Universidad CEU Cardenal Herrera

Departamento de Fisioterapia

THE EFFECTIVENESS OF EXERCISE INTERVENTIONS AND THE FACTORS ASSOCIATED WITH THE PHYSICAL PERFORMANCE IN OLDER ADULTS.

TESIS DOCTORAL

Presentada por:
D. Vicent Benavent Caballer

Dirigida por:
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Dr. Pedro Pablo Rosado Calatayud
Dra. Eva Segura Ortí

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VICENT BENAVENT CABALLER

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IGNACIO PÉREZ ROGER, Presidente de la Comisión de Doctorado de la Universidad Cardenal Herrera-CEU

C O M U N I C A:

La aprobación por la Comisión de Doctorado reunida el 6 de Abril de 2016, de la Tesis de D. Vicent Benavet Caballer, titulada "The effectiveness of exercise interventions and the factors associated with the physiscal performance in older adults" y dirigida por los Doctores D. Juan Francisco Lisón Párraga, D. Pedro Pablo Rosado Calatayud y Dña. Eva Segura Ortíz., en la modalidad de Compendio de Publicaciones, tras el estudio de los informes de los directores de la misma y la revisión y autorización del Consejo de Departamento de Fisioterapía.

Y para que conste a los efectos oportunos, firma la presente en Moncada a seis de abril de dos mil dieciséis.

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INFORMA

Que D. Vicent Benavent Caballer, con DNI número 22578756-R, presentó la documentación al Departamento solicitando la autorización del mismo para presentar la Tesis Doctoral como compendio de publicaciones. La documentación aportada incluye un informe de los directores de Tesis, Profesores Doctores D. Juan Fco. Lisón Párraga, D. Pedro Pablo Rosado Calatayud y Dña. Eva Segura Ortí autorizando la presentación de la Tesis en esta modalidad. En el informe se indican los cuatro artículos que se pretende que formen el cuerpo de la Tesis. En 4 de ellos es primer autor y en 4 lo son sus directores de tesis. Los artículos presentados han sido publicados en

1.-"Effects of three different low-intensity exercise interventions on physical performance, muscle CSA and activities of daily living: A randomized controlled trial", índice de Impacto según el JCR 2014 de 3,485; posición 12 de 50 (Q1) en el área "GERIATRICS & GERONTOLOGY".

2.-"The effectiveness of a video-supported group-based Otago Exercise Programme on physical performance in community-dwelling older adults: A preliminary study", índice de Impacto según el JCR 2014 de 1,911; posición 16 de 64 (Q2)en el área "REHABILITATION".

3.-"Factors associated with the 6-minute Walk Test in nursing home residents and community-dwelling older adults", índice de Impacto según el JCR 2014 de 0,392; posición 61 de 64 (Q4) en el área "REHABILITATION".

4.-"Physical factors underlying the Timed "Up and Go" Test in older adults", índice de Impacto según el JCR 2014 de 1,200; posición 38 de 110 (Q2) en el área "NURSING".

El informe contiene también un resumen y conclusiones generales del trabajo realizado. La documentación incluye la renuncia expresa de D. Alejandro Sendín Magdalena, coautor de 1 de los artículos, a presentar dicho artículo como parte de su tesis doctoral.

Que, Vista la documentación aportada en la reunión del Consejo de Departamento celebrado y comprobado que cumple con los requisitos legales exigidos, se procede a dar conformidad para que se pueda realizar el depósito de la Tesis Doctoral en la modalidad de compendio de publicaciones con Mención Internacional de acuerdo con las normas que marca la Universidad.

Moncada, 05 de Abril de 2016

D. Pedro Pablo Rosado Calatayud

Director del Departamento de Fisioterapia de la Universidad CEU Cardenal Herrera.

Juan Francisco Lisón Párraga, Pedro Pablo Rosado Calatayud y Eva Segura Ortí profesores de la Universidad CEU Cardenal Herrera,

AUTORIZAN, en calidad de co-directores del doctorando **VICENT BENAVENT CABALLER**, a que presente la Tesis Doctoral titulada "THE EFFECTIVENESS OF EXERCISE INTERVENTIONS AND THE FACTORS ASSOCIATED WITH THE PHYSICAL PERFORMANCE IN OLDER ADULTS" en la línea "PROGRAMA DE DOCTORADO FISIOTERAPIA DEL DEPORTE". Esta Tesis Doctoral aporta cuatro artículos de investigación que se detallan a continuación:

I. **Benavent-Caballer V**, Rosado-Calatayud P, Segura-Ortí E, Amer-Cuenca J, Lisón JF. Effects of three different low-intensity exercise interventions on physical performance, muscle CSA and activities of daily living: A randomized controlled trial. Exp Gerontol 2014 10;58:159-165.

II. **Benavent-Caballer V**, Rosado-Calatayud P, Segura-Ortí E, Amer-Cuenca J, Lisón JF. The effectiveness of a video-supported group-based Otago Exercise Programme on physical performance in community-dwelling older adults: A preliminary study. Physiotherapy 2015 Sep 1.

III. **Benavent-Caballer V**, Lisón JF, Rosado-Calatayud P, Amer-Cuenca J, Segura-Ortí E. Factors associated with the 6-minute Walk Test in nursing home residents and community-dwelling older adults. J Phys Ther Sci 2015; Nov;27(11):3571-8.

IV. **Benavent-Caballer V**, Sendín-Magdalena A, Lisón JF, Rosado-Calatayud P, Amer-Cuenca J, Salvador-Coloma P, Segura-Ortí E. Physical factors underlying the Timed "Up and Go" Test in older adults. Geriatr Nurs 2015 Dec 17.

Los artículos se han publicado en revistas de impacto (Índice JCR) dentro de las áreas GERIATRICS & GERONTOLOGY, REHABILITATION y NURSING. La primera es **Experimental Gerontology** con un índice de impacto de **3,485** y una posición de 12 entre las 50 revistas incluidas en el área GERIATRICS & GERONTOLOGY, Q1 (JCR 2014). La segunda es **Physiotherapy** con índice de impacto de **1,911** y una posición de 16 entre las 64 revistas incluidas en el área REHABILITATION, Q2 (JCR 2014). La tercera es **The Journal of Physical Therapy Science** con un índice de impacto de **0,392** y una posición de 61 entre las 64 revistas incluidas en el área REHABILITATION, Q4 (JCR 2014). La cuarta es **Geriatric Nursing** con un índice de impacto de **1,200** y una posición de 38 entre las 110 revistas incluidas en el área NURSING, Q2 (JCR 2014). Todos nosotros somos co-autores de estos artículos y aceptamos que el doctorando utilice dichos artículos como parte integral de su tesis, además confirmamos que Vicent Benavent Caballer ha sido el investigador principal. Alejandro

Sendín Magdalena y Pablo Salvador Coloma, coautores del artículos IV renuncian expresamente a usar dicho artículo como posible parte de una futura tesis doctoral firmando el documento adjunto, como indica la normativa vigente aprobada el 7 de junio de 2011 por el Consejo de Gobierno de la Universidad CEU Cardenal Herrera.

En líneas generales, con la publicación de estos artículos se ha conseguido

- Evaluar la efectividad de la aplicación de ejercicios a baja intensidad sobre la mejora de la capacidad funcional, la sección transversal del recto femoral y la capacidad para realizar actividades básicas de la vida diaria en adultos mayores que residen en un centro geriátrico.

- Evaluar la efectividad de un programa de ejercicios *Otago Exercise Programme* realizado en formato group-based y suplementado con material audio-visual, para la mejora del equilibrio, la movilidad y capacidad funcional en adultos mayores que habitan en la comunidad.

- Investigado la contribución de una serie de factores demográficos y medidas físicas para explicar los resultados de las pruebas 6MWT y TUG en una muestra de adultos mayores que habitan en la comunidad y residen en un centro geriátrico.

Los trabajos son originales, ya que son los primeros en estudiar los efectos de la aplicación de ejercicios a baja intensidad, la aplicación de un programa de ejercicios suplementado con material audio-visual y la contribución de los factores demográficos y físicos para la explicación de la capacidad de la marcha y la movilidad en una población de avanzada edad. Los resultados serán fácilmente aplicables dentro del ámbito geriátrico y la salud pública, además de abrir futuras líneas de investigación que confirmen estos hallazgos.

Juan Fco. Lisón Párraga **Pedro Pablo Rosado Calatayud** **Eva Segura Ortí**

D. Alejandro Sendín Magdalena, con DNI 53188337-D y coautor del artículo *"Physical factors underlying the Timed "Up and Go" Test in older adults"*, publicado en Geriatric Nursing en el año 2015 **ACEPTA** que Vicent Benavent Caballer presente este trabajo en su Tesis Doctoral y **RENUNCIA** expresamente a presentarlo como parte de otra tesis doctoral.

En Moncada, 05 de Abril de 2016

Fdo.: Alejandro Sendín Magdalena

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Sin duda el doctorado ha sido uno de los caminos más apasionantes que he recorrido en mi vida. Uno llega a perder la noción del tiempo dedicado y deja de ser importante si fueron 3, 4 o 5 años. Sin embargo, de lo que si me doy cuenta al tomar perspectiva y tratar de hacer un balance de lo vivido, es del tremendo crecimiento personal y profesional que ha supuesto para mí la oportunidad de cursar los estudios de doctorado. Tengo la certeza de que no he recibido nunca una formación que me aportara tanto y tan bueno.

Desde el primer momento, me di cuenta de que este camino hay que recorrerlo en compañía. Es cierto que la mayor parte del trabajo lo tiene que hacer el doctorando y que para alcanzar el grado de doctor no existen los atajos, por tanto el faro que te guía es fundamental para no perderse en un inmenso mar de conocimiento. El consejo, apoyo, sabiduría e incluso personalidad de aquellos en los que he confiado durante este tiempo ha sido fundamental para guiarme hasta el final.

El primero de los agradecimientos es para mis directores que han sabido guiarme, hacerme crecer, sacar lo mejor de mí mientras me mostraban el valor del esfuerzo, y lo más destacable, me han hecho disfrutar del camino como nunca podría haberme imaginado. Además, en todo momento he sentido su apoyo, motivación y empuje, apagando cualquier posible desencanto. Pero no todo ha sido tiempo, apoyo y dedicación, esta tesis no hubiera avanzado sin sus conocimientos y experiencias compartidas. Nunca pidieron nada a cambio, tan solo han sido coherentes con su espíritu investigador, docente y tremendamente humano. Gracias a su actitud, me han hecho sentir profundamente afortunado, y dudo que para un doctorando exista mejor energía para completar una tesis doctoral. Es por estas razones, y por otras muchas que no citaré aun teniéndolas muy presentes, que mis tutores Dr. D. Juan Francisco Lisón Párraga, Dr. D. Pedro Pablo Rosado Calatayud y Dra. Dña. Eva Segura Ortí han de

ser los primeros en recibir mis más sinceros agradecimientos, además mostrarles plena disposición para seguir aprendiendo de ellos.

En segundo lugar, tengo que destacar que esta tesis es el resultado de un trabajo en grupo, sin el que nunca habría completado las sesiones de registros, ni perfilado el diseño de la estructura metodológica, ni pulido la redacción y revisión de los textos, ni resuelto las dudas durante los análisis estadísticos. Soy muy consciente de que estoy escribiendo estas líneas gracias al trabajo de un grupo. Un grupo que durante estos años de trabajo se ha convertido en algo más, en un equipo. Este equipo presenta una singularidad que lo hace especial, muchos de sus integrantes no llegan a conocerse entre ellos, pero sin saberlo conforman una maquinaria de trabajo ejemplar. El Dr. Juan José Amer, y su inestimable contribución durante las sesiones de registro, no conoce a Birju Hassomal y sus fantásticas clases de conversación en inglés. De la misma forma, Birju no conoce a Carmen Puerto Rentero y su valía, apoyo incondicional y amistad que trasciende más allá de lo profesional. Carmen tampoco conoce al Dr. Miguel Ángel Buil y su paciencia y pericia con el ecógrafo. Así como el Dr. Buil no conoce a los directores de los centros sociales y residencias geriátricas que nos abrieron sus puertas, permitiéndonos realizar las intervenciones de los estudios. De esta forma, podría extenderme demostrando la singularidad de este grupo. Sin embargo, existe un punto en común a todos los miembros de este equipo que los convierte en fundamentales: todos realizaron una labor sin la cual esta tesis no hubiera sido posible.

En tercer lugar están los miembros de mi familia, a los que he tenido muy presentes gracias a su apoyo durante estos años. De todos ellos, quisiera destacar dos personas que merecen especialmente estas líneas. La primera es Katia Esteve. Katia es sin duda la mejor compañera de viaje que uno pueda tener. Soy de la opinión de que a todos, de una manera u otra, la fortuna nos sonríe en algún momento de la vida. Mi suerte es Katia, quien me da hambre de vida, me hace mejor persona y a la que siento como alma gemela en todo momento. Durante estos años he vivido auténticos momentos de plenitud durante los que siempre ha estado a mi lado. Sin duda lo que

Katia representa para mí la convierte en alguien profundamente especial, sin la que hubiera sido imposible llegar hasta aquí. La segunda es Esperanza, mi madre, quien siempre se ha preocupado por darme lo mejor que me podía dar y hacerlo de la mejor manera posible, en forma de tiempo y dedicación. Quiero darle las gracias por haberme inculcado su espíritu de lucha y el valor de las cosas, por ser un apoyo incondicional en todo momento, y por demostrarme durante toda una vida con su ejemplo, que lo que realmente importa es lo que uno lleva dentro. Sin todo esto seguramente yo no sería quién soy y esta tesis tampoco sería la que es.

A todo este maravilloso equipo de personas que me ha permitido llegar hasta aquí, gracias de todo corazón.

“I think your age is just a number. It's not your birthday, it's how you age which makes the difference. It's your attitude to all the things that happen in your life that plays the biggest part”

Olga Kotelko at the age of 95 with over 30 world records and 750 gold medals to her name (2014).

LIST OF ABBREVIATIONS

ADL	Activities of Daily Living.
BBS	Berg Balance Scale.
BMI	Body Mass Index.
CD	Community-Dwelling Group.
CG	Control Group.
CT	Computer Tomography.
CMI	Clinically Meaningful Improvement.
CSA	Cross-Sectional Area.
CI	Confidence Interval.
HRQOL	Health-Related Quality of Life
ICC	Intraclass Correlation Coefficient.
IG	Intervention Group.
MR	Magnetic Resonance.
NH	Nursing Home Group.
NMES	Neuromuscular Electrical Stimulation.
NMES+	Neuromuscular Electrical Stimulation Superimposed Onto Voluntary Contractions.
OEP	Otago Exercise Programme.
OLS	One-leg Stand.
PRT	Progressive Resistance Training.
SD	Standard Deviation.
SPPB	Short Physical Performance Battery.
STS-5	Repeated Chair Stand Tests.
TUG	Timed "*Up and Go*" Test.
VC	Volitional Muscle Contraction
X	Mean.
1RM	One Maximal Repetition.
6MWT	6-min Walk Test.

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APPENDIX

Aging is a wonderful and unique experience that every human being shares but no one fully understands. Describing it as wonderful does not suggest that aging is only full of good things, but it's exceptional and remarkable (Ashford et al., 2005). The Aging process occurs not only in later parts of an individual's life. It begins at the onset of life itself and continues along the continuum of lifespan representing the changes in the organism and not the pathology (Bower and Atwood, 2004). Beyond affecting every individual, the aging process influences the characteristics of the community as a group changing the structure of the world population (Christensen et al., 2009).

A common starting point to understand the aging process has been to categorize individuals depending on the number of years lived since birth. This chronological criterion known as the chronological age has been commonly set at 65 yr. for the category of "older adult" (Nelson et al., 2007). Even though chronological age reflects the length of time, it's an independent measure from the physiological, psychological or social factors involved in the aging process. Additionally, chronological age does not differentiate between the "state" of individuals from the same age, and does not report any information about how a person is doing as he or she grows older (Borkan et al., 1980). It´s clear that we do not age at the same rate and do not experience the same changes with the passage of time. The uniqueness of the individual is the norm when we grow older (White et al., 2013; Guiding principles for the care of older adults with multimorbidity, 2012). Therefore, understanding the aging process as a chronological manner, focusing on the calendar time remains incomplete and needs to be supplemented with additional measures designed to differentiate between individuals of the same age (Bautmans et al., 2004).

However, the use of a chronological age criterion has been useful for demographic studies in order to recognize the demographical changes occurred along the past decades, and to analyse the future projections of size and composition of populations. Current estimates report that the proportion of older adults in Western European countries and the United States of America is rapidly growing, and is projected to double in the next 30 years (Christensen et al., 2009; Caffrey et al., 2011). In Spain, a country with 46.5 million populations, a proportion of 18.2% (8.4 million) of the total population is aged ≥65 yr. (INE, 2014). This group of population is projected to reach a rate of 24.9% (an increase of 2.9 million of older adult's ≥65 yr.) of the total population in 2029 (INE, 2014). Similarly, the Spain neighbouring countries, as well as United States of America, will experience an identical projection in the next decades (INSEE, 2010; FSO, 2010; ONS, 2012; EC, 2012; USCB, 2014; USCB, 2015).

- France (64 million population 2014) (INSEE, 2010).
    - 18.2% (≥65 yr. 2014).
    - 22.4% (≥65 yr. 2030).
- Germany (81 million population in 2010) (FSO, 2010).
    - 20% (≥65 yr. 2010).
    - 29% (≥65 yr. 2030).
- United Kingdom (63 million population in 2010) (ONS, 2012).
    - 17% (≥65 yr. 2010).
    - 23% (≥65 yr. 2035).
- European Union (506 million population in 2014) (EC, 2012).
    - 18% (≥65 yr. 2012).
    - 30% (≥65 yr. 2060).
- United States of America (319 million population 2014) (USCB, 2014; USCB, 2015).
    - 15% (≥65 yr. 2014).
    - 21% (≥65 yr. 2030).

On the other hand, and setting aside the demographic estimates, when analysing the characteristics of this group of population in the present context, one of the most important characteristics observed is the heterogeneity manifested in its demographical structure according to their accommodation. More than 70% of older adults live in urban areas (USCB, 2011; Grimley et al., 2003), and this proportion of older adults is mainly divided in two groups; community-dwelling older adults and individuals living in geriatric nursing homes. A remarkable number of older adults between 65 to 75 yr., with enough level of independence to perform most of the basic and instrumental activities of the daily living, live alone in their own houses and dwell in the community. However, this trend reverses when individuals are aged around 80 to 85 yr., and the proportion of older adults living in geriatric nursing homes increases (Grimley et al., 2003). This observation is mainly explained as a result of the age-related decline of the health condition and the increase of the functional limitations, which may result in the need of institutionalization or long-term care (Benavent-Caballer et al., 2015). As an example, 11.8% and 18.1% of the Spanish men and women respectively aged ≥90 yr. live in geriatric nursing homes, while 1.8% of women and 2.1% of men aged 65 to 69 yr. are living in institutions (INE, 2013). Hence, the level of institutionalization is strongly associated with advanced age, rising as a correlation of demographical ageing and the increase of people living to the oldest ages. Additionally, levels of institutionalization are higher for women than for men, an observation consistent with the fact that women in institutions are far more likely than men to be widowed (INE, 2013).

According to physical characteristics, older adults can be categorized not just according to their age or accommodation, but from healthy and active to sick and frail, which proves the more-heterogeneous and individual variability of the older adult's population (Serra-Rexach et al., 2011). As previously reported, the aging process is not a disease, it´s based on the changes that occur with the passage of time without including the changes due to a disease process. However, evidence reports that the aging process affects all of our systems (including cardiovascular, respiratory or the muscular-skeletal system), resulting in a loss of lung capacity, a reduction in the aerobic endurance, a decrease in muscle mass and a reduction in muscle strength as we grow older (Watsford et al., 2007; Janssens et al., 1999; Daubney and Culham., 1999; Lindle et al., 1997). The magnitude of decline in each system may differ between individuals, but certain biological and functional changes are recognized as transitional markers of the human ageing process.

One of the main changes associated to the aging process is the profound change in body composition. Changes could start from the 3th decade of life and contribute to a progressive increase in the total body fat mass, a gradual and steady reduction of the muscle cross-sectional area (CSA) (Lexell, 1995; Ikezoe et al., 2011), that accelerates after the 6th decade of life (Reeves et al., 2006; Skelton et al., 1994). This muscle CSA loss amounts approximately to 25-40% over the lifespan (Klitgaard et al., 1990; Lexell and Taylor, 1988). Sarcopenia is the term generally used to describe the changes that occur within skeletal muscle and peripheral nervous system innervation, contributing to a muscle atrophy and weakness. Both changes are major contributors to the loss of functional performance, independence, and the increase of frailty in older adults (Roubenoff and Hughes, 2000; Roubenoff, 2001; Doherty, 2003).

Physiological mechanisms to explain the progressive loss in the muscle CSA have been proposed. Evidence reveals that muscle CSA loss results as a reflection of motor units (MU) reorganization (Doherty and Brown, 1993) and a muscle fiber atrophy (Nilwik et al., 2013). MU reorganization causes a progressively reduction in the number of MUs innervating the muscle. As a consequence, there is a selective denervation and atrophy of both muscle fibers (especially type II fibers) (Lexell and Taylor, 1988; Nilwik et al., 2013). Denervation and atrophy of muscle fibers is followed by a reinnervation by the juxtaposed innervated MU, leading to an increase in the MUs size and the number of muscle fibers innervated by a single MU (Wang et al., 1999). Due to an increase in the number of fibers per MU, a progressive decrease in the ability to activate the existing muscle mass occurs (Doherty and Brown, 1993; Ling et al., 2009). Consequently, the number of muscle fibers and its size decreases, as well as the relative area occupied by both muscle fibers (predominantly of type II fibers), with the consequent loss in the muscle CSA (Nilwik et al., 2013). The relative maintenance in the type I muscle fibers could be explained according to the Henneman's "*size principle*" or pattern of MU recruitment. This principle shows that during voluntary contractions, MUs are recruited in an orderly fashion from slow (type I fibers) to fast (type II fibers) in relation to the stimulus intensity (Henneman et al., 1965). Because of the MUs reorganization observed, type I fibers will remain in relatively regular use, whereas the type II fibers will rarely be recruited and therefore are subject to disuse and atrophy (Nilwik et al., 2013).

Differences in the mechanical properties among muscle fibers types, the muscle CSA loss, and the decrease in the ability to activate the existing muscle mass, represent the major factors that contribute to the muscle weakness (Frontera et al., 2000; Frontera et al., 1991; Hugbes et al., 2001; Newman et al., 2003). On the other hand, strength represents the amount of force that a muscle can generate during a single maximal contraction. Strength loss begins during the fifth decade of life, and continues at an annual rate of 1 to 2% loss (Skelton et al., 1994; Vandervoort, 2002). Similarly to the muscle CSA decrease, the average in strength loss along the lifespan has been described to be between 20 to 40% (Larsson et al., 1979; Murray et al., 1985; Murray et al., 1980; Young et al., 1985) even in healthy individuals (Doherty and Brown, 2003; Young et al., 1985), and similarly for both genders (Doherty and Brown, 2003; Goodpaster et al., 2006). This rate is not linear, it progressively increases late in life to reach a 50% loss or more in individuals in their ninth decade and beyond (Murray et al., 1985; Murray et al., 1980). Additionally, strength loss affects to a greater extent the lower-limb muscles (Beneka et al., 2005; Rosenberg, 1997; Janssen et al., 2000) reaching up to a 3% loss per year even in healthy older adults (Ikezoe et al., 2011; Goodpaster et al., 2006). Strength loss is exacerbated by baseline weakness, sedentary behaviour (Doherty and Brown, 2003; Park et al., 2010; Ikezoe et al., 2011) or the reduction of physical activity (Sandler et al., 1991; Hunter et al., 2004). Furthermore, strength decline has reported to be an important determinant in the loss of functional performance capacity, and a key component in the maintenance of the personal independence (Rantanen et al., 2002; Fiatarone et al., 1990). As we grow older, the ability to perform activities of daily living (ADL) may become difficult (Brill et al., 2000; Lauretani et al., 2003; Salem et al., 2000), especially those activities related with the lower-limbs (Visser et al., 2002). Lower-limb muscle weakness has been related with difficulties in performing basic ADL such as walking, rising from a chair or getting out of bed or keeping balance, as well as increments in the risk of falling (Guralnik et al., 1995; Janssen et al., 2002; Janssen et al., 2004; Moreland et al., 2004).

Older adults may be performing ADL while generating forces closer to their maximal capacity. Hence, there is a minimum criteria of physical functioning (considering strength, range of motion, endurance or balance) required to perform basic daily tasks, defined as the *Functional Performance Threshold* (Thompson, 2000). Once an individual has a maximal physical functioning capacity closer to that threshold, it needs only a small further decline to go from being "just able" to being "just unable" to perform that activity. A small decline in muscle function in individuals just above this threshold means that independence is lost, and assistance is needed when performing basic ADL. In healthy older adults, the consequence of a decrement in capacity are unlikely to be seen in performances of easy tasks, but are likely to be seen in performances of demanding tasks, accompanied perhaps by compensatory changes in performance strategies.

Treating or reversing age-related decline by preserving health-related quality of life (HRQOL) and life expectancy, is an essential public health goal for the 21st century (Baker et al., 2007). During the past few decades, a substantial number of studies have investigated different types of exercise intervention focusing on the maintenance and improvement of the functional performance and health-related quality of life in older adult's population (Liu and Latham, 2009; Kalapotharakos et al., 2005; Cyarto et al., 2008; McAuley et al., 2013; Gillespie et al., 2012; Sherrington et al., 2008; Chandler and Hadley, 1996). Consequently, it has been widely demonstrated that regular exercise and physical activity provide substantial health benefits and attenuate the age-related consequences, and that exercise may well be the single most important thing we can do to keep ourselves healthy as we age (Peterson et al., 2010; Chodzko-Zajko et al., 2009; Teri et al., 2001).

The most frequently approach to exercise has been the Progressive Resistance Training (PRT). Participants involved in those interventions, perform muscle contractions against an external force that is progressively increased as strength increases (Latham et al., 2004; Hunter et al., 2004). Two commonly used techniques that have demonstrated to be effective for reducing muscle weakness in healthy and impaired older adults are; volitional muscle contractions (VC), and Neuromuscular electrical stimulation (NMES). NMES consists in the application of an electric current using surface electrodes on weakened but otherwise normally innervated muscles, for improving muscle strength by generating an electrically evoked muscle contraction (Maffiuletti, 2010; Vanderthommen and Duchateau, 2007). Both techniques, VC and NMES, progressively overload and stimulate muscles with a moderate-to-high intensity, given that exercise intensity is a determining factor for achieving positive results (Latham et al., 2004; Liu and Latham, 2009; Maffiuletti, 2010). The higher the muscle overload intensity, the greater the muscle-size and strength gains (Hunter et al., 2004; Peterson et al., 2010); likewise, the higher the NMES intensity, the greater the muscle size and strength gains (Maffiuletti, 2010) (Miller and Thepaut-Mathieu, 1993). However, given the heterogeneity and individual variability in terms of the health status and physical function levels represented in the older adults' population, care and individual supervision may be needed to reduce orthopaedic injury risks and adverse effects, particularly in frail or recently ill individuals (Pollock et al., 1991; Vincent et al., 2002).

Additionally, a substantial limiting factor for the use of high intensity NMES is the discomfort associated with peripheral stimulation (Maffiuletti, 2010; Stevens-Lapsley et al., 2012). Volitional (Galvao and Taaffe, 2005; Kalapotharakos et al., 2005; Taaffe et al., 1996; Vincent et al., 2002) and low-intensity electrically evoked contractions (Takano et al., 2010) have proved to be a safe alternative to high-intensity exercises, showing positive results in muscle size and strength gains in older adults. Indeed, low-intensity exercises could be an attractive alternative and a better recommendation for physical activity for the elderly, and exercise participation and adherence might be improved, muscle soreness minimized, and injury rates reduced (Galvao and Taaffe, 2005; Vincent et al., 2002). However, to the best of our knowledge, no study has been conducted to compare the efficacy of volitional contractions, NMES evoked contractions, and NMES superimposed onto voluntary contractions (NMES+) using a low intensity (40% of 1RM) exercise to improve muscle CSA, physical performance and the capacity to perform daily tasks in older adults.

On the other hand, a different approach to exercise for reducing muscle weakness and increasing physical performance in healthy and impaired older adults are the multimodal exercise programs. Recent exercise and physical activity guidelines for older adults stress the importance of using multi-modal exercise programs, which should include strengthening, balance, and cardiovascular exercises (Cress et al., 2005; Chodzko-Zajko et al., 2009). The *Otago Exercise Programme* (OEP) incorporates all these suggested aspects.

The OEP consists of progressive-resistance strength exercises, balance exercises related to everyday activities, and aerobic exercises supplemented with walking periods (Gardner et al., 2001). Commonly, it has been conducted at the patient´s homes. Its effectiveness has been demonstrated by improved muscle strength, functional balance and physical performance in older adults (Campbell et al., 1997; Robertson et al., 2002). Recently, the group-based modality has been proved to be as effective as the home-based one (Kyrdalen et al., 2013), and it has been recommended for use in conjunction with other group activities (Gardner et al., 2001). Incorporating the use of video materials in group-based OEP intervention could improve participants understanding of the exercises, and their physical performance, by offering accurate visual guidance. In addition, verbal instruction and music could be motivational for the participants (Vestergaard et al., 2008). Furthermore, a group-based program may be a good recommendation because it provides an opportunity for social interaction during the training sessions. However, to the best of our knowledge, no study has been conducted using video to support a group-based OEP intervention in the older adult´s population.

An important methodological aspect when defining intervention as the OEP or exercise programs based on NMES, NMES+ and VC in older adults, is the choice of the measures or tests to use during the assessment of the participants. The selection of those measures should be based on how well the purpose of the given measures matches the specific capacity that needs to be assessed in the sample of the study (Steffen et al., 2002). Additionally, the interpretation of the measures scores and its implications in the related physical performance capacities in older adult's populations needs to be clearly defined.

The walking ability has demonstrated important implications in the preservation of the function and independence (Tinetti et al., 1995), and to be a key component of the HRQOL (Guralnik et al., 1989). Different measures evaluate the walking ability in older adults focusing on the distance walked (Rikli and Jones, 1998), the gait speed (Peters et al., 2013) or the functional gait (Shumway-Cook et al., 1997). One of those measures is the 6-minute Walk Test (6MWT), a quick and inexpensive performance-based measure widely used in exercise rehabilitation (Alison et al., 2012) and clinical research (Lord and Menz, 2002), both in healthy (Troosters et al., 1999; Camarri et al., 2006; Benavent-Caballer et al., 2014) and impaired (Eng et al., 2002; Mossberg, 2003; Savci et al., 2005; Cahalin et al., 1996) older adults. Originally developed by Butland *et al.* in 1982 (Butland et al., 1982), the 6MWT measures the total distance walked during a 6-minute period (Rikli and Jones, 1998). The test has established a good reliability (Kervio et al., 2003), and to be a valid measure for overall physical functional performance (Rikli and Jones, 1998) and exercise capacity, at levels corresponding to efforts commonly performed during daily tasks (Bautmans et al., 2004). It has been reported that the performance of the 6MWT is determined by a range of factors including age, gender, height and weight (Troosters et al., 1999; Enright et al., 2003). Additionally, correlations between the 6MWT, mobility-related measures and physical measures have been found in community-dwelling older adults and nursing homes residents (Duncan et al., 1993; Harada et al., 1999; Lord and Menz, 2002).

Another performance-based test that has been developed to demonstrate sensitivity to a therapeutic intervention or as screening tools to identify older adults at risk of functional decline (Donoghue et al., 2014) is the Timed *"Up and Go"* Test (TUG) (Podsiadlo and Richardson, 1991). The TUG is a quick measure of mobility, extensively studied in both impaired (Matinolli et al., 2009; Swanenburg et al., 2014) and in healthy older adults (Benavent-Caballer et al., 2014; Storer et al.,W 2008) that include balance and gait manoeuvres used in everyday life, as it has been recommended when studying physical mobility in older adults (Podsiadlo and Richardson, 1991). Additionally, the TUG has demonstrated a high reliability (ICC=.98) and validity supported by studies among healthy older adults (Podsiadlo and Richardson, 1991; Shumway-Cook et al., 2000; Hughes et al., 1998). During the test, the subject is observed and timed while performing different subtasks including transitions, straight-line walking, and turning (Mirelman et al., 2014). The TUG differs from other tests in that it measures mobility as a continuous entity (over time), and not as the sum of the scores of its subtasks. Additionally, the TUG has been demonstrated to predict health decline and disability in the activities of daily living (Wennie Huang et al., 2010). However, to the best of our knowledge, it has not been made clear whether physical factors, such as muscle strength (STS-5; Repeated Chair Stand Test), balance (BBS; Berg balance scale, OLS; One-leg Stand Test), knee extension strength and muscle CSA may explain the TUG performance.

These observations suggest that the performance of the 6MWT and the TUG may be influenced by different demographic and physical measures. However, to the best of our knowledge, it remains unclear which are the factors that better explain the 6MWT and the TUG performance in older adult's populations. It seems important to identify the physical function measures that better explain the walking capacity and the mobility, so that therapists could include them in the assessment protocol of the aged population and therefore design the most appropriate interventions aimed to mitigate the walking and mobility declined associated with age.

Description of the quality of journals according to the impact factor (JCR).

Effects of three different low-intensity exercise interventions on muscle CSA, physical performance and activities of daily living: A randomized controlled trial.

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Rank in Category: EXPERIMENTAL GERONTOLOGY

Journal Ranking

For **2014**, the journal **EXPERIMENTAL GERONTOLOGY** has an Impact Factor of **3.485**.

This table shows the ranking of this journal in its subject categories based on Impact Factor.

Category Name	Total Journals in Category	Journal Rank in Category	Quartile in Category
GERIATRICS & GERONTOLOGY	50	12	Q1

The effectiveness of a video-supported group-based Otago Exercise Programme on physical performance in community-dwelling older adults: A preliminary study.

V. Benavent-Caballer, P. Rosado-Calatayud, E. Segura-Ortí, J.J. Amer-Cuenca, J.F. Lisón

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Journal Ranking

For **2014**, the journal **Physiotherapy** has an Impact Factor of **1.911**.

This table shows the ranking of this journal in its subject categories based on Impact Factor.

Category Name	Total Journals in Category	Journal Rank in Category	Quartile in Category
REHABILITATION	64	16	Q2

Factors associated with the 6-minute Walk Test in nursing home residents and community-dwelling older adults.

V. Benavent-Caballer, J.F. Lisón, P. Rosado-Calatayud, J.J. Amer-Cuenca, E. Segura-Ortí

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Rank in Category: Journal of Physical Therapy Science

Journal Ranking

For **2014**, the journal **Journal of Physical Therapy Science** has an Impact Factor of **0.392**.

This table shows the ranking of this journal in its subject categories based on Impact Factor.

Category Name	Total Journals in Category	Journal Rank in Category	Quartile in Category
REHABILITATION	64	61	Q4

Physical factors underlying the Timed "*Up and Go*" test in older adults.

V. Benavent-Caballer, A. Sendín-Magdalena, J.F. Lisón, P. Rosado-Calatayud, J.J. Amer-Cuenca, P. Salvador-Coloma, E. Segura-Ortí

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Rank in Category: GERIATRIC NURSING

Journal Ranking

For **2014**, the journal **GERIATRIC NURSING** has an Impact Factor of **1.200**.

This table shows the ranking of this journal in its subject categories based on Impact Factor.

Category Name	Total Journals in Category	Journal Rank in Category	Quartile in Category
GERIATRICS & GERONTOLOGY	50	39	Q4
NURSING	111	38	Q2

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Objectives

We sought to develop two relatively short-term exercise interventions (16 weeks period), safe, accessible, and easy to follow, that would help older adults living in geriatric nursing homes and dwelling in the community to gradually reduce the age-related decline in their physical condition. Additionally we conducted two analyses of the demographic factors and physical measures that may explain the walking ability and the mobility in older adults living in a geriatric nursing home or dwelling in the community.

The purposes of the present thesis are divided in three main objectives. The first objective was to evaluate the effects of three different resistance training programs (VC, NMES, and NMES+), performed at low intensity, on the physical performance, muscle CSA and the capacity to perform daily tasks in healthy older adults. All intervention groups targeted major knee extension muscles over a 16-week period in men and women aged 75 and older living at a geriatric nursing home. It was hypothesized that all exercise groups would significantly improve muscle CSA, physical performance and the capacity to perform daily tasks from a short-term perspective, and that the NMES+ program would show the larger improvements. The second objective was to evaluate the effects of a video-supported group-based OEP intervention over a 16-week period, on the balance, mobility, physical performance and aerobic endurance in a sample of community-dwelling adults aged 65 or older. Finally, the third objective was to investigate the relative contributions and extent to which a range of demographic factors and physical measures explain the results on the 6MWT and TUG performance in a sample of older adults dwelling in the community and living in a geriatric nursing home.

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General Goals

Effects of three different low-intensity exercise interventions on muscle CSA, physical performance and activities of daily living: A randomized controlled trial.

- Evaluate the short-term effects of three different resistance training programs (Voluntary contractions, Neuromuscular electrical stimulation, and Neuromuscular electrical stimulation superimposed onto voluntary contractions), performed at low intensity, on the physical performance, muscle CSA and the capacity to perform daily tasks in a sample of healthy older adults living in a geriatric nursing home.

The effectiveness of a video-supported group-based Otago Exercise Programme on physical performance in community-dwelling older adults: A preliminary study.

- Evaluate the effects of a group-based Otago Exercise Programme supported by video on the physical performance and the capacity to perform daily tasks in a sample of healthy community-dwelling older adults.

Factors associated with the 6-minute Walk Test in nursing home residents and community-dwelling older adults.

- Investigate the relative contributions and extent to which a range of demographic factors and physical measures may explain the performance on the 6MWT in a sample of healthy older adults.
- Compare the factors associated with the 6MWT between older adults dwelling in the community and residents in a geriatric nursing home.

Physical factors underlying the Timed "*Up and Go*" Test in older adults.

- Investigate a range of selected physical measures for their relative contributions and extent to which they may explain the performance of the TUG in a sample of healthy community-dwelling older adults and residents in a geriatric nursing home.

Studies Design and Studies Populations

Studies Design

All studies (ClinicalTrials.gov ID:NCT01086592) (ClincicalTrials.gov ID:NCT02218411) were designed to adhere to the recommendations of the *Consolidated Standards of Reporting Trials Statements* (Altman et al., 2001). The cross-sectional studies and the intervention studies designs, protocols and informed-consents procedures were approved by the Bioethics and Clinical Research Committee of CEU-Cardenal Herrera University. All studies followed the ethical guidelines of the Declaration of Helsinki. All participants provided written informed-consent statement. Participants included in the two interventional studies were randomly assigned to the intervention groups or to the control groups after baseline assessment. All participants were assessed at baseline, additionally participants taking part on the interventional studies were assessed at the end of a 4-month intervention, by the same independent assessors.

Studies populations

The sample of these studies consisted in healthy older adults aged 65 years or older living in a geriatric nursing home (n=117) and dwelling in the community (n=156), in the city of Valencia, Spain. The two hundred and seventy-three potential participants were voluntarily recruited through advertisements in the bulletin boards of the different local community centres and the geriatric nursing home, as well as through presentations by researchers in both centres. The sample recruitment started in September 2012 and was completed in May 2015. A physical therapist, with 27 years of clinical experience, conducted an individual interview where all potential participants were screened for inclusion. Additionally, a medical doctor with 24 years of clinical experience determined possible unstable cardiovascular diseases, neurological disorders or mobility limitations that could represent a risk for the participants during the assessment and exercise sessions. All participants received fully explained information of the proposed studies and its objectives. Participants who 1) were aged ≥65 years; 2) were able to ambulate independently without walking aids; 3) had no severe medical contraindications to performing physical activities; 4) were able to communicate and follow simple commands; 6) had self-reported visual and auditory capacities to follow the measures procedure; and 7) provided a signed informed-consent statement, were included in the study. Participants who 1) were unable to ambulate independently; 2) had a Mini-mental State Examination score of <24 (Folstein et al., 1975); 3) had a Barthel Index score <80 (Wade and Collin, 1988); 4) had an unstable cardiovascular disease or a neurological disorder that could compromise them to perform physical activities; 5) had reported moderate to severe pain while walking; and 6) had upper- or lower-extremity fracture in the past year, were excluded. Participants how met the inclusion criteria completed a baseline assessment and were enrolled in the intervention or the cross-sectional studies.

Randomization and blinding

After the baseline assessments, participants in the interventional studies were randomly allocated to one of the intervention groups or to the control group using computer-generated random numbers. The group allocation was concealed to the researchers. The assessors who collected the data were blinded to the group allocation; however, it was not possible to conceal the group assignment from the co-investigators involved in the training procedures.

Measures

The 6-minute Walk Test

The 6-minute Walk Test (6MWT) evaluates the maximum distance that can be walked during a 6 minute period along a 30-m long corridor (Rikli and Jones, 1999; Rikli and Jones, 1998). The test is a modification of the 12-minute Walk-Run Test originally developed by Butland *et al*. in 1982 (Butland et al., 1982). The 6-minute Walk Test has been used to evaluate physical endurance in patients with various medical conditions, both impaired and healthy older adults. An adequate level of aerobic endurance during aging is necessary in order to perform many everyday activities such as walking, shopping, or performing recreational or sports activities.

Equipment: 40-m long corridor, score sheet, stopwatch, long measuring tape, plastic cones, masking tape (or some other type of marker), chairs and a blood pressure monitor.

Set-up: Two plastic cones delimited the corridor and every two-meter-long, pieces of tape indicated a 2-m interval. Behind the cones a 2-m long area allowed the participants to turn around the cone safely. The walking area was well lit and level surface, with a non-slippery floor (Figure 1).

Protocol: A physiotherapist with specific experience administered and supervised the test following the published guidelines (Rikli and Jones, 1999; Rikli and Jones, 1998). Before starting the test, the heart rate and blood pressure were measured in order to ensure the participants were not above the safety limits on the heart rate and blood pressure. The participants stood in front of the starting point and on the signal "*Go*", the participants were instructed to walk along the walkway path as fast as possible (running was not allow), as many times as they can. When needed, participants stopped and rested (on the provided chairs alongside the walkway path), and if possible resumed walking. As it has been reported, the 6MWT is a measure for aerobic capacity and is conducted as submaximal measure of physical endurance (Rikli and Jones, 1998). Because performing the test without the possibility of stopping and resting may be too strenuous for many older adults, participants were allowed to stop and rest if needed. Statistics indicate that 40% of community-dwelling adults over 75 have difficulty walking even ¼ mile (Select Committee on Aging, 1992). The assessor walked alongside the corridor behind the participants to ensure their safety. Standardised verbal encouragement at minute 1, 3 and 5 ("*you are doing well*" and "*keep up the good work*") were called out. The end of the test was determined after completing the 6 minute period or in case of chest pain, dizziness or dyspnea was reported by the participants.

Safety: Chairs should were disposed at several points alongside de walking path, to help participants in case they needed to stop and rest. At the end of the test participants slowly walked around for a while (about a minute or two) in order to cool down.

Scoring: The total distance covered in 6 minutes in meters to the nearest 2-m segment was the final score of the test.

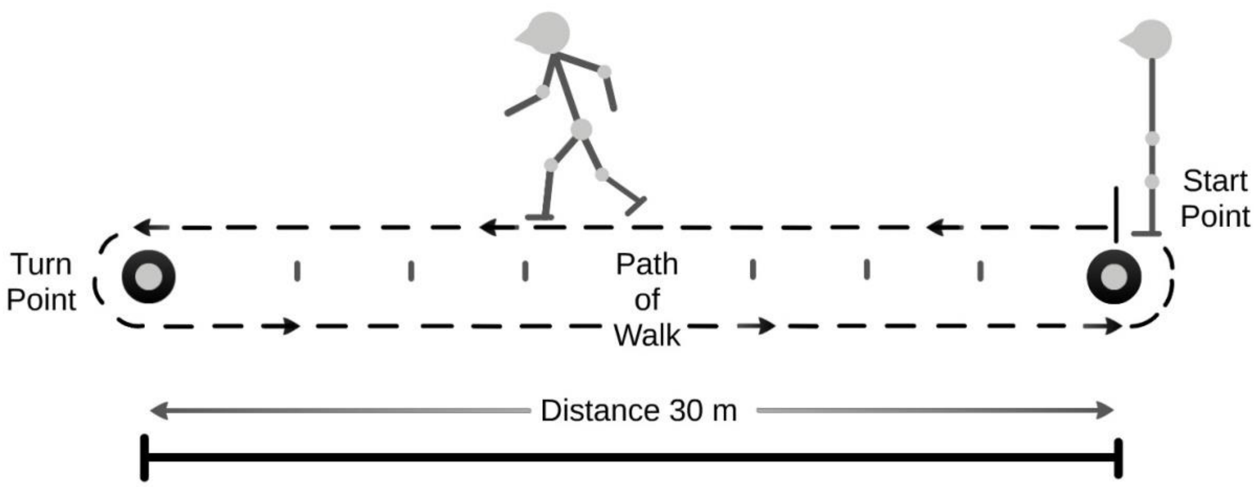

Figure 1. *Schematic illustration of the 6-minute Walk Test.*

Berg Balance Scale

The Berg Balance Scale (BBS) is a performance-based well-known balance measurement tool (Berg et al., 1992). It was originally designed to measure balance in the elderly, and has been used in both healthy and impaired older adults. The test consists of 14 tasks common in everyday life with varied difficulty of balance (5 static and 9 dynamic) (Figure 2).

Equipment: Score sheet, stopwatch, two standard chairs (one with armrest and one without armrest), 30cm ruler, three objects (a shoe, a watch and a book) and a step.

Set-up: Because the test measures the balance ability, the testing area was well lit with a non-slippery floor and level surface. Additionally, the testing area was large enough to perform all tasks comfortably without any disturbance. In one side of the testing area the two chairs were placed together with the back rest touching the wall to ensure the safety during the performance, and in the opposite side of the testing area a step was placed touching the wall.

Protocol: An experienced physiotherapist administered the test following the published guidelines (Berg et al., 1992). The test consisted of 14 tasks quantified on a 5-point scale. The items evaluated the ability to keep in balance by increasing difficulty tasks such as; keep stand for a time, keep stand with eye closed, stand keeping a side-by-side position or tandem position or keep standing on one leg. Additional items evaluated the ability to perform specific tasks of the daily living related with balance such as; transfer between chairs, reaching forward, turning round, pick up an object from the floor or place feet alternatively on the step.

Safety: The assessor stood near the participants to ensure their safety and avoid falls.

Scoring: Each task was graded on a 5-point scale of 0 (“unable to perform” or “need assistance”) to 4 (“able to perform independently”). Scoring was based on the ability to perform the task independently, the distance requirements, or the time taken to complete the task. At the end of the test, individual task scores were summed for a potential maximal score of 56 points (higher scores represented better performance).

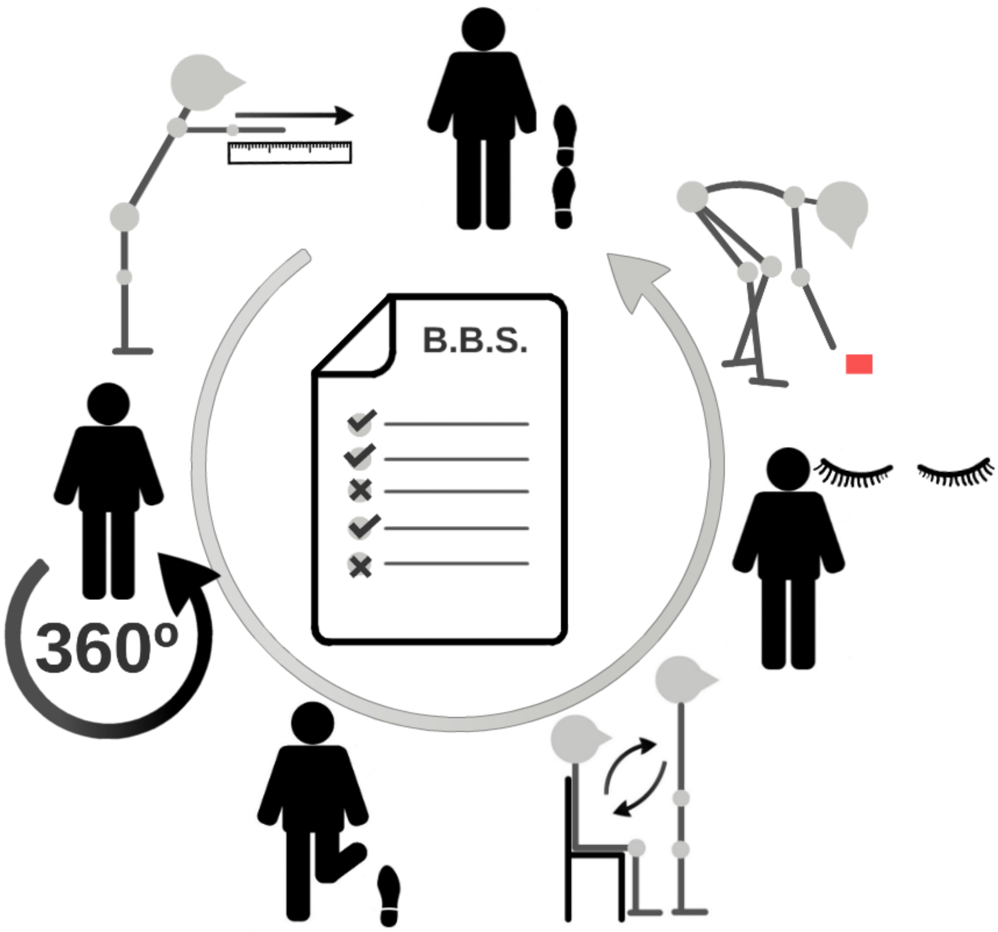

Figure 2. *Schematic illustration representing some of the 14 tasks present in the Berg Balance Scale*.

Timed "*Up and Go*" Test

The Timed "*Up and Go*" Test (TUG) is a measure of mobility, which assesses the time needed to rise from a chair, walk 3 m as quickly as possible to reach a plastic cone, turn around the cone, return to the chair, and sit down again (Podsiadlo and Richardson, 1991). It was originally developed by Mathias *et al.* as "the Get-up and Go Test" (Mathias et al., 1986) as a clinical measure of balance in elderly people, and further modified by Podsiadlo *et al.* in 1991 and proposed as a short test of basic mobility skills. The assessment of physical mobility is an essential component of the geriatric assessment. For independent mobility older adults should be able to perform basic mobility skills such as getting in and out of a bed and chair, on and off a toilet or walking a few feet. Therefore, the TUG is a useful, quick and easy to perform test, without special equipment or training.

Equipment: 10-m long corridor, score sheet, stopwatch, long measuring tape, a plastic cone, masking tape (or some other type of marker) and a standard chairs with armrests following the published guidelines (Podsiadlo and Richardson, 1991).

Set-up: Because the test involves walking, turning and stand from a chair and sit down, the testing area was well lit, with a non-slippery floor and level surface. In one side of the area a chairs with armrests was placed with the back rest touching the wall. A tape line indicating the starting point of the walking course was placed in the base of the chair, where the participant placed their feet. A plastic cone was placed 3 m away from the tape line. Additionally, a 2-m long free area behind the cone allowed the participants to turn around safely (Figure 3).

Protocol: The participants wore their regular footwear and could use their customary walking aid (none, cane, or walker), however no physical assistance was given during the tests. Participants started the test with their back against the chair, arms resting on the chairs arms (and walking aid at hand if necessary). One practice trial was conducted before the participants performed the three test trials in order to become familiar with the test. From the command "*Go*", the participants were instructed to rise from a chair, walk the 3 m as quickly as possible at safe pace to reach a plastic cone, turn around the cone, return to the chair, and sit down again. The assessor registered the time from the command "*Go*" until the participants back touched the backrest of the chair.

Safety: The assessor stood near the participants to ensure their safety and avoid falls.

Scoring: The score was the quickest time in seconds to complete the test in the three test trials.

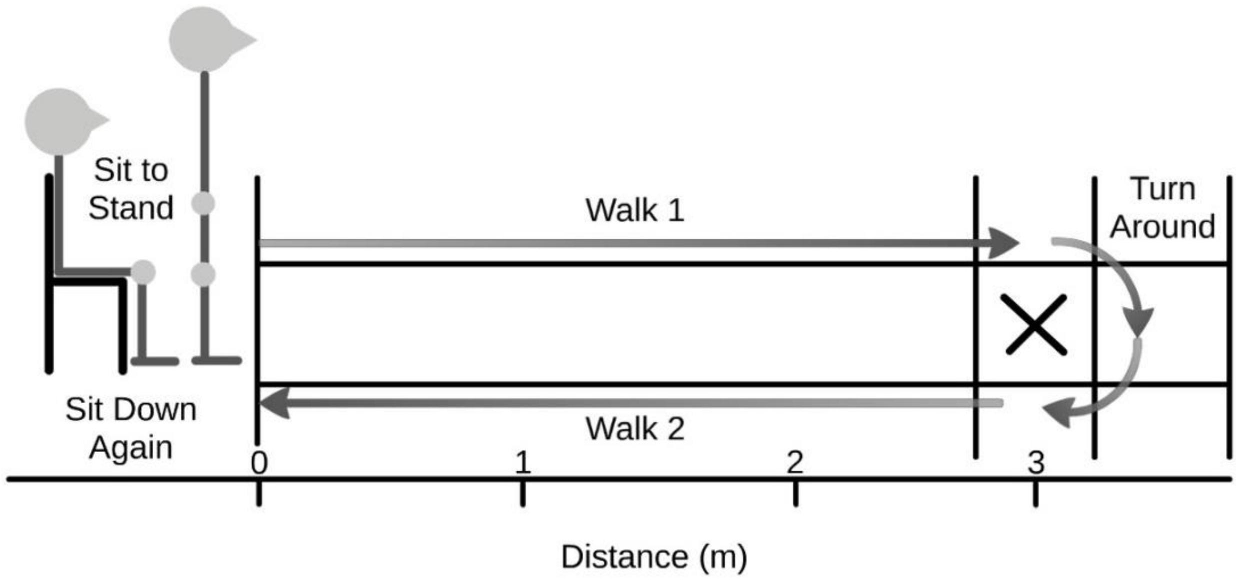

Figure 3. *Schematic illustration of the Timed "Up and Go" Test*.

Rectus Femoris Cross-Sectional Area

Structural changes in muscle architecture can be assessed by imaging techniques. For anatomical cross-sectional areas, ultrasonography has gained importance as a reliable and inexpensive instrument of measurement to obtain images of muscle and adipose tissues. The ultrasound B-mode stands out by allowing a two-dimensional analysis to identify and measure the anatomical cross-sectional area. Additionally, this technique has demonstrated a high correlation with other imaging techniques like magnetic resonance imaging (Esformes et al., 2002; Reeves et al., 2004).

Equipment: A portable B-mode ultrasound unit (Sonosite Inc., Bothell, WA, USA) with a linear probe transducer of 80 mm, ultrasound gel, and a standard massage table.

Set-up: The rectus femoris of participant's right leg was chosen due to its superficiality, accessibility and facility to visualize and measure by ultrasonography (Bemben, 2002).

Protocol: An assessor with 17 years of clinical experience conducted the procedures and instructed the participant´s to remain placed in supine position, legs extended and relaxed, and toes pointing to the ceiling. The length of the thigh was marked by the distance between the greater trochanter of the femur and the articular cleft between the femur and tibia condyles, and then two marks were made on the anterior thigh at 50% of the thigh length and at 15 cm above the superior border of the patella. Three consecutive measurements were performed with the transducer placed perpendicularly to the skin surface, and positioned midway between the epicondylus lateralis and the greater trochanter of the femur with minimal compression (e Lima et al., 2012).

Scoring: Images were analysed in the same ultrasound unit using the program ImageJ (version 1.42; National Institutes of Health, Bethesda, MD, USA), widely used for this purpose (Reeves et al., 2004 ;e Lima et al., 2012) and the mean area of the three measurements was recorded in cm^2 as the rectus femoris cross-sectional area (Figure 4).

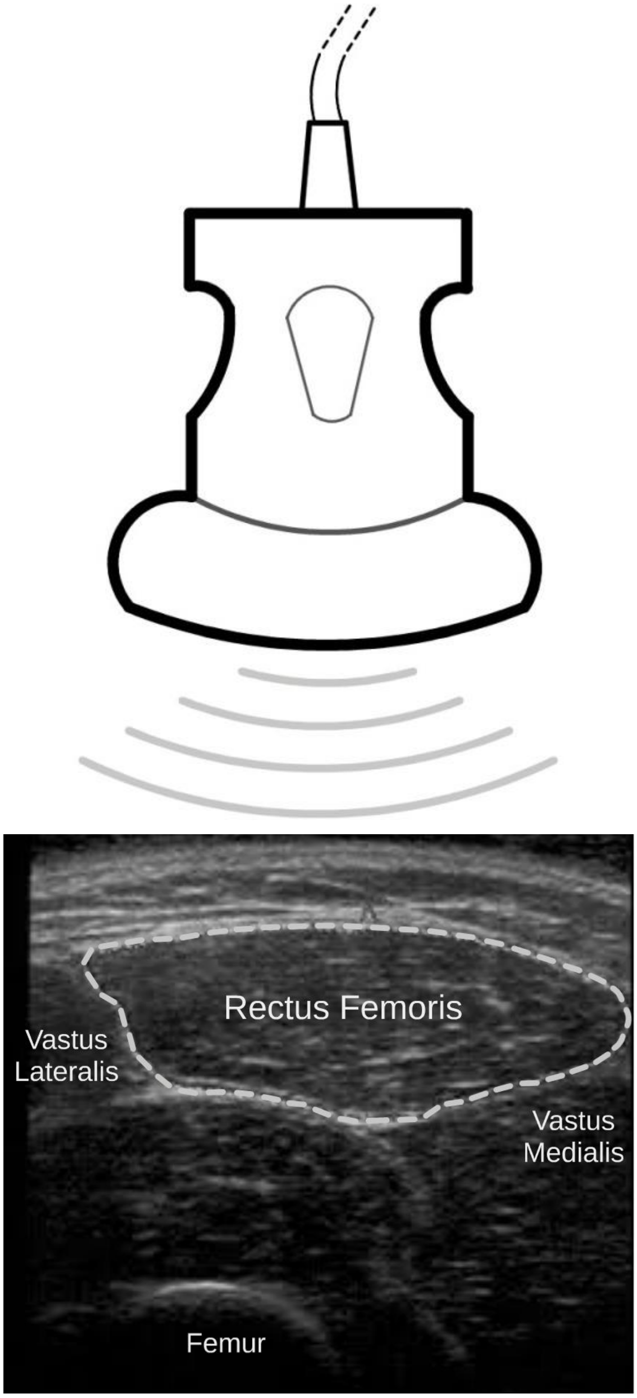

Figure 4. *Schematic illustration of the Rectus Femoris Cross-Sectional Area*.

Short Physical Performance Battery

The Short Physical Performance Battery (SPPB) is a performance-based measure for lower-limb function (Guralnik et al., 1994). The SPPB has been widely used to provide objective information about physical function in older adult's populations. This measure consists of three tasks representing standing balance, gait speed, and repeated chair stands scored each task from 0 to 4 points, with a summated total score of 12 points. It takes a few minutes to complete the SPPB battery and requires little training and simple equipment.

Equipment: 10-m long corridor, score sheet, stopwatch, long measuring tape, two plastic cones, masking tape (or some other type of marker) and a standard chair without armrests.

Set-up: Because the test involves assessing balance, gait speed and the capacity to stand from a chair and sit down again, the testing area was well lit, with a non-slippery floor and level surface, and large enough to perform all tasks comfortably. For the gait speed assessment, a 4-m long corridor delimited by two tape lines was set and two plastic cones were placed two meters behind the tape lines. For the chair stand assessment, a chair without arms-rest was placed with back-rest touching the wall.

Protocol: To measure the **Standing Balance**, a physiotherapist instructed the participants to stand and maintain their feet in a side-by-side (feet together) position, semi-tandem (heel of one foot placed to the side of the first toe of the other foot, with the participant choosing which foot to place forwards) position, and tandem stand (heel of one foot directly in front of the toes of the other foot) position for ≥10 seconds each (Figure 5). **Gait Speed Test** was measured over a 4-m walking course delimited by two tape lines. Participants were instructed to stand with their feet next to a starting plastic cone placed 2 m behind the first tape line. After the command "*Go*", participants walked past the end of the course to reach a second cone placed 2 m behind the second tape line. Timing stated after the first foot of the participants crossed the first tape line, and stopped when this foot completely crossed the second tape line. The quickest time in seconds of two trials was recorded, and then calculated as meters per second (Figure 6). Finally, the **Repeated Chair Stand Test** (STS-5) measured the time needed to rise from a chair and sit down again five consecutive times without using the arms. Participants were instructed to perform this test as fast as possible keeping with arms folded across the chest and feet flat on the floor. Timing started after the command "*Go*" with the participants seated, and the test finished when the participants stood up for the fifth time (Figure 7).

Safety: The assessor stood near the participants to ensure their safety and avoid falls.

Scoring: Each component was scored according to the participant performance or the time needed to complete the task on a scale from 0 "Unable/Not attempted" to 4 points "Quickest time/Best performance". Maximum score awarded for ≥10 seconds in the Standing Balance. Shorter time to complete the task represented better performance in Gait Speed Test. Higher scores were given for shorter performance time recorded in seconds in the Repeated Chair Stand Test. Additionally, a total summary score of the three components was determined from 0 to 12 points, with higher scores representing better functioning.

Figure 5. *Schematic illustration of the Standing Balance included in the Short Physical Performance Battery*.

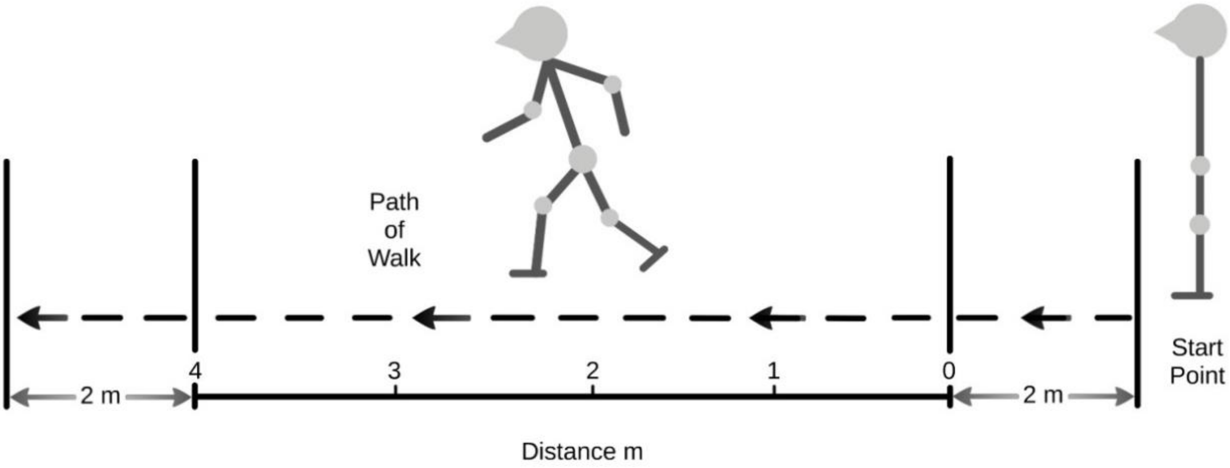

Figure 6. *Schematic illustration of the Gait Speed included in the Short Physical Performance Battery*.

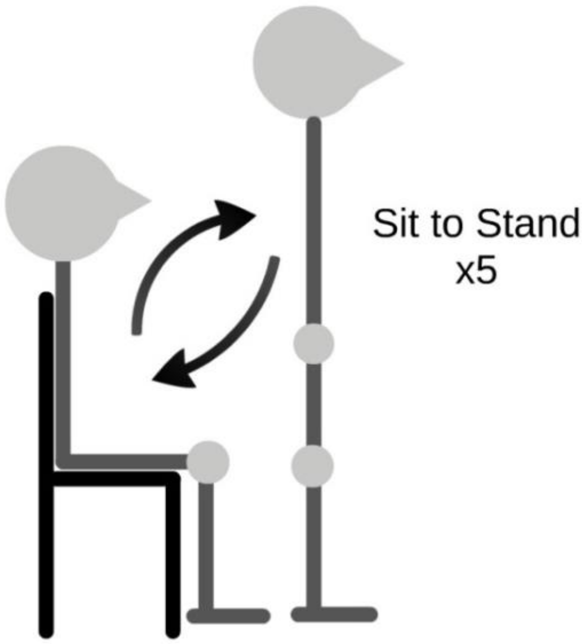

Figure 7. *Schematic illustration of the Repeated Chair Stand Test included in the Short Physical Performance Battery*.

Hand-Grip Strength

Jamar hydraulic hand dynamometer (JAMAR) is a tool to measure the maximal hand-grip strength. Hand-grip strength is not only a direct measure of hand skeletal muscle strength, is also an index of overall muscle strength, endurance and ability. Additionally, low hand-grip strength is a predictor of cognitive decline, functional limitations, disability, prolonged hospitalization, and mortality in older adults. Furthermore, JAMAR has demonstrated to be a simple, reliable and inexpensive test, and to be considered as the best measure for hand-grip strength (Sallinen et al., 2010; Mathiowetz et al., 1984).

Equipment: A standard analogic adjustable-handle JAMAR (JAMAR, Sammons Preston Rolyan, Chicago, Illinois, USA), a score sheet, and a standard chair without arm rests (Figure 8).

Set-up: Before testing, the dominant hand was defined as the preference hand used for daily tasks, and then chosen for assessment. A physiotherapist asked the participants "*Are you right-handed or left-handed?*" and "*Which is the hand that you usually use for common everyday activities such as write or eat?*" The preference hand was then chosen for assessment. For standardization, second handle position of the dynamometer was set for all participants (at a fixed value of 5.5 cm) (Ruiz-Ruiz et al., 2002). Peak values occur most frequently with the second or third handle position and on the first or second attempt of a series of successive trials. The American Society of Hand Therapists recommends that the second handle position of the dynamometer should be used when evaluating hand-grip strength. The dynamometer was lightly held around the readout dial by the assessor to prevent inadverted dropping (Mathiowetz et al., 1984).

Protocol: Participants were comfortably seated on a standard chair without arm rests, with his shoulder adducted and neutrally rotated, elbow flexed at 90° and forearm and wrist between 0° and 15° or ulnar deviation and dorsiflexion. The assessor instructed the participants to hold the handle and squeeze it as hard as possible for 3 to 5 s. The assessor demonstrated the correct performance of the test and then gave the dynamometer to the participant. After the command "*Go*" and when appropriately positioned, the participant began to squeeze the handle as hard as possible. During the three test trials, the assessor used strong verbal encouragement such as "*Harder!... Harder!... and Relax*" (Mathiowetz et al., 1984).

Scoring: The mean score in kg of the three test trials was used as the measure of hand-grip strength.

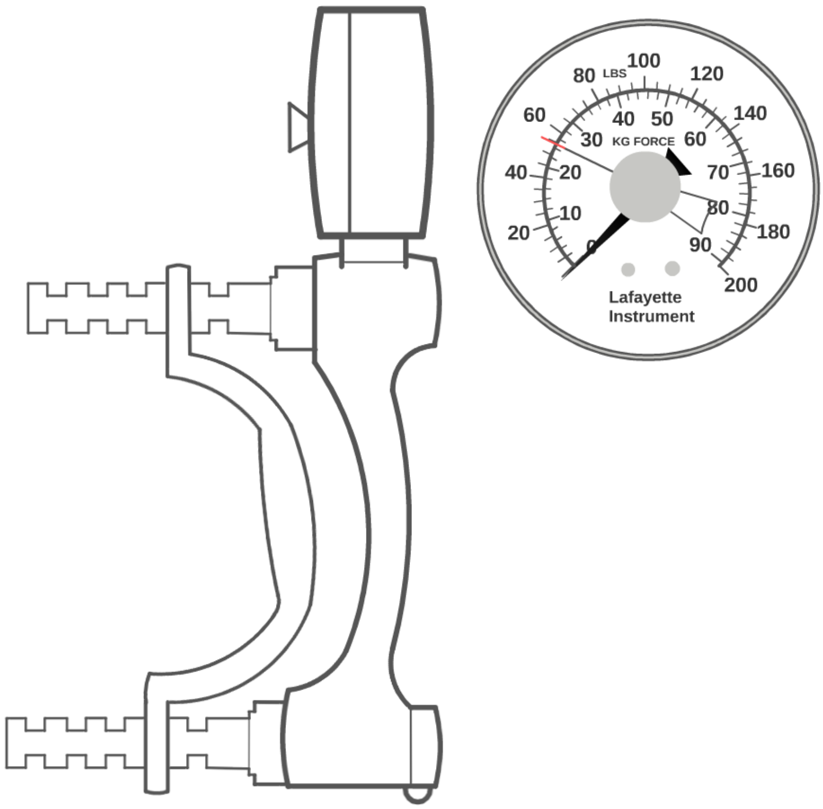

Figure 8. *Schematic illustration of the Hand-Grip Strength*.

One-leg Stand

The One-leg Stand (OLS) is a quick and easy to administer predictor of falls that measures the ability to stand on one leg for 5 seconds or longer (Vellas et al., 1997 JAGS; Vellas et al., 1997). Additionally, the OLS is a useful clinical indicator and predictor of functional decline in older adults (Drusini et al., 2002).

Equipment: Score sheet and a stopwatch.

Set-up: Because the test involves assessing balance ability, the testing area was well lit, with a non-slippery floor and level surface, and large enough to perform the test comfortably.

Protocol: Before starting the tests, the participants were asked to test and chose a leg to stand on (choosing the one they feel more comfortable with). A physiotherapist instructed the participants to start the test from a standing position with their eyes open and arms at their sides, then stand on the chosen leg and flex the opposite knee allowing the foot to clear the ground. Participants stood unassisted on one leg as long as possible and were allowed to use their arms in order to keep in balance (Figure 9). The assessor recorded the time in seconds and noted whether the participant was able to keep balance for 5 seconds or longer. The timing was stopped if the participant could maintain balance in excess of 60 seconds.

Safety: The assessor stood near the participants to ensure their safety and avoid falls.

Scoring: The total time in seconds keeping balance on one leg was recorded as the total score.

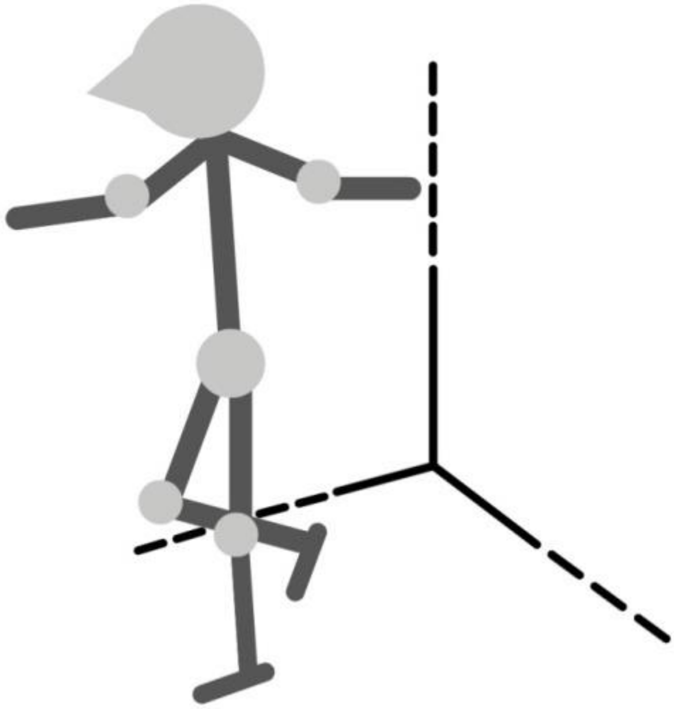

Figure 9. *Schematic illustration of the One-leg Stand Test*.

Knee Extension Strength

Knee extension strength, defined as the ability to produce maximal muscle force during an isometric contraction of the knee extension muscles (Crockett et al., 2013), is considered an important indicator of overall functional status of lower-limbs (Kaminska et al., 2015). This functional status includes the walking performance, the ability to get in and out of a chair, or step-climbing speed (Crockett et al., 2013). Additionally, the knee extension muscles strength has demonstrated to be a modifiable factor that may protect against decline of physical function in older adult's populations (Accettura et al., 2015).

Equipment: A fixed strain gauge (TESYS 400®, Globus Italia, Italy) (previously calibrated by a physiotherapist with specific experience) and attached to the extensor chair lever arm and the chair legs, a score sheet, and a knee extension chair without arm rests.

Set-up: Before testing, the dominant leg was defined as the preference leg used for basic daily tasks. A physiotherapist asked the participant which foot they would use to "*Kick a soccer ball*" or "*Write one´s name in the sand*". The preference leg was then chosen for assessment.

Protocol: A physiotherapist with specific experience administered and supervised the test. Participants were seated on the knee extension chair in a straight-back position, with the knee and hip joints at 90° of flexion (Newman et al., 2003) (Figure 10). Adjustable straps were placed on the pelvis and the distal thigh to stabilize the participants, and the lever arm of the extensor chair was placed on the ankle above the malleoli. Participants were instructed to push as hard as possible for 5 seconds of isometric contraction. Strong verbal encouragement was used during the test. After the command "*Go*", the participant tried to extend the dominant leg as hard as possible. Three test trials were performed, with a 90 seconds of resting period between trials (Sillanpää et al., 2014).

Safety: The assessor stood near the participants during the three test trials, and in case of intense knee pain during the trials the test was interrupted.

Scoring: The mean score in kg of the three test trials was used as the measure of knee extension strength.

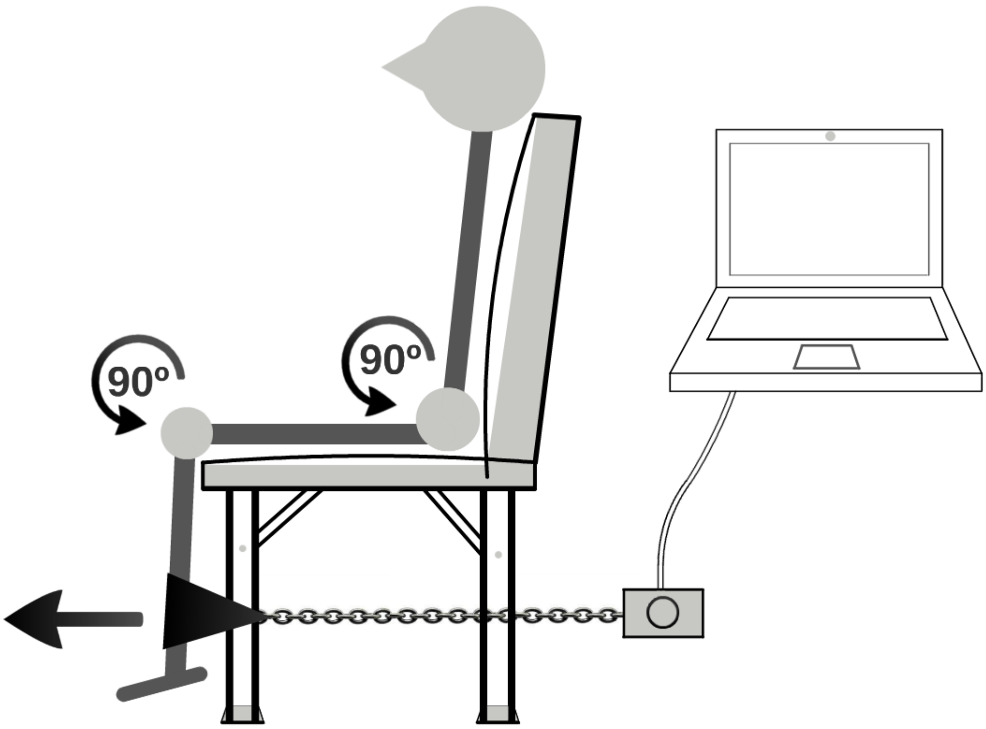

Figure 10. *Schematic illustration of the Knee Extension Strength assessment*.

Barthel Index

Originally developed in 1965, the Barthel Index is a 10-item self-reported questionnaire that measures functional independence in basic activities of the daily living by assessing the capacity to perform those tasks without assistance (Mahoney and Barthel, 1965). The ten activities are grouped according to self-care (personal hygiene, bathing, feeding, toileting, dressing, bowel control and bladder control) and mobility (ambulation or wheelchair, stair climbing chair–bed transfer) (Wade and Collin, 1988) (Figure 11).

Protocol: The questionnaire was administered directly to participants. The assessor asked the participants to answer to the questions reporting not what he or she could do, but what he or she does. The assessor selected the scoring point for the statement that most closely corresponds to the participants answer.

Scoring: Each item was scored depending on the amount of physical assistance required, in a range from 0 ("unable to perform" or "need assistance") to a maximum of 5, 10 or 15 points ("able to perform independently"). Bathing and personal hygiene were scored 0 or 5 points. Feeding, toileting, dressing, bowel control, bladder control and stair climbing were scored 0, 5 or 10 points, and ambulation and chair–bed transfer were scored in 0, 5, 10 or 15 points according to the level of independence of the participant. Individual task scores were summed up for a potential maximal score of 100 points (higher scores represented completely independent).

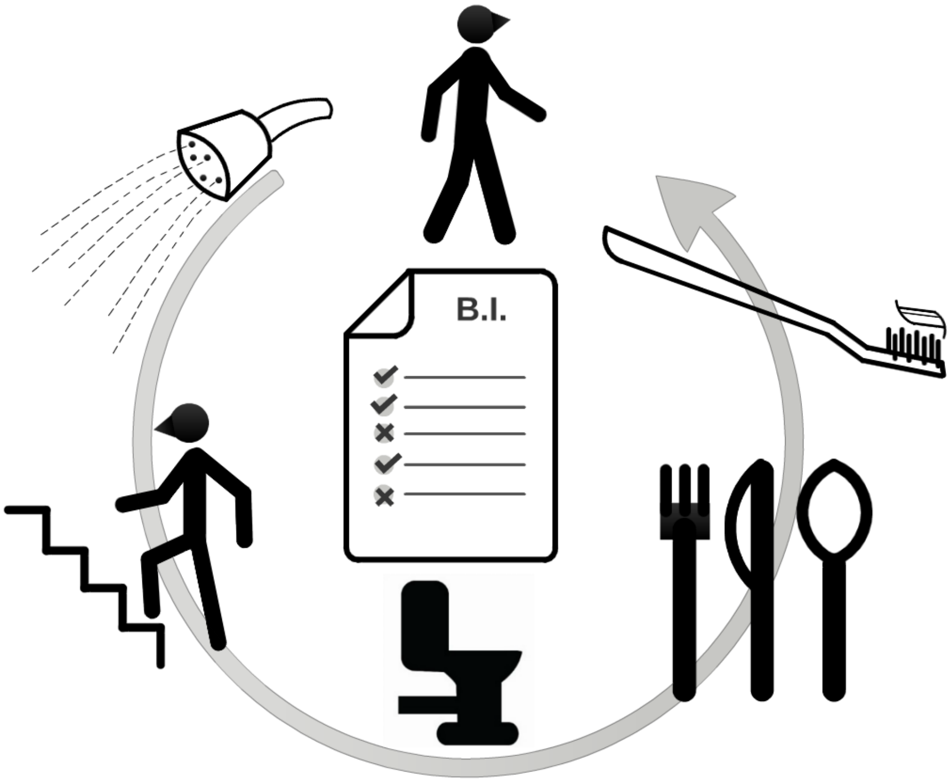

Figure 11. *Schematic illustration representing some of the 10 items present in the Barthel Index*.

Mini-mental State Examination

Originally developed in 1975, the Mini-mental State Examination is a widely used and accepted standardized tool for measuring cognitive functioning. The test includes 11 items divided into two sections. The first section requires verbal responses to questions assessing orientation, memory and attention. The second section measures the ability to name objects, follow verbal and written commands, write a sentence and copy a drawing (Folstein et al., 1975) (Figure 12).

Equipment: Score sheet, two blank sheets, a sheet with the phrase "*close your eyes*" written and a sheet with two superimposed pentagons.

Protocol: An assessor administered directly the questionnaire to the participants.

Scoring: To each item it was attributed a different set of scoring points ranging from 0 to 5 according to the participant answer or performance (higher scores representing better cognitive functioning). If participant's answered correctly or performed the requested activity correctly, one point was given to each task. The total score ranges from 0 to 30, with lower values representing greater impairment.

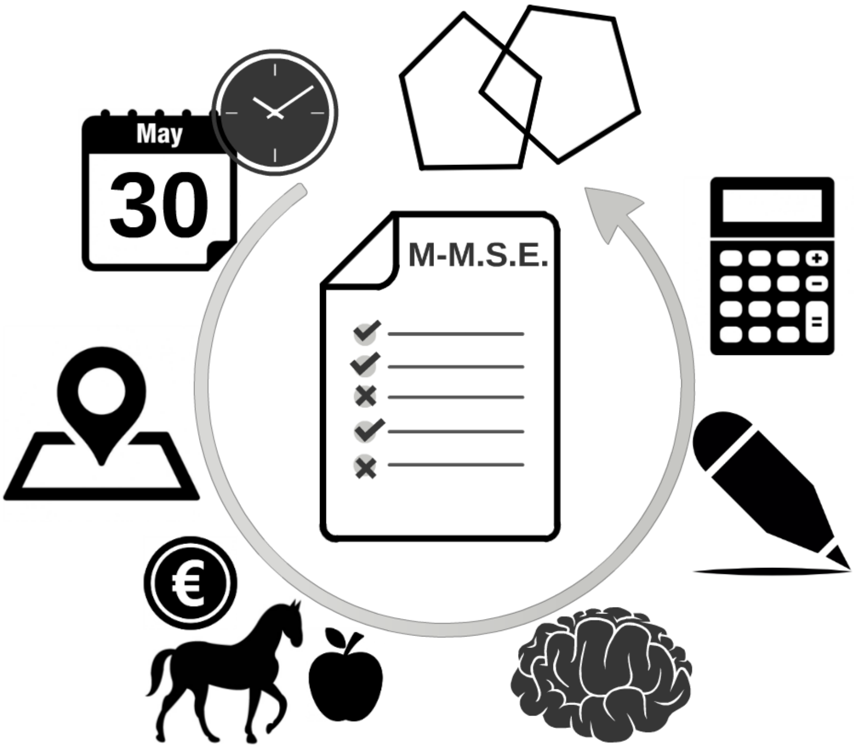

Figure 12. *Schematic illustration representing some of the tasks present in the Mini-mental State Examination*.

Body Mass Index

Height and body mass were recorded using a portable stadiometer and balance weighing scales, respectively. Body mass index (BMI) was calculated using the standard formula: [mass (kg)/height^2 (m)] (Figure 13).

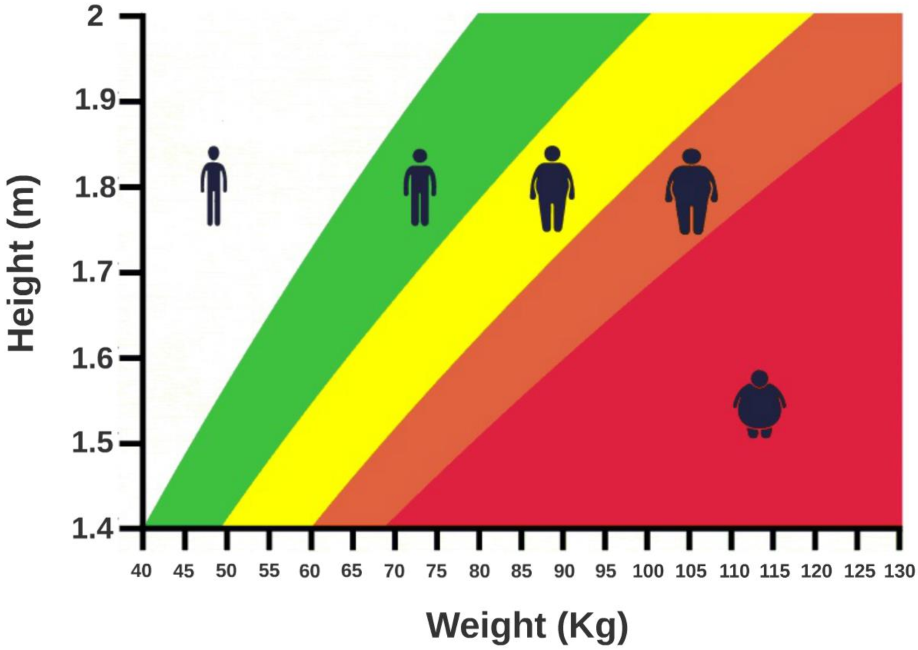

Figure 13. *Schematic illustration of the Body Mass Index*.

One Maximal Repetition

To calculate the % of 1RM, adjustable ankle cuff weights were used. A physiotherapist instructed the participant's to seat on a knee extension chair with a 90° of knee and hip flexion, and perform a single repetition with a weight that they could lift through a complete knee extension (Figure 14). In the case of a successful lift, 0.5 to 1 kg was added at the discretion of the assessor for the next attempt, with 60 seconds rest periods between lifts. This procedure was repeated until the participants could no longer lift the weight to complete a full knee extension. The highest value of weight lifted successfully was recorded in kg as the 1RM (Wood et al., 2002).

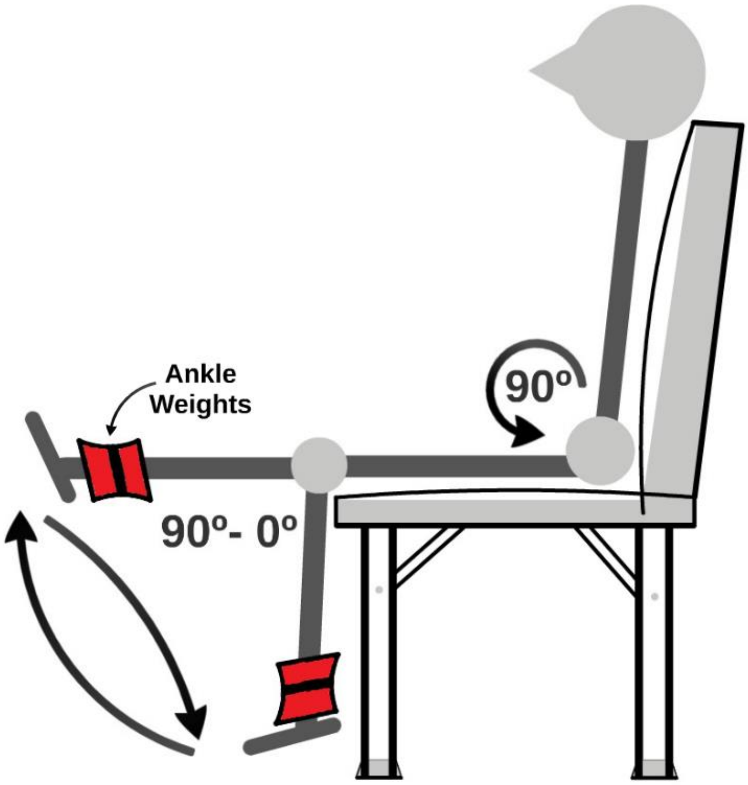

Figure 14. *Schematic illustration of the One Maximal Repetition assessment*.

Interventions

Effects of three different low-intensity exercise interventions on muscle CSA, physical performance and activities of daily living: A randomized controlled trial.

Participants allocated in the intervention groups enrolled in a three weekly non-consecutive exercise sessions for 16 weeks at the geriatric nursing home of "*Residencia Geriátrica Hermanitas de los Ancianos Desamparados*". Each session lasted between 30 to 35 minutes, and was performed individually, always under a close supervision of two physiotherapists, who provided guidance and adequate instructions in order to ensure that the exercises were performed properly and safely. All intervention sessions were conducted in the same indoor room. The goal, for all participants in the intervention groups, was to perform a total of 48 exercise sessions. In order to calculate the correct intensity of the exercise in all groups, 1RM of the knee extensors was assessed. Dynamic muscle strength was defined as the 1RM or the maximum amount of weight that a participant could lift throughout the complete range of motion (Wood et al., 2002), and the intensity of the exercises was set at 40% of the 1RM. The procedure was calculated at the beginning of the intervention period and every two weeks until the intervention period was completed.

Volitional Contractions (VC) group

The participants performed knee extension exercises in both legs using adjustable ankle cuff weights. The participants started the exercise seated in a knee extension chair with 90° of knee and hip flexion, and then extended the leg to a full knee extension. All participants performed three sets of fifteen repetitions each in both legs with a 3-minute resting period between sets. The participants were instructed to raise the weight in 1 second (concentric phase), keep a full knee extension for 3 seconds (isometric phase) and slowly lower the weight in 2 seconds to the starting position (eccentric phase). Each contraction was followed by 2 seconds of resting period before starting with the next repetition (Figure 15). The exercise timing was designed to adhere to a functional knee extension exercise. Additionally, given the low intensity of the exercise (set at 40% of 1RM during the whole session), 2 seconds were considered time enough to perform the next repetition without fatigue.

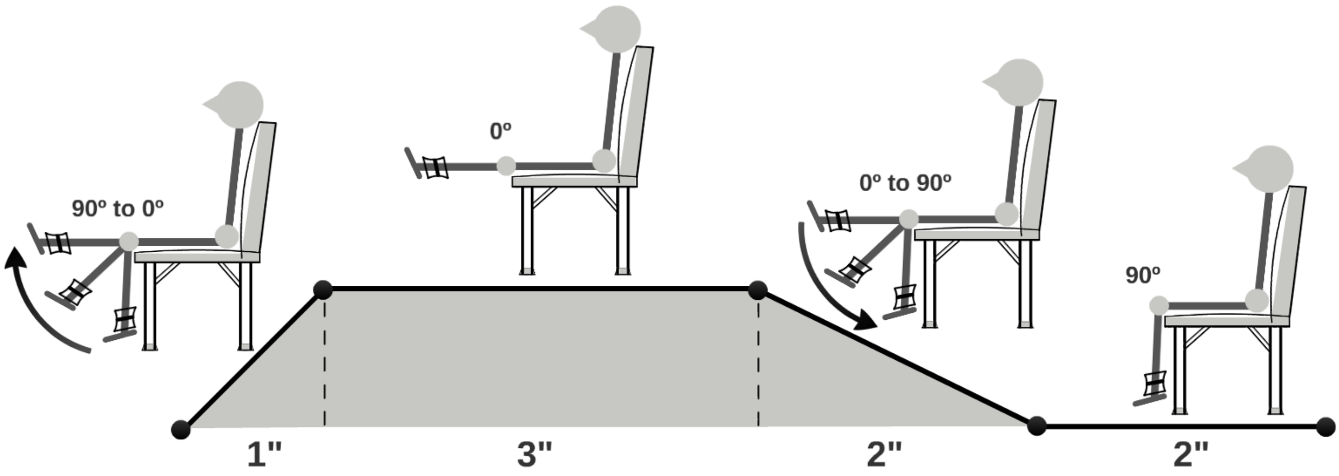

Figure 15. *Schematic illustration of the knee extension exercises in VC, NMES and NMES+ groups*.

NMES and NMES+ groups

Participants allocated to the Neuromuscular Electrical Stimulation group (NMES) and NMES exercises superimposed onto voluntary contractions group (NMES+), incorporated NMES or NMES+ to the knee extension exercise, performed involuntarily or voluntarily respectively. The NMES technique consisted of the application of an electrical current to the neuromuscular junction in order to generate evoked muscle contractions (involuntary muscle contractions). The participants in the NMES group were asked not to participate actively with voluntary contractions during the knee extension. An electrical stimulus was applied through the skin of the thigh using surface electrodes connected to a portable device (TensMed S82). Four adhesive surface electrodes (5×5 cm) were placed on the distal, medial and proximal lateral portions of the participant´s anterior thigh (Lyons et al., 2005) (Figure 16), as findings show that the longitudinal electrode position produces significantly more torque than the transverse position when the knee extensor muscles are electrically stimulated (Brooks et al., 1990). A biphasic symmetrical square waveform with a frequency maintained at 50 Hz and phase duration of 400µ was used. The pulse current was delivered following the same pattern as the VC group, with a ramp-up time of 1 second increasing intensity as the knee was extended from 90° to full extension, a total of 3 seconds keeping the knee in full extension, 2 seconds of ramp-down decreasing intensity and gradually returning the knee to the starting position of 90° of flexion, and an off time of 2 seconds as a rest period.

The NMES group current intensity was adjusted to tolerance and maintained according to reach a full knee extension while participants used ankle cuff weights set at 40% of their 1RM during each electrically evoked contraction. The NMES+ group performed the same knee extension exercises and weight-lifting protocol as the VC group, and incorporated simultaneously the neuromuscular electrical stimulation protocol as the NMES group during the voluntary contraction. The NMES+ group current intensity was adjusted to tolerance and training intensity was set at 40% of their 1RM.

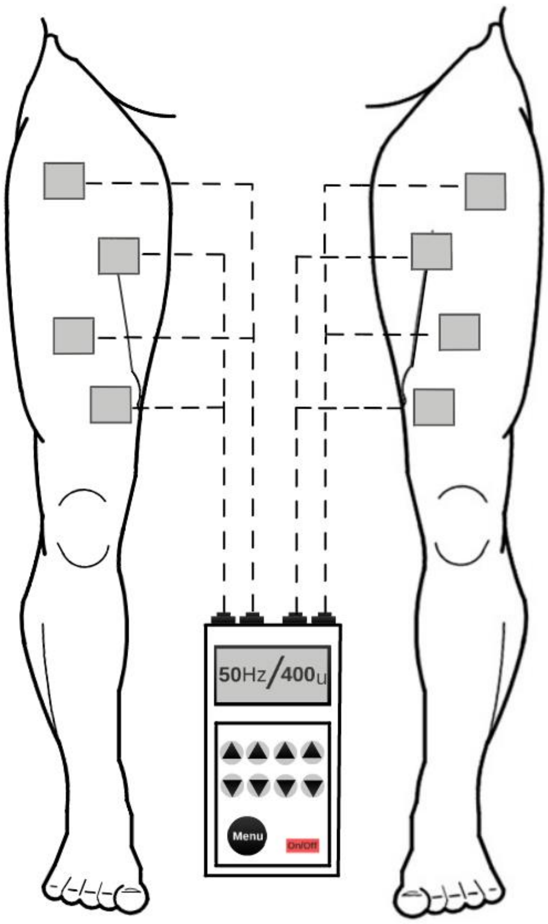

Figure 16. *Schematic illustration of the surface electrodes placement.*

Control group

The participants in the control group did not receive any intervention. Moreover, they were asked to resume their ordinary daily living and not participate in any kind of exercise program throughout the study, as this could influence the results.

During 4 months, all participants in the intervention group (IG) enrolled in a three-week non-consecutive exercises program at the local community centre of "*Centro Municipal de Actividades para Personas Mayores Sant Pau*". All exercises were undertaken in a large indoor room equipped with a DVD player, a large screen where the video was projected, and a 45 cm height chair without armrest for each participant. The exercise routine performed in each session was based on the Otago Exercise Programme (Gardner et al., 2001; Campbell et al., 1997).

Intervention group

One week before starting the program, a trained physiotherapist instructed and supervised the IG during three familiarization sessions, to help participants understand the video instructions, the correct use of the ankle cuffs, and to ensure a confident, safe and correct exercise performance. The video content provided safety information, verbal instructions and accurate visual guidance on how to perform the exercises during a total of 45 minutes. Additionally, each IG participant received an exercise booklet which illustrated and described all exercises (Figure 18), and ankle cuff weights (starting at 0.5 kg) to provide resistance during the strengthening exercises (Figure 17).

Figure 17. *Illustration of the ankle cuff weights used during the intervention*.

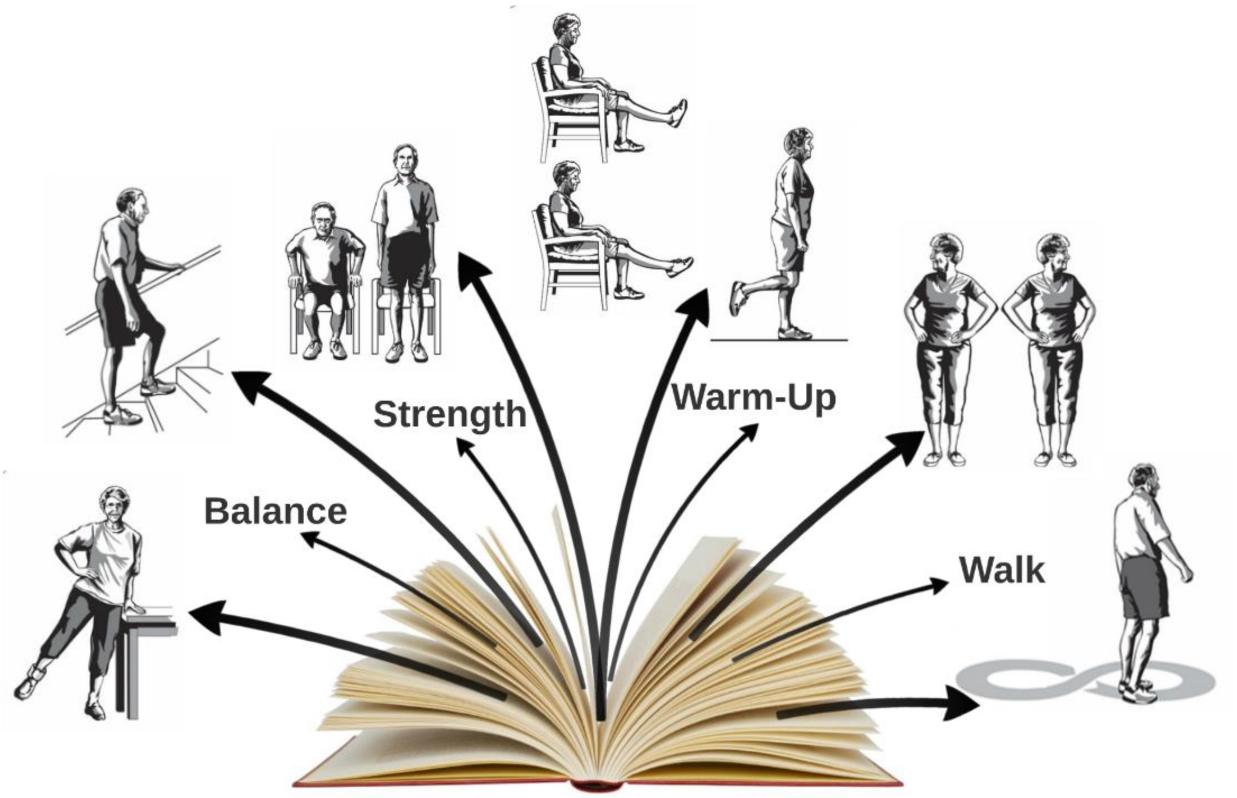

Figure 18. *Schematic illustration of the Otago Exercise Programme booklet*.

During the training sessions, the video showed four exercise routines for standing and seated positions. Participants stood in front of the projection screen and followed the exercise instructions (Figure 19). The session started with 7 minutes of moderate warm-up exercises focusing on mobility and flexibility, that included head, neck, trunk, back and ankle movements. Secondly, the strengthening exercises were performed, consisting of knee extensions, knee flexions, hip abductions, ankle plantar flexions, and ankle dorsi-flexions. Thirdly, a set of balance exercises were performed, consisting of knee bends, backwards walking, walking and turning around, sideways walking, tandem stance, tandem walk, one-leg stand, heel walking, toe walking, toe to heel walking backwards, sit-to-stand, and stair walking. Fourthly, participants were instructed to walk at their usual pace for at least 10 minutes and return to the exercise room. Finally, there was a 10-minute cool-down period after the session was completed. All strengthening and balance exercises were performed at the appropriate level of difficulty during the 4-month intervention, according to a dedicated publication (Gardner et al., 2001). Additionally, strategies to incorporate walking times into daily activities were suggested.

Figure 19. *Illustration of an Otago Exercise Programme session*.

The same physiotherapist who provided the familiarization sessions returned every week to the community centre to encourage participants to persist in the program and to make progressive adjustments according to the OEP protocol. A total of 48 sessions were performed during the 4-month intervention.

Control group

The participants of the control group (CG) were asked to resume their ordinary daily living, and did not receive any intervention during the length of the program.

Factors associated with the 6-minute Walk Test in nursing home residents and community-dwelling older adults.

For this cross-sectional analysis, five independent assessors registered all measurements at the geriatric nursing home of "*Residencia Geriátrica Hermanitas de los Ancianos Desamparados*", and the local community centre of "*Centro Municipal de Actividades para Personas Mayores Sant Pau*" in a single assessment session, except the rectus femoris cross-sectional area (CSA) that was assessed in a consecutive day. On the first day, participants were assessed for baseline demographics, health-status and physical measures. To accommodate the participant´s assessment, a total of four functional tests stations were set in a large indoor room, except the 6MWT that was set in a long indoor corridor next to the assessment room. Measurements were chronologically organized in order to minimize fatigue, and then registered in the following order: BMI, BBS, TUG, Hand-grip strength, SPPB and 6MWT. Additionally, a 5 minute resting period in a seated position was permeated to the participants between measures.

For this cross-sectional analysis, all measures performed have been determined from the literature to be valid and reliable in assessing mobility (TUG) (Steffen et al., 2002), balance (BBS) (Berg et al., 1992), knee extension strength (Gagnon et al., 2005), lower-limb strength (STS-5) (Rikli and Jones, 1999), and upper-body strength (Hand-grip strength) (Bohannon, 2008) in older adults. Data collection was carried out by six experienced independent assessors (physiotherapists) at the geriatric nursing home of "*Residencia Geriátrica Hermanitas de los Ancianos Desamparados*", and the local community centres of "*Centro Municipal de Actividades para Personas Mayores Sant Pau*", "*Centro Municipal de Actividades para Personas Mayores Malvarrosa*", "*Centro Municipal de Actividades para Personas Mayores Giorgeta*" and "*Centro Municipal de Actividades para Personas Mayores Trafalgar*" in two assessment sessions.

To accommodate the participant´s assessment, a total of four functional test stations were set in a large indoor room. All measurements were administered in a single session, except the rectus femoris CSA which was assessed on a consecutive day. In order to standardize the data collection schedule, all tests were conducted between 10am and 2pm. During the first day, data collection was chronologically organized in order to minimize fatigue, and then completed in the following order: BMI, TUG, BBS, OLS, Knee Extension Strength, Hand-grip strength and STS-5. Additionally, a 5 minute resting period in a seated position was permeated to the participants between measures. Furthermore, to avoid the possible fatigue between the two lower-limb strength tests, knee extension strength was assessed before the grip strength assessment, which provided an extra period to the participants in a seated position, and then the STS-5 was conducted. Finally, the rectus femoris CSA was determined to be measured in a consecutive day to avoid a possible muscle changes as a consequence of the administration of the previous tests, which could alter the rectus femoris CSA measured by ultrasonography.

Data analysis

Effects of three different low-intensity exercise interventions on muscle CSA, physical performance and activities of daily living: A randomized controlled trial.

The desired sample size was calculated by an external researcher not involved in the procedures, and therefore blind to the intervention. The calculation was based on detecting changes in mobility (2 s) and rectus femoris CSA (1 cm^2), and we selected the larger result from the two calculations, which would provide adequate power for detecting both differences. With a statistical power equal to 80% and an alpha risk of .05, a sample size of 22 patients per group was necessary.

The statistical analysis was performed according to intention-to-treat. To compare the success of randomization, preliminary analyses of variance and Chi-squared tests were used to determine baseline differences between groups.

Two-way mixed ANOVA tests were used to compare the study effects on TUG, rectus femoris CSA, BBS, hand-grip strength, Barthel Index and 6MWT between groups, with the exercise period serving as the within-group factor and the intervention type as the between-group factor. The data are presented as the mean ± SD. Statistical analyses were performed using SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA). $P<.05$ was considered statistically significant.

Normal distribution of the data was tested using the Kolmogorov-Smirnov test. The necessary sample size was calculated by an external researcher not involved in the procedures, and therefore blind to the intervention. The calculation was based on the TUG time reduction between the estimated mean and the sampling mean. A 1.5 seconds reduction in the TUG was defined as significant. A statistical power equal to 80% and an alpha risk of .05, a minimum sample size of 21 patients per group was necessary.

The statistical analysis was performed based on intention-to-treat. To compare the success of randomization, preliminary independent t-tests and Chi-squared tests were used to determine baseline differences between groups. Two-way mixed ANOVA tests were used to compare the study effects on TUG, BBS, OLS, 6MWT and SPPB and its individual components between the two groups, with the intervention period serving as the within-group factor, and the treatment group as the between-group factor. The data are presented as mean ± SD. Statistical analyses were performed using SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA). P<.05 was considered statistically significant.

Factors associated with the 6-minute Walk Test in nursing home residents and community-dwelling older adults.

Data analysis was conducted using SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA). Descriptive statistics (mean ± SD) were generated to summarize demographic, health-related, and physical measures data for all participants. The Student's t-test or Mann-Whitney U test and Chi-squared tests were used to determine baseline significant differences between the NH and CD groups. The normality of the distribution of the data was determined with the Kolmogorov-Smirnov test before performing parametric or non-parametric analysis.

In order to determine the independent relationship between the 6MWT and the demographic and physical measures, bivariate correlations were calculated for all participants and for the NH and CD groups (the Pearson product moment correlation coefficient (r) was used for normally distributed data, and Spearman's rho was used for non-normally distributed data).

Stepwise linear regression analyses were conducted to construct a model for identifying independent contributors to performance in the 6MWT. Analyses were conducted for the whole sample as well as for the NH and CD groups separately. Demographic and physical measures that could be associated with the 6MWT were used as independent variables (age, BMI, Gait Speed, BBS, TUG, rectus femoris CSA, STS-5, SPPB, and Hand-grip strength), and the 6MWT was used as a dependent variable. Furthermore, variable selection was preceded by checking for correlation coefficients between the independent variables and the 6MWT. If a significant correlation was found for a variable, it was chosen for further analysis. The alpha level for significance was set at $P<.05$.

Data analysis was conducted using SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA). Descriptive statistics (mean ± SD) were generated to summarize demographic, health-related and physical measures data for the whole sample. The normality distribution of the data was determined with the Kolmogorov-Smirnov test before using parametric or non-parametric analysis.

In order to determine the independent relationship between the TUG and the selected physical measures, partial correlations adjusted for age and gender were calculated for both, nursing home residents and community-dwelling participants.

Stepwise linear regression analyses were conducted to construct a model for identifying independent contributors to the TUG. TUG was determined as a dependent variable, and the selected physical measures that could be associated with the TUG were used as independent variables (BBS and Knee Extension Strength). The variable selection was preceded by checking for correlation coefficients between the independent variables and the TUG. If a significant correlation was found for a variable, it was chosen for further analysis. The alpha level for significance was set at $P<.05$.

INTRODUCTION

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Effects of three different low-intensity exercise interventions on physical performance, muscle CSA and activities of daily living: A randomized controlled trial

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ABSTRACT

Objectives: To evaluate the short-term effects of three different resistance training programs, conducted at low intensity, on physical performance, muscle cross-sectional area (CSA) and the capacity to perform daily tasks in older adults living in a geriatric nursing home.
Design: Randomized controlled trial, with a 4-month intervention period.
Setting: A geriatric nursing home in Valencia, Spain.
Participants: Eighty-nine adults aged 75 to 96 who were independent in their daily activities.
Intervention: After a baseline assessment, the participants were randomly assigned to the control group or one of the three intervention groups: volitional contraction (VC; n = 22), neuromuscular electrical stimulation (NMES; n = 22), or neuromuscular electrical stimulation superimposed onto voluntary contractions (NMES+; n = 22). The intervention focused on knee extension exercises and its intensity was set at 40% of one-repetition maximum (1RM).
Measurements: The primary outcome measure was mobility. Secondary outcomes were rectus femoris CSA, balance, aerobic endurance, upper-body strength and the capacity to perform daily tasks. All data were collected at baseline and after the 4-month intervention period.
Results: The two-way ANOVA analysis showed a significant group × time interaction effect for the mobility ($P =$ .022), rectus femoris CSA ($P =$ .001), and the capacity to perform daily tasks ($P =$ .05). The within-group analysis found a more prominent effect in the NMES+ group. Significant improvements were seen in rectus femoris CSA and the capacity to perform daily tasks in all intervention groups. Mobility only improved in the NMES+ group ($P =$ .026).
Conclusion: From a short-term perspective, NMES+ exercise training, performed at low intensity, can improve physical performance, muscle CSA, and the capacity to perform daily activities, and to partially mitigate age-related consequences in older adults.

1. Introduction

The proportion of older adults in Western Europe countries and the U.S. is rapidly growing (Christensen et al., 2009). For example, the number of US residents aged 65 or older is projected to double in the next 30 years, and amount to 20% of the population (Caffrey et al., 2011). It is known that the elderly constitute the least physically active age group, and in addition generate the highest medical care expenditures (Nelson et al., 2007). One effect of aging is a gradual and steady reduction of muscle size and strength, especially and to a greater extent in the lower-limb muscles (Beneka et al., 2005; Rosenberg, 1997). This progressive muscle weakness has important functional consequences with regard to the ability to perform daily tasks, the maintenance of personal independence, and it has been associated with a higher risk of falls, hospitalization and mortality (Guralnik et al., 1995; Janssen et al., 2004). Treating or reversing age-related decline is important for preserving health, health-related quality of life and life expectancy. It is well documented that regular exercise can attenuate this phenomenon and provide substantial health benefits (American College of Sports Medicine et al., 2009).

Neuromuscular electrical stimulation (NMES) is the application of an electric current with surface electrodes on weakened but otherwise normally innervated muscles for improving muscle strength (Vanderthommen and Duchateau, 2007). During the last two decades, volitional contractions (VC) and electrically evoked contractions have frequently been the approach of choice for reducing muscle weakness and age-related decline both in healthy and diseased older adults. Both techniques stimulate and overload muscles with a moderate-to-high intensity, given that exercise intensity is a determining factor for

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achieving positive results (Latham et al., 2004; Liu and Latham, 2009; Maffiuletti, 2010). The higher the muscle overload intensity, the greater the muscle-size and strength gains (Hunter et al., 2004; Peterson et al., 2010); likewise, the higher the NMES intensity, the greater the muscle-size and strength gains (Maffiuletti, 2010; Miller and Thepaut-Mathieu, 1993). However, given the heterogeneity and individual variability in terms of the health status and physical function levels represented in the older adults' population, care and individual supervision may be needed to reduce orthopedic injury risks and adverse effects, particularly in frail or recently ill individuals (Pollock et al., 1991; Vincent et al., 2002). Additionally, a substantial limiting factor for the use of high-intensity NMES is the discomfort associated with peripheral stimulation (Maffiuletti, 2010; Stevens-Lapsley et al., 2012).

Volitional (Galvao and Taaffe, 2005; Kalapotharakos et al., 2004; Taaffe et al., 1996; Vincent et al., 2002), and low-intensity electrically evoked contractions (Takano et al., 2010) have proved to be a safe alternative to high-intensity exercises, showing positive results in muscle-size and strength gains in older adults. Indeed, low-intensity exercises could be an attractive alternative and a better recommendation for physical activity for the elderly, exercise participation and adherence might be improved, muscle soreness minimized, and injury rates reduced (Galvao and Taaffe, 2005; Vincent et al., 2002). However, to the best of our knowledge, no study has been conducted using a combined program of low-intensity NMES exercises superimposed onto voluntary contractions (NMES+) in older adults.

Therefore, the purpose of the present study was to evaluate the effects of three different resistance training programs (VC, NMES, and NMES+), performed at low intensity, on the physical performance, muscle CSA and the capacity to perform daily tasks in healthy older adults. All intervention groups targeted major knee extension muscles over a 16-week period in men and women aged 75 and older living at a geriatric nursing home.

It was hypothesized that all exercise groups would significantly improve muscle CSA, physical performance and the capacity to perform daily tasks from a short-term perspective, and that the NMES+ program would show the larger improvements.

2. Methods

2.1. Study design

This study (ClinicalTrials.gov ID: NCT01086592) was designed to adhere to the recommendations of the Consolidated Standards of Reporting Trials statements (Altman et al., 2001). The study design, protocol and informed consent procedure was approved by the Bioethics and Clinical Research Committee of UCH-CEU University. All participants signed a written informed-consent statement, and were randomly assigned to a control group or to one of the three intervention groups. Participants included in this study were evaluated at baseline and at the end of a 4-month intervention period by the same independent assessors. The study followed the ethical guidelines of the Declaration of Helsinki.

2.2. Study participants and selection criteria

One hundred and seventeen potential participants were voluntarily recruited from a geriatric nursing home of Valencia, Spain. Participants were screened for inclusion by individual interviews conducted by a physical therapist (PT). During the interviews, all participants received fully explained and comprehensive information of the proposed study, its objectives, benefits, risks, and length. To be eligible for inclusion participants had to be aged 75 or older, able to ambulate independently, able to communicate, and willing to stay in the same geriatric nursing home for the next 6 months. Excluded were those who were unable to ambulate independently, had a lower-extremity fracture or a metal implant, had a Mini-Mental State Examination score of <24 (Folstein et al., 1975), or presented with an unstable cardiovascular disease or a neurological disorder that could compromise them from exercising. Eighty-nine of the 117 eligible participants met the inclusion criteria and completed a baseline assessment. Fig. 1 shows the flow of the participants through the trial.

2.3. Randomization and blinding

The participants were assigned to one of the three intervention groups: volitional contraction (VC, n = 22), neuromuscular electrical stimulation (NMES, n = 22), neuromuscular electrical stimulation superimposed onto voluntary contractions (NMES+, n = 22), or to the control group (C, n = 23), using computer-generated random numbers. The allocation was concealed. The assessors who collected the data were blind to the group allocation; however, it was not possible to conceal the group assignment from the co-investigators involved in the intervention, as it is an inherent issue in all trials applying electrical physical agents (Claydon et al., 2008; Johnson and Tabasam, 2003).

2.4. Outcome measurements

Six assessors administered the baseline measurements in two consecutive assessment sessions. To accommodate the participants' assessments, all test stations, except 6MWT, were set up in a large indoor room. The measurements performed have been determined from the literature to be valid and reliable in assessing mobility, balance, aerobic endurance (Steffen et al., 2002), the capacity to perform daily tasks (Wade and Collin, 1988), and upper-body strength (Bohannon, 2008) in older adults. In this study, physical performance was considered as the sum of mobility, balance and aerobic endurance.

2.4.1. Primary outcome

Mobility was assessed using the timed "Up-and-Go" test (TUG) (Podsiadlo and Richardson, 1991), which measures the time needed to stand up from a standard arm chair, walk 3 m, turn around, return to the chair, and sit down again as fast as possible without running. Participants performed three trials and the quickest time was recorded in seconds.

2.4.2. Secondary outcomes

The rectus femoris cross-sectional area (CSA) of the right leg was assessed using a portable ultrasound unit (Sonosite Inc., Bothell, WA, USA). The rectus femoris was chosen due to its superficiality and accessibility to be measured by ultrasonography (Bemben, 2002). It afforded visualization in a single field in all participants; other muscles of the quadriceps femoris could not be included in this manner. The Measurements were performed by a single investigator with 15 years of clinical experience. The procedures were conducted with the participants in a supine position with both legs extended and relaxed, and toes pointing to the ceiling. The transducer was positioned midway between the epicondylus lateralis and the greater trochanter of the femur. The distance between these points was measured using a measuring tape. Care was taken to ensure that the transducer was placed perpendicularly to the skin surface, using contact gel and minimal pressure to avoid compression of the muscle and achieve a clear image (e Lima et al., 2012). The average of three measurements was recorded as the rectus femoris CSA. Balance was assessed using the Berg Balance Scale (BBS) (Berg et al., 1992). Participants performed 14 tasks common in everyday life with varied difficulty of balance. Each task was scored on a five-point scale (0–4) according to the quality of the performance or the time taken to complete the task; the total score, with a maximum of 56 (higher scores representing better performance), was recorded. Aerobic endurance was assessed using the 6-min walk test (6MWT) (Rikli and Jones, 1999), which measures the maximum distance that can be walked in 6 min along a 30 m corridor. Participants were instructed to walk as fast as possible (without running) and the total walking

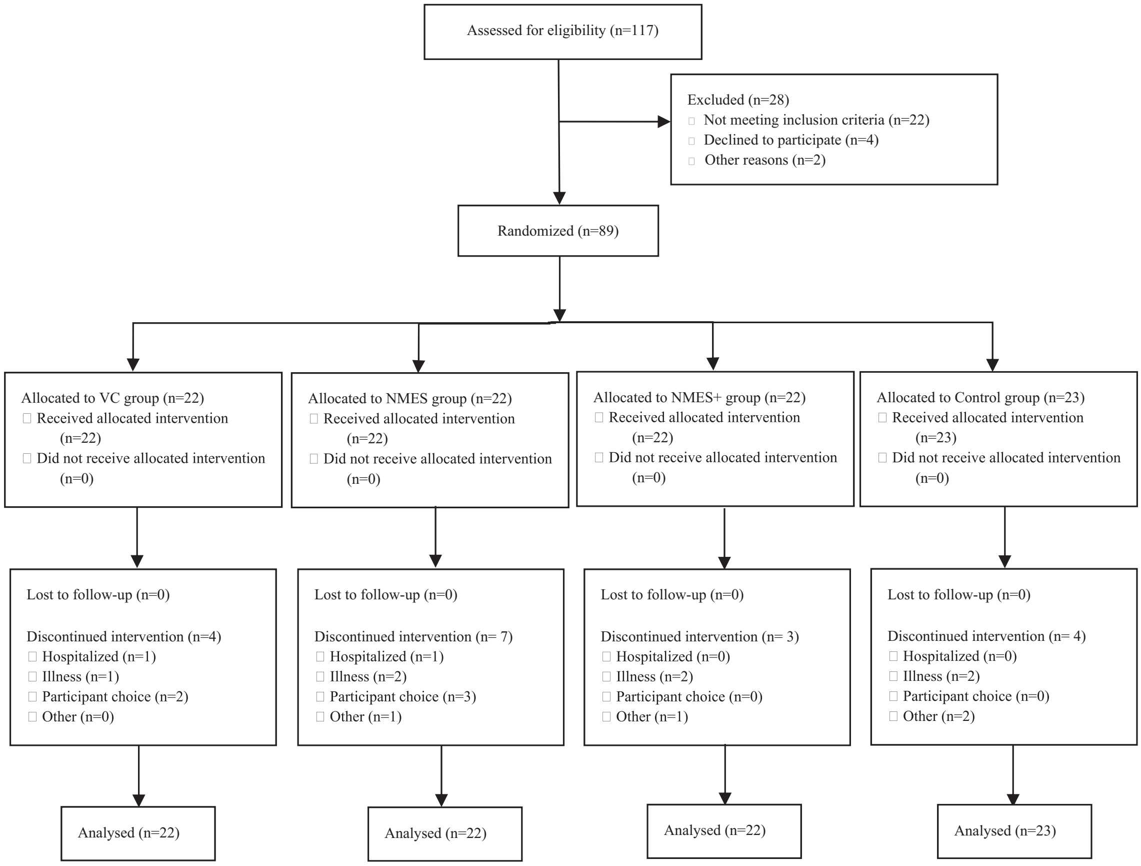

Fig. 1. Flow of participants through the trial.

distance in meters was recorded. Finally, the capacity to perform daily tasks without assistance was assessed using the Barthel Index (BI) (Wade and Collin, 1988). The questionnaire was administered by one of the assessors and the sum of each item score was recorded for analysis.

Upper-body strength was assessed using a Jamar hydraulic hand dynamometer (JAMAR, Sammons Preston Rolyan, Chicago, Illinois, USA). The dominant hand was defined as the preferred hand used for daily tasks and chosen for assessment. During the measurement, participants were instructed to squeeze the dynamometer handle as hard as possible, and to remain seated with the shoulder adducted and neutrally rotated, the elbow flexed at 90°, and the forearm and wrist in neutral position and unsupported (Mathiowetz et al., 1984). Assessors used strong verbal encouragement during the tests and the highest value of three attempts was recorded.

2.5. Intervention

Participants allocated in the intervention groups enrolled in three weekly non-consecutive exercise sessions for 16 weeks. Each session lasted 30 to 35 min, and was performed individually, always under a close supervision of two PTs, who provided guidance and adequate instructions in order to ensure that the exercises were performed properly and safely. All intervention sessions were conducted in the same indoor room. The goal was for all participants in the intervention groups to perform a total of 48 exercise sessions.

In order to calculate the correct intensity of the exercise in all groups, 1RM of the knee extensors was assessed. Dynamic muscle strength was defined as the 1RM or the maximum amount of weight that a participant could lift throughout the complete range of motion (Wood et al., 2002). To calculate the % of 1RM, adjustable ankle cuff weights were used. The participants performed a single repetition with a weight that they could lift through a complete knee extension. In the case of a successful lift, 0.5 to 1 kg was added at the discretion of the assessor for the next attempt, with 60 s rest periods between lifts. This procedure was repeated until the participant could no longer lift the weight to complete a full knee extension. The highest value of weight lifted successfully was recorded as the 1RM. The procedure was calculated at the beginning of the intervention period and every two weeks until the intervention period was completed.

2.5.1. VC group

The participants performed knee extension exercises in both legs using adjustable ankle cuff weights. The participants started the exercise seated in a "quadriceps chair" with 90° knee and hip flexion and then the leg was extended to a full knee extension. All participants performed three sets of fifteen repetitions in each leg with a 3-minute resting period between sets. The participants were instructed to raise the weight in 1 s (concentric phase), keep a full knee extension for 3 s (isometric phase) and slowly lower the weight in 2 s to the starting position (eccentric phase). Each contraction was followed by a 2-second rest period, and the training intensity was set at 40% of 1RM.

2.5.2. NMES and NMES + groups

Participants allocated to the NMES group and NMES + group, incorporated NMES or NMES + to the knee extension exercise performed involuntarily or voluntarily, respectively. The NMES technique consisted of the application of an electrical current to the neuromuscular junction in order to generate evoked muscle contractions with participants asked not to participate with voluntary contractions. An electrical stimulus was applied through the skin of the thigh using surface electrodes connected to portable devices (TensMed S82). Four adhesive surface electrodes (5×5 cm) were placed on the distal medial and proximal lateral portions of the subject's anterior thigh (Lyons et al., 2005), as findings show that the longitudinal electrode position produces significantly more torque than the transverse position when the knee extensor muscles are electrically stimulated (Brooks et al., 1990). A biphasic symmetrical square waveform with a frequency maintained at 50 Hz and phase duration of 400 μ was used. The pulse current was delivered with a ramp-up time of 1 s increasing intensity as the knee was extended from 90° to full extension, a total of 3 s keeping the knee in full extension, 2 s of ramp-down decreasing intensity and gradually returning the knee to the starting position of 90° of flexion, and an off time of 2 s as a rest period. The NMES group current intensity was adjusted to tolerance and maintained according to reach a full knee extension while participants used ankle cuff weights set at 40% of their 1RM during each contraction. The NMES+ group performed the same knee-extension exercises and weight-lifting protocol as the VC group, and incorporated simultaneously the neuromuscular electrical stimulation protocol as the NMES group during the voluntary contraction. The NMES+ group current intensity was adjusted to tolerance and training intensity was set at 40% of their 1RM.

2.5.3. Control group

The participants in the control group did not receive any intervention. Moreover, they were asked to resume their ordinary daily living and not participate in any kind of exercise program throughout the study, as this could influence the results.

2.6. