Ageing effect on strength specific characteristics among generally active subjects

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Abstract:

Introduction: Strength level is a good predictor of health outcomes such as mortality or future disability. During an usual individual life span, strength and neuromuscular function are decreased, due to a reduction of the muscle mass and the fiber type switch that manifests at the age of 50-60 years old. Physical activity can prevent, or at least reduce these changes. The fact that the physical activity level is also reduced by age, makes it difficult to distinguish between the effects of aging and those of a sedentary lifestyle. Therefore, this work attempts to study the differences in hand-grip strength, jump height and rate of force development as strength predictors, between physically active elderly and young adults. **Material & Methods:** 16 healthy and physically active adults formed 2 groups: experimental group (8 old adults, mean age 72.24 years old, SD 4.82) and control group (8 young adults, mean age 24.94 years old, SD 1.67). They all performed hand-grip strength, jump height and rate of force development tests. Statistical analysis were performed by using JASPS software. **Results:** Significant differences were found in hand-grip strength ($t = 2.133$, $p = 0.07$) and jump height ($t = 9.949$, $p = 0.001$), whereas no significant difference was obtained in rate of force development ($t = -0.300$, $p = 0.773$). **Conclusions:** There is a life-long reduction in whole body strength capabilities in active adults. Nevertheless, the importance of physical activity for keeping strength capabilities with increased age was evident. Furthermore, both hand-grip strength and jump height can be considered as reliable predictors of whole-body strength levels, whereas RFD should be taken with caution, due to its specificity.

Key Words: Hand-grip strength, jump height, rate of force development and physical activity.

Introduction

Currently, the population age is increasing, to the point that the proportion of elderly people (adults older than the age of 65) is projected to be higher than 24% of the total population by 2051 (Lloyd et al., 2014). During this age frame, some physiological changes occur, such as a depletion of muscle mass (Faulkner, Davis, Mendias & Brooks, 2018) and a 25% of peak strength loss (Frontera et al., 2000).

Strength, whose training is defined as an activity which voluntary, brief and repeated contractions occur against greater resistance to those usually encountered in daily life (Li et al., 2015), is an essential capacity in training. Through its development, muscular power and strength are improved by way of various mechanisms, such as the increase in the voluntary activation of the trained musculature, or the changes that occur in the cross-sectional muscle area and muscle fibers (Karavirta et al., 2011). According to these authors, these processes are invariable to the population age group, although the magnitude of the effect may vary.

Strength is also a predictor of various health outcomes such as mortality, future disability, and post-operative complications (Bohannon, 2008). Therefore, according to Devries & Phillips (2014), strength training from the health point of view is postulated as a fundamental factor to consider for any age group.

There are several existing forms of measuring strength. As Balsalobre-Fernández, Glaister & Lockey (2015) mentioned, the evaluation of the rate of force development (RFD) using a force platform is considered as the gold standard method of assessing lower limb strength. Nevertheless, there are other commonly used means of evaluating physical fitness in various populations, such as vertical jump tests (Buchheit, Spencer & Ahmaidi, 2010; De-Villarreal, Izquierdo & Gonzalez-Badillo, 2011; Rodacki, Fowler & Bennett, 2002; Taipale, Mikkola, Vesterinen, Nummela & Häkkinen, 2013). Specifically, jump height is used to evaluate leg power in sports, such as basketball and football (Argus, Gill, Keogh, Hopkins & Beaven, 2009; Duncan, Lyons & Nevill, 2008; Hartman, Clark, Bembien, Kilgore & Bembien, 2007). Furthermore, the height achieved during a vertical jump has been also used to evaluate non-athletic populations such as elderly (Pereira et al., 2012). Besides, vertical jump training has been established as positive for improving bone mineral density among aged people (Allison, Folland, Rennie, Summers & Brooke-Wavell, 2013).

Moreover, grip strength should be considered as another important factor for assessing physical fitness. Buckley, Stokes & Samuel (2017) showed that grip strength is a reliable predictor of whole-body strength in sedentary older adults, since they presented a moderate association between quadriceps peak torque and grip strength in their study carried out with active older females. In this line, Bohannon, Magasi, Bubela, Wang &

Gershon (2012) showed that handgrip strength and isometric knee extensor strength were correlated. Finally, and taking into account the above, grip strength may be considered as a useful marker of frailty (Syddall, Cooper, Martin, Briggs & Sayer, 2003) and sarcopenia (Lauretani et al., 2003; Park, Ha, Yoo & Ryu, 2016; Yoo et al., 2016) in older adults, since they are both strongly correlated with strength loss.

During the ageing process of an ordinary person, strength and neuromuscular function decrease, interfering with activities of daily living (Kenney, Wilmore & Costill, 2015). It manifests around the age of 50-60 years and results from a decrease in muscle mass, related to some physiological processes that occur in the human body, by all means. First, the fat-free mass starts to decrease around the age of 40, due to reduced muscle and bone mass, sarcopenia and reduced protein synthesis (Kenney et al., 2015).

The mentioned authors explain that these processes are related to a reduction of the growth hormone insulin-like growth factor 1 that normally occurs at that age frame. Second, there is a fiber type shift related to ageing. Regarding to Kenney et al. (2015) type II motor neurons amount decreases, whereas type I neurons may innervate old type II fibers. That originates a change in the fiber type, with higher percentage of type I fibers compared with both type IIA and IIB muscle fibers. Further, the size and number of all kind of muscle fibers decrease with age. Regarding to Kenney et al. (2015) a 10% of muscle size is expected to be lost per decade after the age of 50.

Nevertheless, since physical activity tends to decline substantially as we age, distinguishing between the effects of aging and those of reduced physical activity is difficult when studying lifelong changes in physiological function (Kenney et al., 2015). Supporting the foregoing, and regarding to some authors like Peterson, Rhea, Sen & Gordon (2010); Wroblewski, Amati, Smiley, Goodpaster & Wright (2011) and Wall, Dirks & van Loon (2013) strength loss, and other physical changes related to age, may be influenced by the lack of physical activity.

Therefore, as Buckley et al. (2017) stated, the promotion of regular physical activity levels is crucial for encouraging elderly to keep general health during their life frame. Supporting that, Kenney et al. (2015) affirm that the decrease in type II motor neurons can be slowed down or even stopped with strength training in older adults, and Borde, Hortobágyi & Granacher (2015) state that the muscle hypertrophy, important to prevent muscle loss, is possible in elderly. In fact, the Physical Activity Guidelines for Americans published in 2018 recommends 2 or more days per week of strength-based physical activity for adults older than the age of 65, encouraging them to perform between 10 to 15 repetitions, from 8 to 10 exercises involving large muscle groups. Given the above, the aim of the present study is to analyse the differences in strength capabilities, and more concretely, the changes in RFD, jump height and hand-grip strength of generally trained elders by comparing them with also generally active young adults.

We hypothesize that generally active elders will present lower RFD, jump height and hand-grip strength compared with the generally active young adults. Secondly, we expect that the difference found between the two groups will be lower than the values available in the literature for a similar comparison among sedentary subjects.

Material & Methods

Participants

A total of 16 subjects participated in the present investigation. They were divided in two gender-matched groups. The control group was formed by 8 physically active young adults, whereas the experimental group consisted in 8 physically active elders (3 male and 5 female), for both groups. Mean and standard deviation ($\pm$ SD) of age, height and body mass of the groups are presented in Table I.

All 16 participants needed to be physically active to be included in the study, performing at least 2 training days per week, with one-hour duration, for, at least, the last 6 months. Subjects forming the control group confirmed that they were taking part in a certain physical activity that fulfilled the requirements previously indicated. On the other hand, participants from the experimental group were all taking part in a physical activity course carried out at the University of Konstanz.

The workout was based on reinforcing physical fitness for elders, twice a week, during the whole scholar year. A single session had one-hour duration. The physical activity level assessment of the subjects was, however, self-reported, since no exhaustive follow up was performed. Further, subjects between the age of 20 and 40 years were included in the control group, whereas subjects between 60 and 80 years old formed the experimental group. Having had a knee, leg, ankle, shoulder, elbow or wrist joint or muscular-related injury in the last 12 months, as well as having suffered a muscular or joint-related operation in the mentioned areas in the last 2 years were exclusion criteria for the present study.

