ORIGINAL RESEARCH

Handgrip strength, quadriceps muscle power, and optimal shortening velocity roles in maintaining functional abilities in older adults living in a long-term care home: a 1-year follow-up study

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Purpose: To assess the relative role of handgrip strength (HGS), quadriceps muscle power (P_{max}), and optimal shortening velocity (υ_{opt}) in maintaining functional abilities (FAs) in older adults living in a long-term care home over a 1-year follow-up.

Subjects and methods: Forty-one inactive older institutionalized adults aged 69.8 ± 9.0 years participated in this study. HGS, P_{max}, υ_{opt}, cognitive function using the Mini-Mental State Examination, depressive symptoms using the Geriatric Depression Scale, nutritional status using the Mini Nutritional Assessment (MNA), and physical activity (PA) using the Seven-Day Physical Activity Recall Questionnaire were assessed at baseline and at 1-year follow-up. FAs were assessed with activities of daily living (ADL), instrumental ADL, and Timed Up & Go test.

Results: Both at baseline and at follow-up, FAs were related to age, HGS, P_{max}/kg, υ_{opt}, MNA, and PA. These associations were generally similar in both sexes. As revealed in multiple regression analysis, υ_{opt} was the strongest predictor of FA, followed by P_{max}/kg, PA, and MNA. FA deteriorated after 1 year as measured by ADL and Timed Up & Go test. P_{max} and υ_{opt}, but not HGS, also decreased significantly after 1 year. Nevertheless, 1-year changes in FAs were not related to changes in HGS, P_{max}, υ_{opt}, or PA.

Conclusion: The 1-year period of physical inactivity among older institutionalized adults was found to have a negative effect on their FAs, P_{max}, and υ_{opt}. The present study demonstrates that P_{max} and, especially, υ_{opt} correlated with FAs of older adults more than HGS, both at baseline and at follow-up. Despite this, 1-year natural fluctuations of PA, P_{max}, and υ_{opt} are not significant enough to influence FAs in inactive institutionalized older adults.

Keywords: aging, handgrip strength, institutionalization, functional status, physical activity

Introduction

In recent years, great attention has been paid to functional ability (FA) in scientific publications. The majority of these studies are dedicated to people of old age, which is generally associated with a progressive drop in physical and psychological health, increased risk of disability and dependency, and an increase in the number of morbidities.[1–6] Functional disability is a predictor of institutionalization,[7,8] worse quality of life, and increased mortality.[5,9]

The role of muscle strength in maintaining independence has been confirmed by many studies, mainly in older adults.[10] According to Reid et al,[11] a loss of muscle strength with age is closely associated with decreasing FA. A certain amount of force is necessary to perform daily tasks such as walking, carrying shopping, unscrewing

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jars, using tools, or holding, for example, the handrail of entry stairs.[12] Handgrip strength (HGS), a simple and reliable technique, has been commonly used as a measure of muscle functioning in the geriatric literature.[13] However, the most important muscles that are necessary to maintain independence in activities of daily living (ADL) are the muscles of the lower limbs.[14] In particular, the quadriceps muscles are responsible for performing basic tasks such as maintaining an upright position; walking, ascending, and descending stairs; and sitting down and getting up from a sitting position.[15] Furthermore, in studies comparing the relationships between muscle strength and muscle power with FA, muscle power, which is the product of force and muscle shortening velocity, almost always seems to be a stronger determinant.[10] Consequently, growing interest in the subject of muscle power (P_{max}) and optimal shortening velocity (υ_{opt}) as measures of muscle functioning has been observed in recent years.[4] The optimal shortening velocity has been found to be even a stronger predictor of FA than strength in one study.[16] Physiologically, the decreasing quantity and quality of fast-twitch muscle fibers are mainly responsible for restricting FA in older people due to lower υ_{opt} and power.[16–18]

The available literature does not include studies that assessed HGS, P_{max}, and υ_{opt} together in older adults residing in long-term care homes. Therefore, the objective of this study was to examine prospectively the impact of P_{max}, υ_{opt}, HGS, and physical activity (PA) on the FA of older institutionalized adults. The following hypotheses were provided: 1) P_{max} and υ_{opt} are more important correlates of FA of older adults than HGS; 2) the higher PA level is associated with better P_{max}, υ_{opt}, and FA; 3) changes in HGS, P_{max}, υ_{opt}, and PA over a 1-year period are related to FA of older institutionalized adults.

Subjects and methods
Participants
The study group was selected from residents of a public nursing home in the city of Lodz, Poland. The study was conducted in two stages. The inclusion criteria of the study were as follows: 1) aged over 55 years; 2) logical and verbal contact; 3) no considerable hearing disorders significantly hampering understanding of questions at the time of the study; and 4) ability to perform exercise tests. Patients with cardiologic contraindications for exercise tests, motor system dysfunction (eg, limited range of motion, severe spasticity, and pain) and patients who did not give their informed consent to participate in the study were excluded. Consequently,

among 595 residents of the nursing home, 371 aged 55 years and older were initially screened and recommended for participation in the study. Ultimately, the initial 371 subjects were reduced to 49 participants, because 205 were of limited verbal contact, 67 were not able to perform exercise tests, and 50 did not give consent to participate in the study. Therefore, 49 older subjects (19 women and 30 men) aged 55 years and older were selected for the first phase of the study.

Each subject underwent a multidimensional assessment, which included demographic and social parameters, health conditions, and physical and cognitive function. The following set of instruments commonly used for health assessments of older populations was utilized: 1) HGS, P_{max}, and υ_{opt} as independent muscle function variables; 2) FAs as dependent variables; 3) cognitive function (Mini-Mental State Examination [MMSE]), depressive symptoms (15-item Geriatric Depression Scale [GDS]), nutritional status (Mini Nutritional Assessment [MNA]), and PA as supplementary variables potentially modifying the relationship between independent and dependent variables. All these questionnaires and tests were completed by researchers during a personal interview of ~2.5 hours, both at baseline and at follow-up. Furthermore, ADL and instrumental activities of daily living (IADL) questionnaires were verified with the medical staff.

Forty-one patients (17 women and 24 men) underwent two assessments, one at baseline and another at 1-year follow-up. Due to health status deterioration (n=4), change in residence (n=1), cancellation of consent to participate in the study (n=1), and death (n=2), eight of their original study group were only involved in the first examination. These patients were not included in a prospective analysis. All the participants led sedentary lifestyles, and none of them practiced regular PA during the 1-year follow-up.

HGS measurements
HGS was tested using a hydraulic hand dynamometer by Jamar® (Sammons Preston Rolyan, Bolingbrook, Canada). The dynamometer facilitates measurements of isometric force to 90 kg. According to the literature, the measurements are influenced by subject position when carrying out the test (lying, sitting, or standing). Previous studies have shown better results with a standing position. Therefore, all subjects carried out the HGS test in the standing position with shoulder adducted and neutrally rotated and elbow in 90° flexion with no radioulnar deviation. The participants were required to squeeze the handle maximally and to sustain this for 1–2 seconds. All measurements were performed for

both hands. Subjects performed three maximum attempts for each grip strength measurement, and the mean value of these trials was recorded. One-minute rests were given between each attempt, and hands were alternated to minimize fatigue effects. Results were recorded in kilogram force (kgf).[13,19]

Power testing

Mechanical measurements were carried out on a friction-loaded cycle ergometer (Ergomedic type 828E, Monark, Stockholm, Sweden). Measurements of P_{max} and υ_{opt} using the ergometer have previously been described and validated in a population of older adults.[18,20] The ergometer was instrumented with a strain gauge (FN3030 type, 20 daN; FGP Instrumentation, Les Clayes sous Bois, France) and with an incremental encoder (Hengstler type RIS IP50, 100 pts/turn; Aldingen, Germany) for measurement of the friction force applied by the tension of the belt that surrounds the flywheel. The strain gauge was calibrated with a known mass (2.553 kg). Flywheel inertia was calculated by the method suggested by Lakomy.[21] For all experiments, the saddle height was adjusted to give optimal comfort for each subject and toe clips were removed to prevent any pulling action of the contralateral leg. After a 5-minute warm-up on the cycle ergometer, the subjects were asked to perform two 8-second sprints from a starting position, each separated by at least 5 minutes of rest. Friction loads were 0.25 N/kg and 0.35 N/kg of body mass, except in the case of the most disabled subjects, in whom friction loads of 0.15 N/kg and 0.25 N/kg of body mass were used.[4,22] At the signal given by the investigator, the subjects were asked to pedal as fast as possible until told to stop (after 8 seconds). During the effort, each subject was vigorously encouraged.[22] The highest value of P (maximum short-term power, P_{max}) and velocity at maximum power (optimal velocity, υ_{opt}) were calculated from a third-order polynomial function. Maximum power is expressed as relative to body mass, P_{max}/kg (W/kg). υ_{opt} is expressed as revolutions per minute (rpm).

FA tests

Using the ADL scale,[23] the ability to perform the basic ADL (bathing, dressing, toilet, sphincter control, eating, and moving around) was evaluated. The number of points scored by the patient indicated full function (5−6 points), moderate impairment (3−4 points), and severe functional impairment (≤2 points).

Using the IADL scale,[24] the ability to perform complex ADL, such as using the phone, shopping, preparing meals, cleaning, laundry, use of different means of transport and self-managing

medication, and handling money were evaluated. The maximum number of points was 8. A smaller number of points scored in these tests reflects an inability to act independently in the basic activities (ADL) or more complex (IADL) ADL.

Using the "Timed Up & Go" (TUG) test,[25] three basic functions of everyday life were evaluated: recovering from a sitting position to a standing position, walking a short distance (3 m), and returning and moving to a sitting position. During the test, a patient performed the following operations as fast as they could: rise from a chair, walk a distance of 3 m, turn back, walk to the chair, and sit back down on the chair. Time of operations was measured with the aid of a stopwatch. The patient performed the test twice. For the analysis, the best score was used. A short time to complete the test indicates good FA.

Cognitive function and emotional status assessment

Cognitive function were evaluated using the MMSE,[26] which contains six groups of tasks to assess the level of functioning of the basic psychological processes such as orientation in time and place, memory, attention and counting, recall, language function, and constructional praxis.

The MMSE scores range from 0 to 30, higher scores indicating better cognitive functioning.

The participants' emotional status was evaluated using the 15-item version of the GDS,[27] characterizing the state of being of the subject in the previous 2 weeks. The GDS contains 15 "yes" or "no" questions characterizing the depressive status of the respondent. The raw scores range from 0 to 15, where a higher score indicates deeper depression.

Nutritional status assessment

The nutritional status was assessed by the MNA. The MNA questionnaire contains 18 questions relating to the essential elements of nutritional status, such as food intake, loss of body weight, the ability to move around independently, the occurrence of acute disease or stress, neurological problems, body mass index, number of medications, and assessment of the arm and calf circumferences. The total number of points in the MNA questionnaire is 30. A result >23.5 is treated as a satisfactory nutritional status, while a score ≤23.5 suggests malnutrition.[28]

PA measurements

PA was evaluated using the Seven-Day Physical Activity Recall Questionnaire (SDPAR).[29] The 7-day recall total score (daily energy expenditure over the past week) was calculated and used for further comparisons.

Statistical analysis

A power calculation was performed to estimate the required sample size. The sample sizes required to detect differences of 10% in functional status and muscle function variables (with 0.80 power, 0.05 alpha type I error rate, and given baseline standard deviation [SD] values) were 10, 53, 36, 36, 34, and 27 for ADL (1 point change), IADL (1 point change), TUG test, HGS, P_{max}/kg, and υ_{opt}, respectively. Data were verified for normality of distribution (Shapiro–Wilk test) and equality of variances (Levene's test). A one-way analysis of variance and the Kruskal–Wallis test were used for comparison of sex groups. Pearson product moment or Spearman correlation coefficients were used to assess the relationship between two quantitative variables. A paired Student's t-test and sign test were used to determine the impact of the 1-year follow-up on dependent numeric variables. Multiple linear regression (with forward stepwise technique) including variables significant in bivariate analyses was used to identify independent variables that predict the changes of FAs during the 1-year follow-up. ADL, TUG, HGS, P_{max}/kg, υ_{opt}, and PA values were normalized using a log transformation for the purpose of statistical analyses. Effect sizes based on Cohen's d were calculated. An effect size of 0.2 to <0.5 and ≥0.5 to <0.8 has been suggested to represent a small and medium effect, respectively, while an effect size ≥0.8 represents a large effect. For numeric variables, the results are presented as mean ± SD. The level of significance was set at $P \le 0.05$ for all the analyses. The obtained data were statistically analyzed with the Statgraphics Plus 5 software package (Statpoint Technologies, Inc., Warrenton, VA, USA) and Statistica 12 software package (StatSoft, Cracow, Poland).

Ethical considerations

The proposal of this study was approved by the Bioethics Committee of the Medical University of Lodz, Poland (ref no RNN/338/08/KB). All the participants signed the informed consent form after hearing the explanation about the methods and aims of the study. All gathered data were confidential.

Results

General characteristics of the study group

The average age of the entire cohort was 69.8±9.0 years. The mean number of years of education was 9.0±3.2. The average number of regular medications taken was 6.46±2.95 per day. Participants had been diagnosed with the following concomitant diseases: ischemic heart disease (n=25), arterial hypertension (n=25), chronic heart failure (n=24), history of stroke (n=7), osteoarthritis (n=16), eye diseases (n=12), chronic obstructive pulmonary disease (n=9), gastrointestinal diseases (n=13), and depression (n=12). Women were older than men and were characterized with significantly lower values of HGS, P_{max}/kg, and υ_{opt} as compared with men, both at baseline and after the 1-year follow-up.

Correlations between FA and independent variables at baseline and after the 1-year follow-up

The relationships of FA (ADL, IADL, and TUG test) to age, HGS, P_{max}/kg, υ_{opt}, GDS, MMSE, MNA, and PA in the study group at baseline and after the 1-year follow-up are presented by sex in Tables 1 and 2, respectively. At baseline, in women, FAs were related to almost all quantitative variables that are presented, excluding GDS and MMSE. In

Table 1 Correlations between FA and age, HGS, P_{max}/kg, υ_{opt}, GDS, MMSE, MNA, and PA in 41 older institutionalized adults at baseline

Quantitative variable	ADL		IADL		TUG	
	Women (n=17)	Men (n=24)	Women (n=17)	Men (n=24)	Women (n=17)	Men (n=24)
Age (years)	−0.50*	−0.25	−0.59*	−0.36	0.66**	0.35
RHGS (kg)	0.39	0.18	0.29	0.14	−0.48*	−0.29
LHGS (kg)	0.41	0.27	0.62*	0.25	−0.66**	−0.09
P_{max}/kg (W/kg)	0.36	0.04	0.57*	0.36	−0.64**	−0.68**
υ_{opt} (r/min)	0.50*	−0.06	0.66*	0.48*	−0.75**	−0.43*
GDS (points)	−0.23	−0.04	−0.31	−0.24	0.36	0.32
MMSE (points)	0.24	−0.10	0.19	0.20	−0.25	−0.01
MNA (points)	0.51*	−0.06	0.32	0.01	−0.22	−0.02
PA (kcal/kg/day)	0.41	0.09	0.73**	0.19	−0.50*	−0.14

Notes: *P<0.05. **P<0.01.
Abbreviations: FA, functional ability; ADL, activities of daily living; IADL, instrumental activities of daily living; TUG, Timed Up & Go; HGS, handgrip strength; RHGS, right handgrip strength; LHGS, left handgrip strength; P_{max}/kg, quadriceps muscle power; υ_{opt}, optimal shortening velocity; GDS, Geriatric Depression Scale; MMSE, Mini-Mental Scale Examination; MNA, Mini Nutritional Assessment; PA, physical activity.

Table 2 Correlations between FA and age, HGS, P_{max}/kg, v_{opt}, GDS, MMSE, MNA, and PA in 41 older institutionalized adults at follow-up

Quantitative variable	ADL		IADL		TUG	
	Women (n=17)	Men (n=24)	Women (n=17)	Men (n=24)	Women (n=17)	Men (n=24)
Age (years)	−0.49*	−0.32	−0.43	−0.38	0.57*	0.24
RHGS (kg)	0.39	0.42*	0.47	0.16	−0.33	−0.37
LHGS (kg)	0.38	0.41	0.50*	0.34	−0.56*	−0.31
P_{max}/kg (W/kg)	0.51*	0.36	0.49*	0.48*	−0.53*	−0.60**
v_{opt} (r/min)	0.63**	0.44*	0.53*	0.42*	−0.58*	−0.64**
GDS (points)	−0.06	−0.23	−0.16	−0.25	0.33	0.24
MMSE (points)	0.37	0.19	0.34	0.15	−0.07	0.11
MNA (points)	0.20	0.57*	0.49*	0.56*	−0.44	−0.25
PA (kcal/kg/day)	0.60*	0.66**	0.62**	0.47*	−0.72**	−0.38

Notes: *$P<0.05$. **$P<0.01$.
Abbreviations: FA, functional ability; ADL, activities of daily living; IADL, instrumental activities of daily living; TUG, Timed Up & Go; HGS, handgrip strength; RHGS, right handgrip strength; LHGS, left handgrip strength; P_{max}/kg, quadriceps muscle power; v_{opt}, optimal shortening velocity; GDS, Geriatric Depression Scale; MMSE, Mini-Mental Scale Examination; MNA, Mini Nutritional Assessment; PA, physical activity.

men, FAs were related only to P_{max}/kg and v_{opt}. At follow-up, both in women and in men, FAs were related to almost all quantitative variables that are presented, excluding GDS and MMSE. For all significant correlation coefficients presented in Tables 1 and 2, effect sizes were large (Cohen's d varied from 0.7 to >2) with the exception of the association between IADL and PA in men at follow-up (Cohen's $d=0.26$).

Muscle strength and power measurements were generally inversely related to age (not shown in the table). In women, P_{max}/kg (Figure 1) and v_{opt} ($\rho=-0.79$; $P<0.001$ and $\rho=-0.69$; $P<0.01$, respectively) were strongly adversely correlated with age, both at baseline and at follow-up. In men, only the association of v_{opt} with age at baseline reached the statistical significance level ($\rho=-0.43$; $P<0.05$). In women, HGS was

also inversely related to age (ρ ranged from −0.53 to −0.73) both at baseline and at follow-up. HGS, P_{max}/kg, and v_{opt} were generally not related to PA (but with positive trend), with only the LHGS–PA association ($\rho=0.54$; $P<0.05$) in women reaching the statistical significance level at baseline (not shown in the table).

Multiple regression analysis by sex at baseline and after the 1-year follow-up

All the statistically significant predictors (independent variables) of FA (dependent variables) in Tables 1 and 2 were subjected to multiple regression analysis.

At baseline, in the group of women, ADL was favorably predicted by v_{opt}:

$$\log ADL = 1.449 + 0.0823 \times \log v_{opt} \quad (\text{adjusted } R^2=18.6\%) \quad (1)$$

IADL was favorably predicted by v_{opt} and PA:

$$IADL = -39.91 + 1.85 \times \log v_{opt} + 10.67 \times \log PA \quad (\text{adjusted } R^2=50.4\%) \quad (2)$$

TUG test was favorably (inversely) predicted only by v_{opt}:

$$\log TUG \text{ test} = 4.69 - 0.692 \times \log v_{opt} \quad (\text{adjusted } R^2=51.1\%) \quad (3)$$

At baseline, in the group of men, IADL was favorably predicted by v_{opt}:

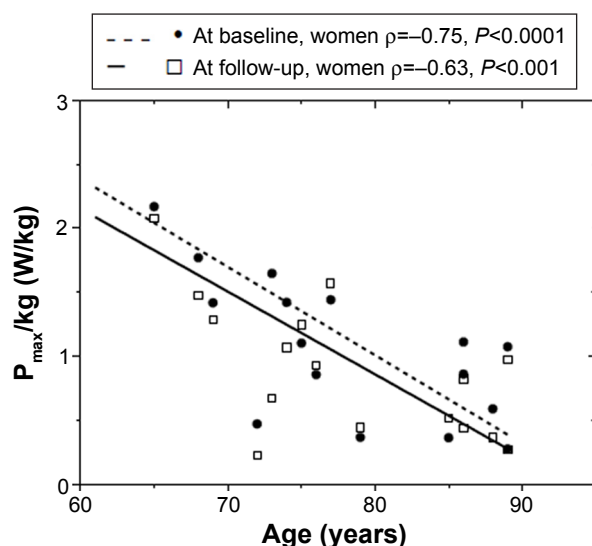$$IADL = -11.7 + 3.91 \times \log v_{opt} \quad (\text{adjusted } R^2=21.6\%) \quad (4)$$

Figure 1 Correlation between the P_{max}/kg (W/kg) and age in 17 older inactive women at baseline and at 1-year follow-up.
Abbreviation: P_{max}/kg, quadriceps muscle power.

Legend in figure:
- - - ● At baseline, women $\rho=-0.75$, $P<0.0001$
— □ At follow-up, women $\rho=-0.63$, $P<0.001$

TUG test was favorably (inversely) predicted by P_{max}/kg:

$$\text{logTUG test} = 3.25 - 0.856 \\ \times \text{logP}_{max}/kg \ (\text{adjusted } R^2 = 48.7\%) \quad (5)$$

At follow-up, in the group of women, ADL was favorably predicted only by υ_{opt}:

$$\text{logADL} = 0.883 + 0.24 \\ \times \text{log}\upsilon_{opt} \ (\text{adjusted } R^2 = 41.0\%) \quad (6)$$

IADL was favorably predicted by PA:

$$\text{IADL} = -57.4 + 17.4 \\ \times \text{logPA} \ (\text{adjusted } R^2 = 34.5\%) \quad (7)$$

TUG test was favorably (inversely) predicted by υ_{opt} and PA:

$$\text{logTUG test} = 14.1 - 0.294 \times \text{log}\upsilon_{opt} - 2.99 \\ \times \text{logPA} \ (\text{adjusted } R^2 = 61.9\%) \quad (8)$$

At follow-up, in the group of men, ADL was favorably predicted by υ_{opt}, MNA, and PA:

$$\text{logADL} = -2.54 + 0.153 \times \text{log}\upsilon_{opt} + 0.73 \times \text{MNA} \\ + 0.383 \times \text{logPA} \ (\text{adjusted } R^2 = 68.3\%) \quad (9)$$

IADL was favorably predicted by P_{max}/kg, MNA, and PA:

$$\text{IADL} = -35.9 + 1.68 \times \text{logP}_{max}/kg + 0.718 \times \text{MNA} \\ + 6.29 \times \text{logPA} \ (\text{adjusted } R^2 = 52.7\%) \quad (10)$$

TUG test was favorably (inversely) predicted by υ_{opt}:

$$\text{logTUG test} = 6.66 - 1.031 \\ \times \text{log}\upsilon_{opt} \ (\text{adjusted } R^2 = 34.2\%) \quad (11)$$

Comparison of the test results at follow-up

Table 3 presents the impact of 1-year follow-up on FA, HGS, P_{max}/kg, υ_{opt}, GDS, MMSE, MNA, and PA in 41 older people. At follow-up, the deterioration of ADL, TUG test, P_{max}/kg, υ_{opt}, and PA reached the statistical significance level. Effect sizes for changes in IADL, HGS, GDS, and MMSE at the 1-year follow-up were small, but close to medium for ADL, TUG test, P_{max}/kg, υ_{opt}, MNA, and PA according to standard criteria.[30]

Changes in FA during the 1-year follow-up were not related to changes in HGS, P_{max}/kg, and υ_{opt}, or fluctuations in PA level, assessed either jointly or separately in both sexes.

Discussion

According to our knowledge, no prospective studies evaluating the relationship between FA and HGS, P_{max}, and υ_{opt} among older institutionalized adults have been carried out previously. This study is the first to show that the FAs of older institutionalized adults are largely related to P_{max} and υ_{opt}, while the other two physiological measures are clearly age-dependent. As compared to P_{max} and υ_{opt}, HGS has a much weaker association with the FA of older institutionalized adults.

In general, muscle strength reduction is particularly pronounced after the age of 50, and it is after the age of

Table 3 Impact of 1-year follow-up on FA, HGS, P_{max}/kg, υ_{opt}, GDS, MMSE, MNA, and PA in 41 older institutionalized adults

Variable	At baseline (n=41)	At follow-up (n=41)	Statistical significance (*P*-value)	Effect size (Cohen's *d*)
ADL (points)	5.76±0.36	5.51±0.67	<0.01	0.46
IADL (points)	4.41±2.14	4.15±2.30	NS	0.12
TUG test (s)	12.10±5.86	13.61±7.93	<0.05	0.22
RHGS (kg)	32.98±13.21	32.20±11.60	NS	0.06
LHGS (kg)	30.63±13.30	30.29±11.63	NS	0.03
P_{max}/kg (W/kg)	2.17±1.26	1.86±1.20	<0.001	0.25
υ_{opt} (r/min)	49.94±21.18	46.09±18.95	<0.05	0.19
GDS (points)	6.37±3.11	6.34±3.21	NS	0.01
MMSE (points)	24.07±4.55	24.02±5.94	NS	0.01
MNA (points)	22.71±3.17	22.07±2.25	NS	0.23
PA (kcal/kg/day)	36.28±3.27	35.74±3.79	<0.05	0.15

Note: Data are represented as mean ± standard deviation unless stated otherwise.
Abbreviations: FA, functional ability; ADL, activities of daily living; IADL, instrumental activities of daily living; TUG, Timed Up & Go; HGS, handgrip strength; RHGS, right handgrip strength; LHGS, left handgrip strength; P_{max}/kg, quadriceps muscle power; υ_{opt}, optimal shortening velocity; GDS, Geriatric Depression Scale; MMSE, Mini-Mental Scale Examination; MNA, Mini Nutritional Assessment; PA, physical activity; NS, statistically insignificant.

70 that losses reach a critical point.[31] Based on a 25-year prospective study of the Honolulu Heart Program including over 6,000 healthy men aged 45−68 years, it was found that the level of HGS is an effective predictor of disability in initially healthy men.[32] The risk of disability in old age (25 years after the first study) was twice as high in men, with low levels of strength identified in the first study compared with men presenting high output strength levels. Higher levels of muscle strength in the hands determine the possibility to perform more complex IADL tasks. Another study conducted by Aoyama et al[33] showed a significant correlation between HGS and the TUG test. Our data show that HGS was moderately associated with the indices of FA, mainly in women. P_{max} and, especially, υ_{opt} were more important correlates of FA than HGS, both at baseline and at the 1-year follow-up in both sexes.

Our findings are consistent with other studies comparing the relationship between muscle strength, power, and υ_{opt} with FA.[11] Some of those studies report that, although muscle strength and power are strongly related to each other, they can determine FA to a different degree. Many ADLs require the ability to perform short, intensive exercises, which demand the generation of appropriate muscle power.[15,34,35] FA depends largely on how quickly the muscles can generate strength, not only on how strong they are.[34] This may be due to the fact that ADLs require more complex muscle activity than just the slow development of strength.[36] Optimal shortening velocity and the ability to develop power are firmly linked to the amount of fast-twitch muscle fibers (FT, Type II).[37] Their number decreases with advancing age and is accompanied by a slowdown of muscle contraction, leading to a greater decline of maximum short-term power with age, and this decline is more heavily related to the loss of FA than the decrease of muscle strength.[20,22,38] In studies comparing the relationships of strength and muscle power to FA, muscle power almost always appears to be a stronger determinant.[10,38,39] In older adults, P_{max} is accountable to a greater extent for the volatility of the results in FA than muscle strength, in particular during low-intensity activities such as walking.[40] Kostka et al[4] studied the effect of muscle strength, power, and υ_{opt} on the FA of elderly women with chronic osteoarthritis. Muscle power and υ_{opt} correlated with functional tests such as ADL, TUG test, Tinetti test, and the 6-MWT (6-minute walking test); there was no correlation of muscle strength with FAs. Clémençon et al[41] also assessed the impact of strength, power, and υ_{opt} of the knee extensor muscles on the FAs of older women. Similarly, only muscle power and υ_{opt} but not strength correlated with functional

tests. Those authors suggest that the assessment of power and υ_{opt} is a better indicator of FA in older women than muscle strength.

In the present study, at the 1-year follow-up, deterioration of P_{max} and υ_{opt} and a deterioration in the results of functional tests such as ADL and TUG were observed, with a concomitant decline of PA. When assessed cross-sectionally, a lower level of PA was related to lower FA. Such an importance of PA in preserving FAs of older subjects has been shown in numerous previous studies.[42,43] On the other hand, PA was not associated to P_{max} or υ_{opt} either at baseline or at follow-up, and 1-year changes in FA, P_{max}, and υ_{opt} were not related to fluctuations of PA. These negative results may be, at least partially, explained by the inactivity and homogeneity of our studied groups. Several studies found positive impact of PA on muscle power, with study protocols lasting from 3 weeks to 12 weeks.[4,44–47] Interesting findings were presented by Fatourus et al.[48] They found that the higher the intensity of the training, the higher the increase in anaerobic power of older men. Such an intensive training, by stressing the muscle with rapid movements, would probably be beneficial for P_{max}. Furthermore, such a training regimen may lead to general health benefits for a prolonged period after the training ceases. Our prospective data seem to confirm this information and further indicates that in inactive elders, cross-sectional associations between P_{max}, υ_{opt}, and FA persist but no apparent relationships exist concerning time-related changes. Therefore, formalized exercise training should be probably applied in this population to achieve muscle P_{max} and υ_{opt} improvements related to functional gains.

Together with associations between muscle physiological properties and FA, our results show a moderate relationship between FA and nutritional status. Proper nutrition, by ensuring an adequate level of nutrients and preventing malnutrition, is conducive to maintaining a satisfactory level of FA.[49–51] Worldwide, malnutrition has become a common problem among the elderly. Older people living in institutions are most vulnerable to malnutrition.[52] For instance, one study showed that ~67% of older adults in nursing homes were malnourished.[53] Malnutrition is associated with the progressive deterioration of the FAs of older adults,[49] and a factor leading to disability.[50,51]

Conclusion

The present study has demonstrated that P_{max} and υ_{opt} are important correlates of FAs of older, inactive adults in a long-term care home. When assessed cross-sectionally,

P_{max} and υ_{opt} are adversely related to age and positively associated with FA. Furthermore, the relationship of P_{max} and υ_{opt} to functional status is stronger than that of HGS, both at baseline and after the 1-year follow-up. Declining PA levels of older adults are accompanied by decreasing FA, P_{max}, and υ_{opt}. Nevertheless, 1-year changes in FA were not related to changes in muscle strength, power, and υ_{opt} or fluctuations in PA level. Further studies are needed to explore the potential possibilities of alleviating functional decline by protecting muscle function in long-term care residents.

Study limitations

This study has several limitations, including 1) the relatively small sample of participants, 2) the lack of an intervention group, 3) some moderate effect sizes, 4) relatively low average age of participants, and 5) the homogeneity of studied group and their reluctance to perform any PA (especially in women). On the other hand, the final point may be also considered as a strength of the present study, as it demonstrates the lack of benefits from habitual variations of PA and indicates the need for structured exercise programs. Bearing in mind these limitations, the present study requires caution in data interpretation and should be confirmed in future studies.

Acknowledgments

Disclosure

The authors declare no conflicts of interest in this work.

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