	-0.102	(-0.475 – 0.271)	.59	
†LTPA	-0.037	(-0.232 – 0.157)	.70	
Model 2			.00002	0.194
†CMJ	-0.466	(-0.678 – -0.255)	.00003	
†Hand grip	-0.050	(-0.250 – 0.150)	.62	
Model 3			.08	0.046
†ABC scale	-0.335	(-0.627 – -0.044)	.03	
†Static balance	-0.067	(-0.267 – 0.132)	.50	
†Chair stand	-0.012	(-0.340 – 0.316)	.94	
†Walking speed	-0.165	(-0.457 – 0.127)	.27	
Combined model			.000002	0.264
†Age	0.259	(0.049 – 0.469)	.02	
†ABC scale	-0.161	(-0.432 – 0.110)	.24	
†CMJ	-0.357	(-0.560 – -0.154)	.001	
Self-rated health	0.249	(-0.044 – 0.542)	.10	

‡BMI: body mass index; CI: confidence intervals; LTPA: leisure-time physical activity; CMJ: countermovement jump; ABC scale: Activities-specific Balance Confidence scale; †Continuous independent variables were standardized.
Statistically significant p-values are in bold (p < .05).

Discussion

To the best of our knowledge no previous study has determined the relationships between agility, personal factors, self-reported LTPA, power of lower extremities, hand grip strength, comprehensive tests of mobility and self-reported balance confidence (ABC scale) in a well-described sample of ageing former elite athletes and their controls. The main finding of the present study was that power of lower extremities and age were the main determinants of agility regardless of previous physical activity during three months or type of sports in the cohort of men aged 66-91 years. Overall, the strongest independent variables, i.e., jumping height, age, self-reported balance confidence and self-rated health were able to explain about one-quarter of the variance in capacity of agility. These findings suggested that the athletes' self-reported average physical activity or career of competitive training and racing, other personal factors or body functions did not appear to provide additional explanatory power on execution of agility among elderly men.

The moderate and robust relationship between agility and jumping height shows that the power of lower extremities appears to be an important part of the capacity of agility among the participants. Somewhat weaker associations compared to our study findings have been reported both among physically active older adults [2] and in young people engaged in team sports [10, 13, 40-42]. Correlation coefficients of equal value with our results have been shown by Alemdaroğlu [43]. It is challenging to compare our results on the relationship between agility and power of lower extremities with corresponding results because of various types of agility tests and the varying participant characteristics. Our findings may partly be explained by the nature of the *ATA* test because the test includes quick jumps both on one foot and on two feet. That demands good interplay between perception, decision making, power of lower extremities and balance.

The multiple linear regression analyses showed that countermovement jump was a significant contributor in execution of agility among elderly men. As expected, this finding is in line with our earlier *ATA* results found in physically inactive or active adult people [17], who were 30 years younger than the men in the present study. *CMJ* has shown to be the most reliable test for the evaluation of lower extremities power among athletes in different age groups [36]; and it has shown to be appropriate test also for older adults [1]. From a clinical point of view, these results, both in younger and in older persons, show that the power of lower extremities plays an important role in maintaining or enhancing agility. Ageing people will have benefits by means of training the capacity of agility using explosive movements e.g., ball games or plyometric exercises [44]. The response to such exercises depends also on genetic qualities of the persons [45]. Furthermore among elderly people, muscle power of lower extremities showed stronger associations with performance in everyday activities than with static muscle strength of lower extremities [46].

Predictably, age was a significant determinant of agility even within the age-range studied. Longer execution time of *ATA* was associated with older age and with poorer self-rated health in our study. We suggest that the influence of age on agility could be seen as a result of decline in the physical and cognitive functioning which generally affects the capacity of agility in the ageing process. First, age-related changes include reduced amount of synaptic inputs [47], a loss of motor units, less stable neuromuscular junction, and smaller skeletal muscle fibres which together impair physical functioning in older adults [45]. It has been shown that the decline in muscle strength (dynapenia) is much more rapid than the loss of muscle mass (sarcopenia) [48]. It has been suggested that muscle weakness associates with impairments in central (neural) activation as reductions in the intrinsic force-generating capacity of skeletal muscle in older adults [49]. We suggest that physical activity has delayed the negative effects of the ageing process on muscular strength and on motor control among our study participants in their later life. Several studies have confirmed the benefits of physical activity in older adults such as improvements in motor control, neuromuscular function and functional capacity [50, 51]. Second, reduced grey matter thickness in the cortex has been found to associate with impaired motor function during motor tasks reducing accuracy of movement among older adults [52]. Third, Clouston et al. [53] have shown that change in cognitive functions during ageing was strongly correlated with change in movement speed of lower extremities. Moreover, it has been found that ageing results in worse capacity of agility [4].

Based upon the above justifications, the progressive generalized decline of physical and psychological functioning goes on when people become older.