Participants were informed of the purpose of the study, testing procedures and potential risks. The study procedures presented minor risks of falling or suffering an ankle sprain. These risks were prevented by the researchers by performing a risk prevention protocol, taking care of the subjects and keeping a good material disposition during the whole testing procedure. Before starting the tests, a written, voluntary and informed consent was obtained from all participants. The study protocol complied with the Declaration of Helsinki for Human Experimentation and the ethical criteria of the ethics committee of the University of Konstanz have been taken into account.

Table I. Subjects' basic data. Mean and standard deviation.

Youths	Age (y.o.)	Height (m)	Weight (kg)	Elders	Age (y.o.)	Height (cm)	Weight (kg)
Sample	8	8	8		8	8	8
Mean	24.940	1.691	64.875		72.240	1.706	73.375
±SD	1.670	0.068	8.806		4.820	0.061	11.488
Minimum	22.000	1.630	57.000		66.000	1.600	52.000
Maximum	29.000	1.840	85.000		79.000	1.800	83.000

Study design

An experimental, controlled and blinded study design was used to analyse the differences in hand-grip strength, RFD and jump height between gender-matched and generally active young and elder adults. In order to do that, the subjects, conforming two groups (N = 8), were tested in one single day during the first two weeks of July 2017 (between 9:00 a.m. and 15:00 p.m.). Measures were taken in the Neuromechanicslab (NML) located at the Human Performance Research Centre (HPRS) at the University of Konstanz, Germany.

Subjects were recruited during the two weeks previous to the measurement's beginning. For the control group, researchers made the participant's recruitment by spreading information about the project at the University of Konstanz and the Athletic Club Konstanz. Besides, subjects forming the experimental group were recruited by going to the physical activity courses from the University of Konstanz in which they were participating, during the normal lessons time. All subjects were asked to make an appointment date and time to go to the HPRS and perform the tests, after a deep explanation of the project and answering all the questions that came up. Initially, 10 subjects were recruited in both groups, but due to 2 drops out in the experimental group, and in order to maintain size- and gender-matched groups, we reduced the sample size to 8 subjects for both experimental and control groups.

Testing protocol

When the subjects arrived to the HPRS researchers gave them written information of the research purpose, testing procedures and risks. After reading it carefully participants signed the written consent and filled in a form for creating their anonymous ID. That was used to blind the researchers when analysing the results and preserve the anonymity of the subjects.

After, subjects were accompanied to the NML where the measurements took place. There, and before starting the measurements, a basic strength-training warm-up was performed to prevent any risk of injury and ensure better muscular and mental conditions for a higher performance. Warm-up consisted of joint mobility exercises of lower and upper limb joints, followed by strength-related warming up exercises (30-seconds hold of squat downwards position, 10 repetitions of hips flexions and 10 squats). Immediately after, testing procedures were performed in the following order: hand-grip strength, RFD and jump height. Researchers were present during the whole measuring process, explaining in detail the technique of the exercises and giving feedback to the subjects to keep their motivation high, in order to make them perform in the best way possible. Furthermore, after the tests finished, subjects received information about their performance and were able to ask questions to the researchers about their results.

Hand-grip strength

For measuring hand-grip strength a JAMAR ® Plus + Digital Hand Dynamometer was used. After the generalized warm-up, each subject was asked to select a preferred arm (usually the stronger one) and try the hand dynamometer, in order to adjust the device features to their more comfortable position. After the device calibration, participants were asked to press as hard as possible, holding it for no more than three seconds, since it is time enough for the device to calculate the maximal force of the trial. For that, subjects were sitting, with the forearm lying on a table, at a comfortable height and distance. After 1 minute-rest, participants performed the second attempt, and same procedure was followed for the third and final one. We encouraged the subjects during the whole process, making sure that the measurements were valid. In case of error, the trial was repeated, to finally have three trials recorded from each subject, as well as the total average and the device error. The average strength (kg) was used for the subsequent statistical analysis.

RFD and jump height

For the measurement of RFD and jump height of the subjects a Leonardo Mechanograph® GRFP STD Force Plate (660 x 660 x 70 mm) was used. After a standardized warm-up, recording subject's basic data in the software (age, height and weight) and calibrating the system, subjects were asked to perform 3 countermovement jumps (CMJ). CMJ technique was defined as the following: subjects needed to jump as high as possible after the signal given by the researcher and land, with two legs in the ground, in the limited area of the platform. They were instructed to place their hands on their hips while performing a downward movement to a 90° knee flexion. That was followed, without any kind of rest phase in between, by a vertical jump (hip, knee and ankle extension) of maximal effort. All subjects were asked to keep their knees straight during the flight phase and land in an upright position. CMJ technique was explained before the test and subjects had the opportunity to practice the jump having researchers' feedback. 3 jumps were performed by each of the subjects, with 1 minute of rest in between them, under the close supervision of the researchers. Invalid trials were repeated as extra-jumps, in order to register 3 valid attempts of each participant.

All trials were performed on a Leonardo force plate connected to an amplifier system. The output signal, representing ground reaction force (GRF), had a sampling frequency of 2000 Hz and was lowpass filtered with a cut-off frequency of 30 Hz. For the data analysis, the Leonardo Mechanography STD analysis software was used.

RFD, which is the force that the subject is able to apply in a defined time during the jump, was calculated afterwards by using the peak force (N) of the jump and the time to achieve that force (s). This data was directly taken from the force platform's results given by the software. We calculated RFD by using the following equation: $RFD (N \cdot s^{-1}) = \text{Peak force (N)} / \text{Time to achieve peak force (s)}$. Besides, for the calculation of the jump height, the time of flight method was used by inputting the time of flight (s) of the subject's jump in the equation: $\text{Jump height: } h = \frac{1}{2} \cdot g \cdot (t/2)^2$. Time of flight was also taken directly from the force platform's results given by the software. The average RFD and jump height values out of the 3 trials were used for the subsequent statistical analysis.

Statistical analysis

First, average values and standard deviation ($\pm$ SD) of hand-grip strength, RFD and jump height were calculated. Second, to analyse if there are any differences between the control and experimental group for the above-mentioned parameters, 3 paired sample *t*-test were applied. In other words, *t*-values were used to check if there were significant differences between the compared means, whereas the *p*-value obtained from the *t*-test was useful in ruling out that the results have been fortunate. For that statistical test, null hypothesis was chosen. Furthermore, descriptive plots (with a 95% confidence interval) were given for a better understanding of the results. The level of significance was set at 0.05. All calculations were performed using JASP (Version 0.10) [Computer software].

Results

Sample size, mean, $\pm$ SD, maximum and minimum values for all measured variables in both experimental and control group are displayed in Table II.

Table II. Hand-grip strength jump height and RFD results. Mean values and standard deviation.

	Elders Hand-Grip (kg)	Elders Jump Height (m)	Elders RFD (N*s-1)	Young Hand-Grip (kg)	Young Jump Height (m)	Young RFD (N*s-1)
Sample	8	8	8	8	8	8
Mean	32.375	0.140	5.809	39.858	0.311	5.360
$\pm$ SD	8.551	0.041	3.665	6.758	0.045	1.586
Minimum	22.000	0.087	1.920	30.700	0.230	3.140
Maximum	46.500	0.227	14.350	50.130	0.370	7.800

The paired samples *t*-test showed significantly lower values of hand-grip strength and jump height in the experimental group, compared with the control group, whereas no statistical difference has been found for the measured RFD in both groups.

First, the *t*-test made to compare the results of hand-grip strength from both control and experimental groups showed a significant difference between the mean values ($t = 2.133$, $p = 0.07$). See Figure I.

Figure I. Student *t*-test. Control and experimental groups hand-grip strength (kg).

Second, the *t*-test comparing the results of jump height of both groups revealed also a significant difference between the mean values ($t = 9.949$, $p = 0.001$). See Figure II.

Figure II. Student *t*-test. Control and experimental groups jump height (m).

Finally and contrarily, the *t*-test made to compare the RFD of both control and experimental groups obtained no statistically significant difference between the mean values ($t = -0.300$, $p = 0.773$). See Figure III.

Figure III. Student *t*-test. Control and experimental groups RFD (N*s⁻¹).

Discussion

The results show differences in two of the three measured parameters predicting strength capabilities (jump height and hand-grip strength), with lower values for generally trained elders compared with young and also generally trained controls. Data presents significant differences for values of hand-grip strength and jump height ($t = 2.133$, $p = 0.07$; $t = 9.949$, $p = 0.001$). As it can be seen by the p values obtained in the *t*-test analysis, we can trust the results and assume that they are not related to luck. Nevertheless, the third measure of strength-related capability, RFD, showed no significant difference when comparing elderly and young trained subjects ($t = -0.300$, $p = 0.773$). In an attempt to explain these results, and supported by the literature evidence, we try to clarify in this section the nature of the differences found in hand-grip strength and jump height between groups. Furthermore, we will discuss the disparities existing for the three measured strength-capabilities predictors.

Firstly, hand-grip strength has been defined as a very relevant tool in order to measure the whole-body strength, and further, the most widely used method (Beaudart et al., 2019). Moreover, it has been shown in epidemiological studies that it is a good predictor of healthy ageing and disease progression (Hahn, Spies, Unglaub and Mühldorfer, 2017). Therefore, it is commonly used for both clinical and scientific purposes (Hahn et al., 2017; Beaudart, McCloskey & Bruyère, 2016), considered as an objective component of the frailty symptom (Cooper, Kuh & Hardy, 2010) and sarcopenia (Anton et al., 2018; Curcio et al., 2016) in elderly. For that reason, it is associated with increased all-cause mortality (Fried et al., 2001), premature mortality, development of disability and an increased risk of complications or prolonged length of stay after hospitalization or surgery (Bohannon, 2008). In order to determine the effect of ageing on this very relevant strength predictor, our data presents clear differences between values obtained for elderly (60-80 years old), lower when compared with gender and physical-activity level matched youngsters (20-40 years old). That difference is supported by the evidence found in the literature, since Dodds et al. (2016) had already stated it by establishing reference values. They reviewed 806 studies to prove that the previously established normative data for hand-grip strength in Great Britain was reliable for assessing sarcopenia and frailty across the worldwide regions. In that line, the values they show present similar differences between elders and youngsters to the ones obtained in our

research. Hence, we confirm the decrease of hand-grip strength values during the life span, as it had previously been stated by the literature.

Nevertheless, it is difficult to draw conclusions about the role of the physical activity level of the subjects. It was not possible to make any comparison of our results with the previously mentioned normative data from Dodds et al. (2016), since they gave reference values for males and females separately, and both our experimental and control groups were gender mixed. To the best of our knowledge, there is no available reference data for gender mixed values, and that is the reason why future research should segregate the sample by gender if the aim is to draw any conclusion by comparing them with reference values.

Secondly, the subject's jump height was also measured in this experiment. The ability to jump has been related to muscle strength and power, speed and amplitude of the lower limb movements (Pijnappels, van der Burg, Reeves & van Dieën, 2007). For elderly in particular, vertical jump height has been shown to be a good predictor of functional capacity (Pijnappels et al., 2007) and risk of falling (Lee, Biggan & Ray, 2016; Pijnappels et al., 2007). Jump height is also, regarding to the results of the present investigation, decreased with age, proving what had previously been established by the literature. Several studies have found the same effect (Thompson, Whitson, Sobolewski & Stock, 2018; Argaud, Pairet de Fontenay, Blache & Monteil, 2016; Haguenaue, Legreneur & Monteil, 2005), with decreased jump height of elderly when compared with young subjects. The mechanisms behind this decrease related to age has been also tried to be explained by the previously mentioned authors. On the one hand, Argaud et al. (2016) showed that the decrease that they found was related to a lower joint power when performing the vertical jump. This lower joint power resulted from both a lesser moment and angular velocity produced at each joint. On the other hand, Haguenaue et al. (2005) found a significant decrease in jump height attached to a more extended hip position at the beginning of the jump and decreased hip, knee and ankle linear and angular amplitude, with ageing. These findings suggest that the jump height reduction with age was attributed to a lower explosive force and range of shortening of the extensor muscles. Therefore, the adjusted pattern of joint coordination that elderly present while jumping may be an important fact in explaining the big difference in jump height. In any case, and confirming our first hypothesis, we found in both the available literature and our own results a significant decrease in jump height across the life span of generally physically active subjects.

Moreover, we tried to make further conclusions about how the physical activity level of the subjects affected the height of the jump. In order to do that, we compared the values that we obtained with the available data from the literature. First of all, the importance of being physically active for having higher jump height values has been proved by Caserotti, Aagaard & Puggaard (2008). For that, they tested the effect of a 36-weeks multicomponent training on elderly adults with a control inactive group. They found as a result a significant decline in countermovement jump (CMJ) and squat jump (SJ) height, exposing the importance of being trained for having higher jump height in elders. Nevertheless, we only found studies analysing the differences in jump height for physically active people, but none for inactive subjects. We obtained in our investigation lower differences in jump height (elders jumped 17 cm or a 55% less than youngsters), than previous studies (28 cm, Haguenaue, Legreneur & Monteil, 2005; 23 cm and 64%, Argaud et al., 2016). These higher values could be explained by the fact that both mentioned researches used generally active elderly subjects with self-defined physical activity levels, whereas our elder subjects were enrolled in a training program. We hypothesize that this fact may be important in order to explain the lower influence of ageing in jump height since the subjects may have better adaptations to a regular training program, rather than having a free and self-designed active lifestyle. Nevertheless, more research with a proper definition of activity levels and controlled by an inactive group is needed in order to strengthen the present results.

Thirdly, RFD is the last strength predictive parameter assessed in the present work. It has been considered as an important neuromuscular parameter of physical fitness in elderly individuals (Guizelini, de Aguiar, Denadai, Caputo & Greco, 2018). Also, it has become quite popular for characterizing explosive strength, not only of elderly individuals, but also of young athletes and clinical patients (Maffiuletti et al., 2016). Nevertheless, RFD turned out to be controversial in our study, since the results contradicted our original hypothesis and there was no significant difference found between groups, as we expected. In an attempt to explain these results, a deep literature review was made. To the best of our knowledge, two studies researched about the difference in RFD values between elders and youngsters, using sedentary (Allison et al., 2013) and active (Granacher, Gruber & Gollhofer, 2010) subjects. Both of them obtained significantly lower RFD values for elderly subjects. Nevertheless, Allison et al. (2013) showed that the decrease in maximum isometric strength (19%) was attached to a decline in peak rate of force development (21%), but peak rate of force development was similar between groups when normalized to maximum strength. That fact can make us suspect about some of the weaknesses of this measurement as a strength predictor. In any case, more research with both active and sedentary populations is needed to clarify the scenario. Furthermore, Maffiuletti et al. (2016) explained that RFD can be improved by both explosive-type and heavy-resistance strength, by an improvement in quick muscle activation, occurring these changes in different subject populations. Since physical activity was not defined in detail for the young subjects in our study, the results can be explained in the sense that we cannot assure that all subjects from each group were performing a training that affected RFD in the same way. For that reason, we

cannot make strong conclusions about our results. Further, future studies should restrict the kind of training that the subjects perform in order to narrow the view and draw more acute conclusions.

Furthermore, there are some studies available in the literature investigating the effect of physical activity in RFD that we used to discuss what is the effect of the training level that our subjects presented. First, a review and meta-analysis conducted with elderly people by Guizelini et al., (2018) showed that the studies included performing explosive or heavy strength training were efficient to improve RFD after a short-to-medium training period. Reinforcing that statement, Aagaard, Magnuson, Larsson, Kjaer&Krustrup (2007) also found a consistent increase in RFD, as well as in muscle fiber size and mechanical muscle performance, for aged individuals exposed to chronic resistance training. Moreover, Saeterbakken, Bårdstu, Brudeseth& Andersen (2018) presented a difference in peak RFD for leg extension as an effect of 10-weeks strength training intervention. Not only studies using strength training protocols were found, since Sundstrup et al. (2010) showed superior RFD for trained elderly footballers, comparing them with a non-trained control group. They affirm that the difference in RFD had such a magnitude that no deficit could be observed when compared with young untrained individuals. That fact reinforces our suspicions about the possibility that the no-difference in RFD obtained in our study can be related to the fact that the physical activity carried out by the young group did not affect their RFD levels, making the difference related to age insignificant.

There is a parallel discussion that can be also done in regard to the results obtained in the present investigation, using the previous scientific evidence, about the usability and reliability of the three measured strength markers as predictors of strength and health-related parameters among elders. First, hand-grip strength is a widely validated and used tool for measuring strength levels, when measured in standard conditions (Roberts et al., 2017). Among elderly people, and regarding to the European Working Group on Sarcopenia in Older People, low hand-grip strength is an important factor for sarcopenia diagnosis (Curcio et al., 2016). In order to prove that, Bohannon et al. (2008) reviewed 45 articles manifesting the validity and simplicity of hand-grip strength as a predictor of important outcomes, such as premature mortality, development of disability, and in general, whole body strength level. Later, Beaudart et al. (2019) reviewed the available literature strengthening the claim about the fact that hand-grip strength is reliable for measuring frailty and sarcopenia, by using a Jamar device (gold reference for this measurement) while an isotonic muscular contraction. Further, there are some studies revealing that this strength predictor is also valuable for monitoring other health-related aspects in elderly, such as cognitive changes (Fritz, McCarthy & Adamo, 2017), cardiovascular cause mortality and gait speed (Chainani et al., 2016). Second, jump height was also defined as a good predictor of strength and functional capacity for elderly (Lee et al., 2016). Even if most of the researches on that topic focus on the importance of jump height as a predictor of lower limb muscle strength and power, some others prove that it is not only related to lower limb strength production, but also with whole body strength related markers such as the previously discussed hand-grip strength (Pijnappels et al., 2007). Furthermore, we can trust that it is a reliable method since Ditroilo, Forte, McKeown, Borheam& De Vito (2011) assessed the intra- and inter-day reliability of a CMJ in healthy middle-aged (55-56 years old) and older (66-75 years old) men and women, showing excellent absolute reliability for jump height and moderate- to high- intraclass correlation for both men and women. Nevertheless, we cannot affirm the same about RFD since the available literature presents contradictory assertions about the topic that supports our unexpected results. First, Saeterbakken et al., (2018), after applying a 10 weeks strength training intervention on isometric strength, physical function and rate of force development found that the improvement in RFD was not followed by a development in physical function or isometric strength, suggesting that RFD was not correlated with these parameters. Reinforcing the former, Maffiuletti et al. (2016) stated that it is difficult to evaluate RFD in a valid and reliable way, since it can be improved only by applying a very specific training method based in explosive or heavy resistance strength training. This is also supported by Guizelini et al. (2018) that affirm that, even if RFD has been stated as an important neuromuscular parameter of physical fitness in elderly individuals (Aagaard, Suetta, Caserotti, Magnusson & Kjaer 2010), muscle strength and RFD seems to adapt differently to resistance training programs, suggesting caution for their interchangeable use in clinical assessment of elderly. Therefore, the lack of changes on RFD obtained in our work can be explained by these affirmations, since the training of the subjects may have not affected RFD enough to see a difference in the values between experimental and control groups. Given that, we can affirm that, whereas hand-grip strength and jump height are reliable and consistent parameters for assessing whole body strength capabilities, RFD seems to be more controversial due to its nature and its specificity of its adaptation to different kinds of training. Therefore, it should be used with caution for assessing whole body strength, although further research is needed to check this statement.

There are, however, a few limitations that should be considered. Firstly, the sample size of only 8 subjects for each group force us to interpret the present results with caution, since a higher sample size would have been needed to obtain more trustworthy results. Secondly, physical activity was self-defined by the subjects forming the control group. That might compromise all the conclusions obtained, but most notably the ones regarding RFD, since it is a variable improved by very specific resistance training methods (either explosive or high-loads resistance training). Thirdly, it was difficult to assess the influence of physical activity levels in hand-grip strength since the available reference data is defined for gender-differentiated populations, whereas in our study we used gender-mixed groups. Finally, we did not assess physiological parameters in order to explain the

mechanisms behind the obtained results, that would have been useful for having a better understanding of the given results.

Conclusions

In conclusion, considering previous research and the given evidence, we can affirm that there is a life-long reduction in whole body strength capabilities in active adults. Concretely, hand-grip strength and jump height are lower for elder populations compared with youngsters. Nevertheless, the importance of physical activity for keeping strength capabilities with increased age was evidenced by being the reductions in strength levels lower when compared with similar experiments conducted with non-trained individuals.

Finally, we conclude that both hand-grip strength and jump height can be considered as reliable and usable predictors of whole-body strength levels, whereas RFD should be taken with caution since it seems to be adapted in a very specific way to different kinds of training.

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