

Effect of a 16-month exercise training program on functional capacities in a centenarian male master athlete: A case study

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ABSTRACT

The effects of exercise training have never been investigated in centenarians. This single-subject research study aimed to assess the effects of a structured training protocol on functional capacities in a centenarian master athlete. A 99.5 years old male subject participated in the study. Before and after a 16-month training intervention the participant underwent a test battery for flexibility (YMCA sit and reach), balance (single leg stance), upper limb strength (hand grip and pinch strength), and lower limb power (counter movement jump) and muscular endurance (horizontal leg press with 85 kg load). After training, sit and reach (-3 cm) and counter movement jump (- 0.5 cm) scores decreased, whereas single leg stance (+1.3 s), left hand grip (+2.0 kg), right hand pinch (+ 0.5 kg), and horizontal leg press (+2 repetitions) scores increased. Right hand grip strength and left-hand pinch strength did not change after training. When pre- and post-training scores were compared to gender-matched normative values, flexibility resulted well below average, maybe because of a relatively broad age category (> 65 years). When more specific age categories were available, the participant's balance resulted slightly below average (age category 80-99 years) and upper limb strength above average (age category > 85 years). No normative values were found for lower limb power and muscular endurance. In conclusion, this study highlights that structured exercise training may play a role in maintaining – and even in increasing – functional capacities in the oldest old age.

Keywords: Oldest old; Single-subject research; Aging; Exercise program.

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INTRODUCTION

Aging is associated with structural and functional decline in most physiological systems, which can affect activities of daily living and physical independence (American College of Sports Medicine et al., 2009). Indeed, in older adults, muscular strength (Gunther et al., 2008; Jansen et al., 2008; Mathiowetz et al., 1985; Puh, 2010; Wang et al., 2018; Werle et al., 2009), balance (Balogun et al., 1994; Bohannon et al., 1984; Springer, Marin et al., 2007), and flexibility (YMCA, 2000) decrease over time.

Lifestyle factors, such as physical activity, can partially slow down this age-associated decline (Chodzko-Zajko, 2014). Amongst them, structured exercise programs have been proved to: 1) counteract some of the negative consequences of aging, increase average life expectancy, mitigate age-related biological changes, influence the development of several chronic diseases and, preserve functional capacity (American College of Sports Medicine et al., 2009) and; 2) improve some quality of life domains (Rejeski and Mihalko, 2001). Indeed, some of the major internationally recognized organizations dealing with physical activity and health (e.g., the American College of Sports Medicine) have specifically developed exercise guidelines for older adults (American College of Sports Medicine et al., 2009; American College of Sports Medicine et al., 2018; Chodzko-Zajko, 2014).

Notwithstanding, the extent of the benefits deriving from an exercise program depends on several factors, among which the subjects' lifestyle and genetic (American College of Sports Medicine et al., 2009). Master athletes are an example of how the aging process occurs differently in subjects having the same chronological age, and how relatively high physical performances can be maintained while aging. This allows us to have an insight into the interaction among the afore-mentioned factors, exercise performance, and physical fitness.

To date, to the best of our knowledge, only one case study was performed in centenarians (Eibel et al., 2011). The study assessed the effect of a functional electrical stimulation training program in a centenarian woman and reported that functional capacity and muscle strength can be improved after 12 weeks of functional electrical stimulation training. However, no study assessed the effect of a structured exercise program, performed by means of active exercise, in a centenarian physically active man, who competes as a master athlete and detains national and world records in several track and field specialities.

The main aim of this study is to assess the effects of a training protocol on functional capacities in a centenarian physical active male, who is already a high-performance master athlete. The secondary aim is to compare his scores with the current normative values available in the literature.

MATERIALS AND METHODS

Participant

A male subject (age: 99.5 years old; body mass: 54 kg; height: 1.68 m; body mass index: 19.1 kg/m²) with a history of world records in master athletic competitions (i.e., triple jump, weight throw, throws pentathlon, 60-meter sprint, long jump, and shot put) participated in the study. Before enrolment, the subject was involved in an unstructured, self-prescribed, and self-administered exercise training program.

Experimental design

The present single-subject research employed a pre-post intervention design. The participant underwent a test battery before (T1) and after (T2) a 16-month training intervention (see below). The study was approved

by the local Ethics Committee and conducted in accordance with the Helsinki Declaration (2013 revision). The participant was informed of potential risks and discomforts associated with the testing procedures and gave written informed consent.

Assessments

Height (barefoot and head in the Frankfurt plane, to nearest 0.01 m) and weight (barefoot while wearing shorts, to nearest 0.5 kg) were measured. The participant performed 6 minutes of warm-up by walking on a treadmill (Runrace HC1200 – Technogym, Cesena, FC, Italy) at 2.9 km/h with the grade set at 0%. The following test battery was then performed: YMCA sit and reach; single leg stance; hand grip and pinch strength; counter movement jump (CMJ); horizontal leg press. Each test was preceded by a familiarization trial, which was followed by complete recovery. The participant was asked to avoid holding the breath during the tests. The best trial of each test was recorded. The test battery was performed at the same time of the day on T1 and T2.

YMCA sit and reach test. The participant sat on the floor with legs extended and was asked to slowly reach forward, with both hands, as far as possible, and holding this position approximately 2 s. Two trials were performed with 3 minutes rest in between (Kaminsky and American College of Sports Medicine, 2014).

Single leg stance test. The participant was asked to stand, with eyes opened, on one limb of his choice (he used the left limb) and the other limb raised up so that the foot was near but not touching the ankle of the stance limb. A stopwatch was used to measure the amount of time the subject was able to stand on one limb (Springer et al., 2007). The subject performed two trials with 5 minutes rest in between.

Hand grip and pinch strength tests. The participant performed the tests in the following order: right hand pinch strength (dominant hand); left hand pinch strength; right hand grip strength; left hand grip strength. Each test was repeated three times with 2 minutes rest in between. During the tests, the participant was verbally encouraged to exert his own maximal effort. Hand grip strength was measured using a handgrip dynamometer (Jamar Hydraulic Hand Dynamometer – New York, USA) with the subject standing with the forearm at the level of the thigh. The subject was asked to squeeze as hard as possible the dynamometer (American College of Sports Medicine et al., 2018), which grip width was previously adjusted according to the dimension of the hand (the same grip width was used in both T0 and T1). Pinch strength was measured using a pinch dynamometer (Jamar Hydraulic Pinch Gauge – New York, USA) with the subject standing with the elbow flexed at 90°. The subject was asked to squeeze the dynamometer as hard as possible with the fingertip of the thumb (Werle et al., 2009).

Counter movement jump. The participant was asked to perform three CMJs, with arm swing, as high as possible. The trials were separated by 5 minutes rest. The test result of each CMJ was the height of the jump, which was estimated from the flying time measured with the contact mat of the Muscle Lab (Bosco System, Roma, RO, Italy).

Horizontal leg press. The subject performed as many repetitions as possible with a load of 85 kg, which was approximately the 50% of his estimated 1 repetition maximum (RM) at T1 and corresponds to light-to-moderate resistance exercise intensity. The load that the subject usually trained with on the horizontal leg press (that was retrieved from his last training log) was input in the 1RM estimating equation proposed by Brzycki (1993) and the 50% of the result was calculated (the same load was used at T1 and T2). The leg press seat was adjusted to allow a maximal knee flexion of about 90°, which was measured using a goniometer. During the test, the participant was verbally encouraged to exert his own maximal effort.

Training intervention

The 16-month training intervention was structured according to the exercise prescription principles contained in the FITT-VP principle (American College of Sports Medicine et al., 2009; American College of Sports Medicine and Pescatello, 2014; Chodzko-Zajko, 2014), which is the acronym for Frequency, Intensity, Time, Type, Volume, Pattern, and Progression. Particular attention was given to the safety of the training sessions and the gradual progression of the training regimen. To this purpose, the participant's usual training regimen was closely and carefully monitored before starting the intervention in order to take into account his skills and preferences in the prescription of the contents of the training intervention.

The weekly training program was composed by: 1) three sessions per week of resistance exercise, aiming to train muscular strength and endurance, followed by balance exercises and specific drills, such as approach and take-off drills for the jump competitions, where the subject, respectively, accelerates to a maximum controllable speed and generates vertical velocity and minimises the loss of horizontal velocity; 2) at least one training session per week was dedicated to specific exercises for the competitions in which the participant was competing, aiming to train the sport-related techniques, skills and performances; 3) two sessions per week of aerobic exercise (e.g., brisk walk and jog), aiming to train cardiorespiratory endurance.

The first three training sessions were used as familiarization to the training program regimen and to the use of the CR-10 rating of perceived exertion scale (Borg, 1982, 1998), which was used as the main method to prescribe and monitor the exercise intensity. Each training session started with a light warm-up and finished with a short cool-down. The training sessions were closely monitored in order to adjust, if needed, the exercise intensity of the following sessions.

Data analysis

No inferential statistic was carried out in this study. Absolute (Δ) and relative ($\% \Delta$) change scores of each test were computed using, respectively, the following formulae: T2 score – T1 score; (T2 score – T1 score) / T1 score x 100. The scores obtained in T1 and T2 were also compared to the normative values found in the literature.

RESULTS

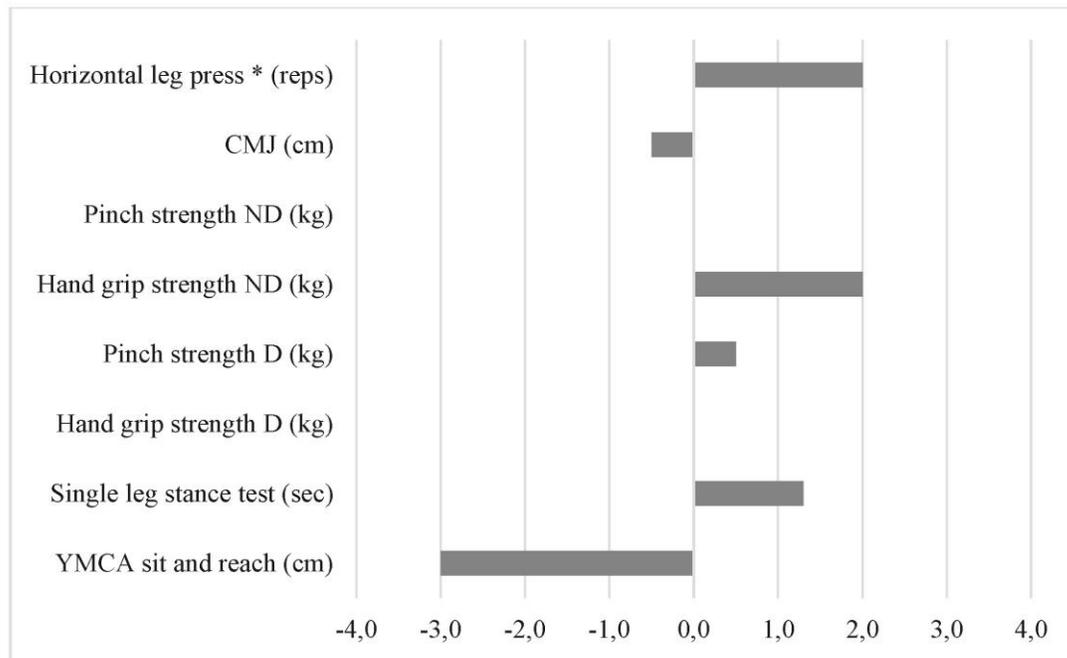
The results of the assessments performed in T2 and T1, and their Δ and $\% \Delta$ are presented in Table 1.

Table 1. Best scores of the tests performed in T1 and T2, along with their absolute (Δ) and relative ($\% \Delta$) changes.

	T1	T2	Δ (T2-T1)	$\% \Delta$ (T2-T1)
YMCA sit and reach (cm)	10	7	-3.0	-30.0
Single leg stance test (seconds)	5.92	7.22	1.3	22.0
Hand grip strength D (kg)	32	32	0.0	0.0
Pinch strength D (kg)	9.5	10	0.5	5.3
Hand grip strength ND (kg)	30	32	2.0	6.7
Pinch strength ND (kg)	9.5	9.5	0.0	0.0
CMJ (cm)	11.8	11.3	-0.5	-4.2
Horizontal leg press * (reps)	21	23	2	9.5

Note. Assessments performed before (T1) and after (T2) the 16-month training intervention; BMI, body mass index; D, dominant hand (right); ND, non-dominant hand; CMJ, counter movement jump. *, horizontal leg press exercise was performed with 85 kg load.

The Δ s of the tests included in the test battery, which show the differences between the scores recorded in T2 and T1, are reported in Figure 1.



Note: D, dominant hand (right); ND, non-dominant hand; CMJ, counter movement jump. *, horizontal leg press exercise was performed with 85 kg load.

Figure 1. Differences between the scores of the test battery performed after and before the 16-month training intervention.

YMCA sit and reach test showed a decrement of 3 cm in the flexibility, whereas subject's balance showed an increment of 1.3 s. Upper limb strength either increased (hand grip strength left hand +2.0 kg and pinch strength right hand +0.5 kg) or was maintained (hand grip strength right hand and pinch strength left hand), i.e., showed no difference at T2 compared to T1. The lower limb endurance (horizontal leg press) and power (CMJ) showed, respectively, an increase of 2 repetitions and a negligible decrease of 0.5 cm.

Participant's scores recorded at T1 and T2, along with the normative values retrieved from the literature (Kaminsky and American College of Sports Medicine, 2014; Springer et al., 2007; Werle et al., 2009; YMCA, 2000) for hand grip strength, pinch strength, balance, and flexibility, are presented in Figure 2, 3, 4, and 5.

Participant's flexibility, measured by means of YMCA sit and reach test, resulted well below average: lower than the 10th percentile (i.e., 10.16 cm) at T1 and lower than the 5th percentile (i.e., 7.62 cm) at T2, when compared with the oldest age group reported in the normative values (i.e., age > 65 years) (Kaminsky and American College of Sports Medicine, 2014; YMCA, 2000). The single leg stance tests showed that the subject's balance was 2.8 and 1.5 seconds below the average (i.e., 8.7 seconds) of males between 80 and 99 years (Springer et al., 2007) at T1 and T2, respectively. When compared to males older than 85 years, participant's hand grip and pinch strength resulted considerably above average. Indeed, the participant hand grip strength resulted higher than the average normative values (Werle et al., 2009) of 9.6 kg in the dominant hand at both T1 and T2, and of 6.8 and 8.8 kg in the non-dominant hand at T1 and T2, respectively. Likewise, the participant pinch strength resulted higher than the average normative values (Werle et al., 2009) of 4 kg

in the non-dominant and at both T1 and T2, and of 4.1 and 4.6 kg in the dominant hand at T1 and T2, respectively.

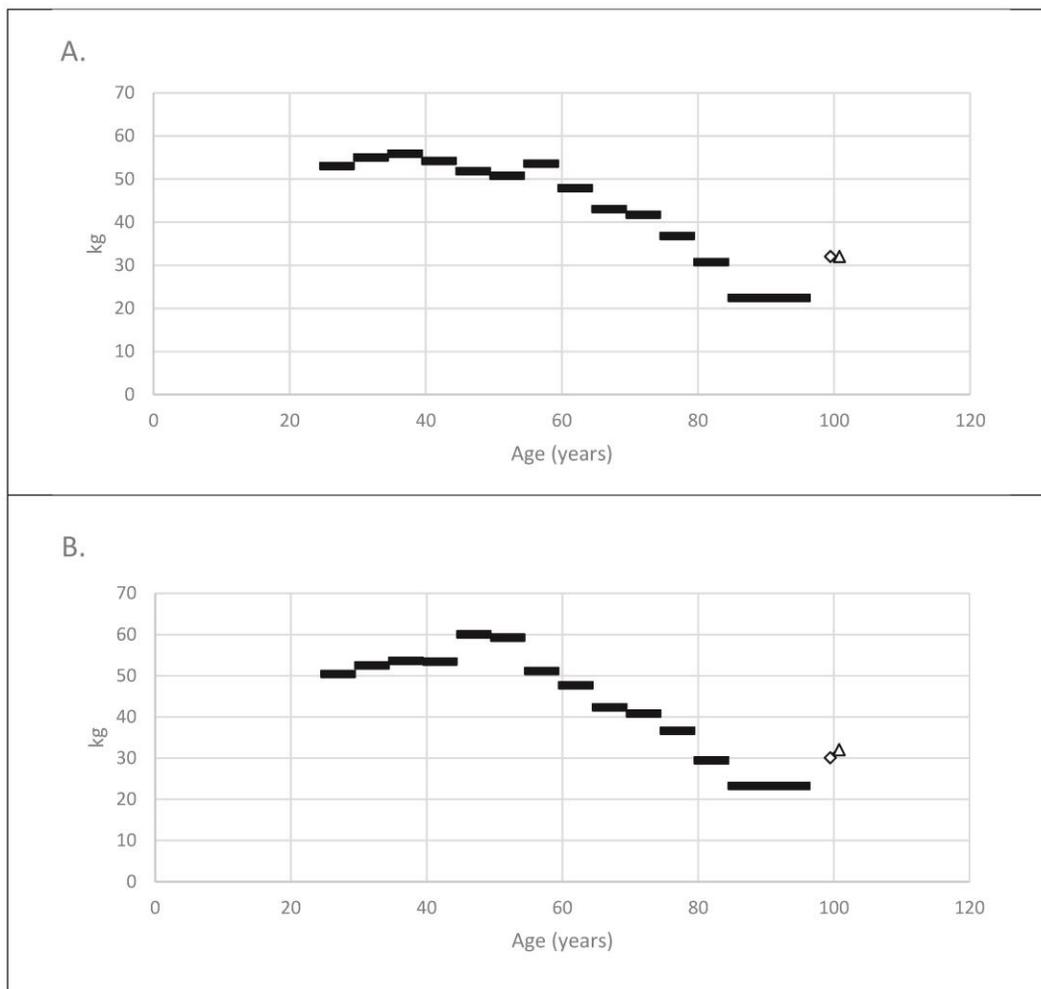


Figure 2. Hand grip strength for the dominant (panel A) and the non-dominant (panel B) hand. Black lines, normative mean values of the corresponding age category, which are plotted using the data retrieved from Werle et al. (2009); empty diamond, participant's best score before training; empty triangle, participant's best score after training.

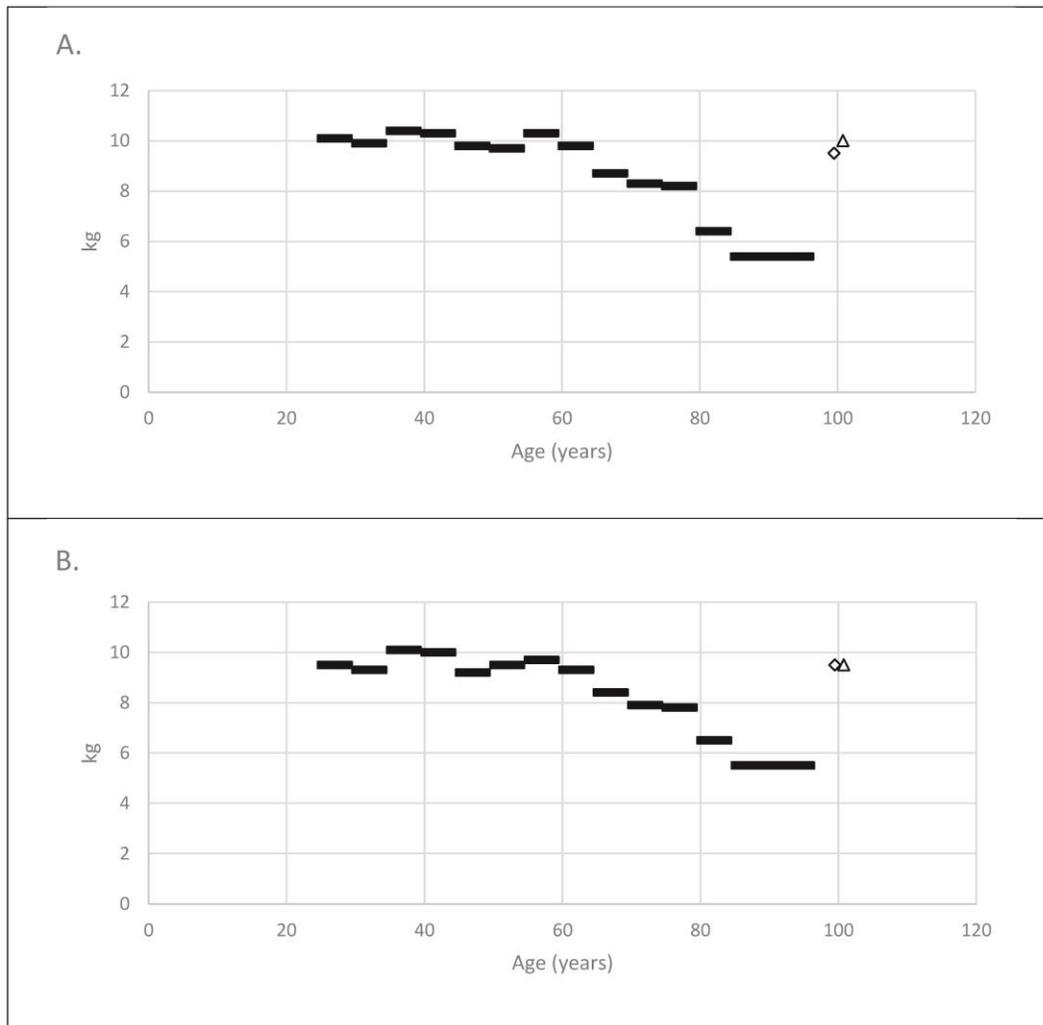


Figure 3. Pinch strength for the dominant (panel A) and the non-dominant (panel B) hand. Black lines, normative mean values of the corresponding age category, which are plotted using the data retrieved from Werle et al. (2009); empty diamond, participant's best score before training; empty triangle, participant's best score after training.

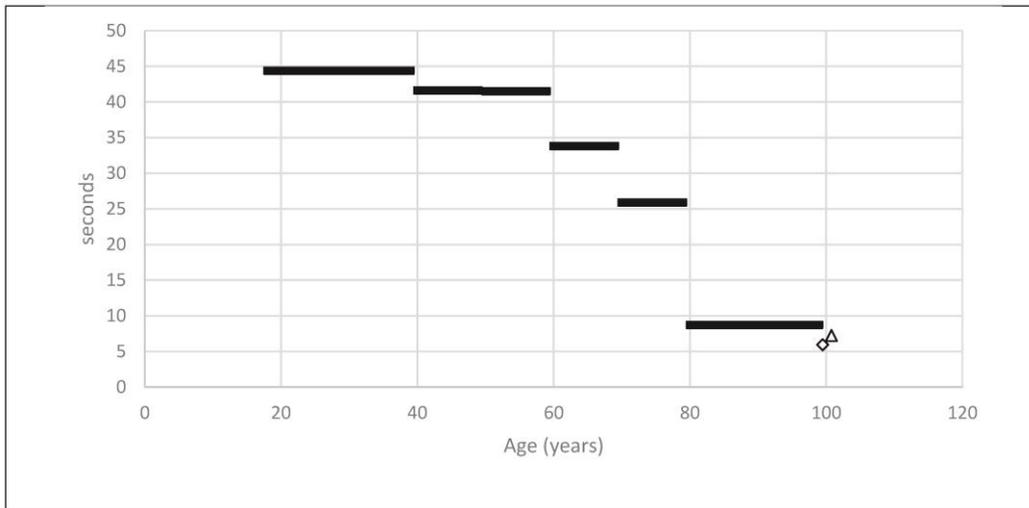


Figure 4. Single leg stance test. Black lines, normative mean values of the corresponding age category, which are plotted using the data retrieved from Springer et al. (2007); empty diamond, participant's best score before training; empty triangle, participant's best score after training.

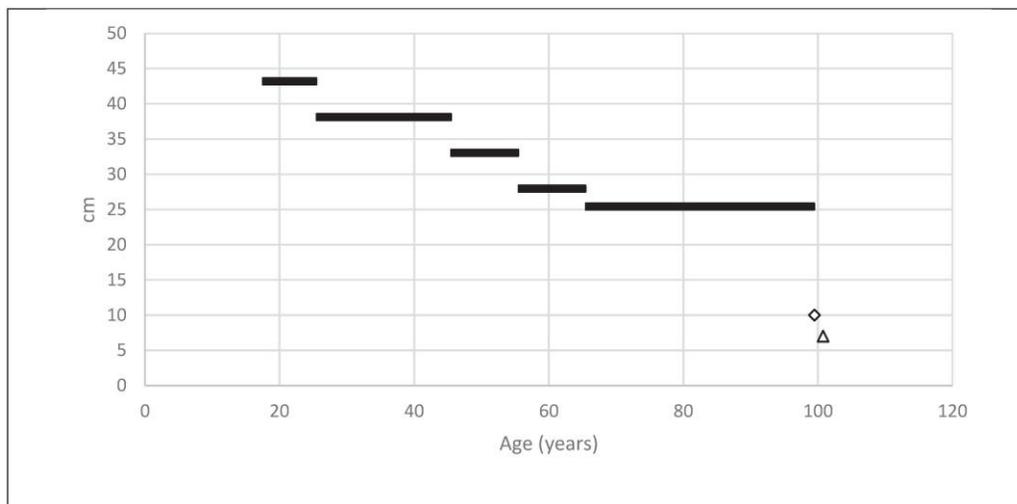


Figure 5. YMCA sit and reach test. Black lines, normative median values of the corresponding age category, which are plotted using the data retrieved from Kaminsky et al. (2014) and YMCA (2000); empty diamond, participant's best score before training; empty triangle, participant's best score after training.

DISCUSSION

The main aim of this single-subject research study was to assess the effects of a structured training protocol in a centenarian male subject.

Overall, the results of this investigation suggest that a training intervention could be effective in improving and maintaining several aspects of the functional capacities evaluated, even if the participant was beyond 100 years old at the end of the study. Indeed, participant's fitness scores regarding balance (i.e., single leg stance test) and strength (i.e., horizontal leg press, left hand grip strength, and right hand pinch strength)

improved after training, whereas other strength scores were either maintained (i.e., right hand grip strength and left hand pinch strength) or showed a negligible decrease (i.e., CMJ). This is in contrast to the physiological decline expected with aging for both upper limb strength (Gunther et al., 2008; Jansen et al., 2008; Mathiowetz et al., 1985; Puh, 2010; Werle et al., 2009) and balance (Balogun et al., 1994; Bohannon et al., 1984; Springer et al., 2007), thus supports the important role of exercise in counteracting the physiological decline of functional capacities associated with aging, even in the oldest old individuals. Noteworthy, upper limb strength has been proved to decrease faster at older ages, therefore showing a nonlinear relationship with age (Angst et al., 2010; Werle et al., 2009). Since the physiological decline is expected to be relatively high after the 16-month intervention, due to the participant age at T2 (i.e., 100.8 years), the positive effects attributable to the training should be seen as an additional support of its efficacy in counteracting the expected high physiological decline with aging. The decrease of flexibility score could be attributed to the lack of specific flexibility training. Indeed, even if stretching exercises were prescribed and performed, improving flexibility was not the aim of any training session.

A limitation of the present study is the lack of a cardiorespiratory endurance assessment. However, testing the cardiorespiratory fitness of the participant was not possible for safety reasons. In fact, the subject's attending physician did not provide medical clearance to perform any cardiorespiratory endurance test.

The secondary aim of this study was to compare the participant's scores with the normative values available in the literature. The comparisons need to be interpreted with caution because the age of the participant, at both the beginning and the end of the study, was either outside the maximum age range or at the high end of the normative values ranges for all tests present in the literature. Indeed, we believe that this comparison would still be useful since a clear decreasing trend can be identified for all the parameters studied as the age of the subjects increases. Therefore, the actual result of each test can be compared and interpreted on the basis of the age category and hypothesised trend. When compared to the normative values, participant flexibility resulted well below average (Kaminsky and American College of Sports Medicine, 2014; YMCA, 2000). Although the age category used as comparison is quite broad (i.e., > 65 years) and may be not representative of oldest old subjects, we believe that this result can be in part attributed to the characteristics of the participant, who reported that he never had good hamstring and lower back flexibility. Conversely, when more specific age categories were available for the normative values of balance (i.e., 80 to 99 years) (Springer et al., 2007) and upper limb strength (i.e., >85 years) (Werle et al., 2009) the subject resulted, respectively, slightly below average and above average. Although participant balance scores were slightly below average, we surmised that this was due to both the age category, which includes younger subjects, and a reported medical condition able to affect his balance (advanced cataract in one eye). Additionally, the subject balance after the training period improved and was overall in line with his age category.

The subject upper limb strength resulted notably above the average of the normative values for his age category (i.e., > 85 years). Indeed, when the upper limb strength scores were compared to the normative values, the participant hand grip strength was higher than the average subject between 80 to 85 years, and the pinch strength was similar to the average subject between 60 to 65 years. Possibly, the relatively high scores in the pinch strength tests could be the effect of the specific tasks performed by the participant throughout his working life. Indeed, before retiring when he was 70 years old, the participant worked extensively as a craftsman, mostly using his hands handling and pinching small objects. However, data from the present study do not allow to confirm this speculation.

Unfortunately, due to the lack of normative values in the age-specific category for CMJ and the horizontal leg press, no comparison with the literature was possible, and this is a further limitation of the present study.

CONCLUSIONS

This study highlights that structured exercise training may play a role in maintaining – and even in increasing – functional capacities in the oldest old age. Although single-subject researches have several limitations that are intrinsic in their design, such as lack of external validity and inferential statistics, this study shed some lights on the poorly explored topic of the effects of structured exercise on older and oldest old adults. Therefore, more research is needed to confirm and/or extend the results of this study. Since the expectancy of life is growing and growing and the number of centenarians is increasing, this study may serve as a starting point for further studies focusing not only on exercise physiology, but also on epidemiology and public health.

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