The *ATA* test differs from other mobility tests due to following reasons: the execution of *ATA* requires e.g. quick processing of visual information, anticipatory and accurate movements, as well as correct and precise type of foot placement [9]. The reference value is 12.6 s in the *Chair Stand* test for elderly aged 70–79 years [54]. Among our participants, the average value was 11.5 s for those who were able to execute *ATA* and 13.9 s for those who were not able to execute *ATA* (Table 3.). The *Chair Stand* test evaluates the ability to rise from a chair and sit back down, as well strength and power of lower extremities. The average execution time was also shorter in the walking speed test for participants (3.5 s) who executed *ATA* than for those (4.8 s) who were not able to do that (Table 3.). All participants, who were not able to execute *ATA*, were able to execute the other mobility tests. For these above mentioned reasons, no significant associations were found between *ATA* and other tests of mobility. Evidence exists that capacity of agility is more likely to be influenced also by cognitive functions rather than by strength functions alone both in male and female team sport athletes [10, 12]. In a sport-specific context, cognitive functions in agility imply to react quickly and accurately in response to external stimuli [11, 12]. In the test track of *ATA*, red cross marks and yellow squares act as external stimuli. However, previous findings are indicative of young team sport athletes but they are not directly proportional to former elite athletes and their matched controls.

The *Timed UP-and-Go* (TUG) test has been developed for the evaluation of mobility and balance among frail elderly persons [55] even though *TUG* has also been used measuring agility. The *TUG* test is not directly comparable with the *ATA*. In both tests is question about speed, but duration and the need for changes in direction and rhythm of movement and accelerations in *ATA*, demand explosive power and so more fast-twitch muscle fibers. Physiological demands are different. Also the *Figure-of-eight* (FIG8) has been used measuring agility but that has been classified into *Changes of Direction and Speed* tests (CODS) since that lacks e.g. cognitive functions [11]. These tests like Chair Stand, *FIG8* or *TUG* are not multidimensional enough to evaluate the capacity of agility among middle-aged or older people.

In our study, we had a possibility to evaluate determinants of agility in a unique dataset consisting of former elite athletes and controls in their senior years. More studies on these potential physiological or psychological mechanisms for capacity of agility are clearly required among older people because agility has been shown to be one of the basic body functions required to execute independently and safely activities of daily living in elderly people [6, 7, 56]. This finding supports our result that agility associates with self-rated balance confidence to perform daily activities in our study. The good capacity of agility can be transferred to the activities of the real life environment in the following way: The before mentioned body functions, e.g. perceptual functions, muscle power or gait pattern, constitute capacity for activities (Figure 2.), which are needed e.g., for walking on a congested street, moving around in a crowded shopping centre, or going by bus without losing balance. Also walking down or upstairs and walking at home without colliding with furniture require people to change their pattern of movement according to task and environment. Patla et al. [57] have also reported that a person modifies ongoing movements by processing available visual, vestibular and somatosensory information (as in execution of agility) to avoid obstacles on the ground. These facts give justifiable significance also for the capacity of agility as a part of daily living for example to avoid falls and stumbles among people of all ages.

Some limitations need to be taken into account when interpreting our findings. The conversion of information from Leisure Time Physical Activities (LTPA) used in this study overestimates MET values in this kind of older population. We did not have also information on the LTPA profiles and details of the participants in their later life, which limit the interpretation of the results of the current study. Unfortunately, our study did not include former elite athletes of ball games because it has been shown that training with a ball or ball games can be positively associated with body functions as agility and static balance in physically active women and men [58]. These findings show that sports, e.g. power sports, which do not demand anticipation or decision making functions, do not develop capacity of agility to same extent as e.g. ball games. The diseases (osteoarthritis of knee or hip joints, poor vision and neurological disorders) reduced the number of successful agility, jumping and static balance executions more than executions of the other physical tests among participants. Therefore, the study sample was small. On the other hand, failure to execute ATA due to the abovementioned conditions provides information on capacity of functions needed to execute ATA successfully. Other selective factors may influence our findings as differences might exist in genetic and biological characteristics regulating the aging process. However, because the relationships between agility, and personal factors, BMI, LTPA, muscle strength and power, mobility and ABC scale were relatively similar between the aged former athletes and controls, selection bias seems to be less probable. The design of this study was structured to minimize most sources of measurement error arising from the environment or measurer. Regretfully, we did not have possibility to evaluate the reproducibility of the scores when a scale is applied by different rater (inter-rater). Participants were elderly and most of them lived far away from the research laboratory. For this reason, there was no possibility to increase the number of test sessions. In an attempt to control the known risks of errors e.g., standardized instructions were used and the same experienced physiotherapist, who was blinded to the athletic history of the participants, carried out all measurements.

The oldest man who executed the *ATA* test successfully was 85 years old. They, who were able to execute *ATA*, broke a reference value (12.6 s) by 1.1 s in *Chair Stand* test. The diseases of lower extremities, neurological disorders and poor vision reduced successful executions of *ATA*. Despite these physical disorders, the participants were able to execute other mobility tests successfully except *Static balance* test. *Chair Stand* and *Walking speed* suited for evaluating the physical functioning of the frail elderly. *ATA* is more sensitive to reveal the physical disorder of participant than the above mentioned tests. According to our data, *ATA* could be used among relatively healthy men up to 80 years of age.

Conclusions

To conclude, power of lower extremities and age were the main determinants on the Agility Test for Adults in a cohort of men aged 66-91years.

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Disclosure statement

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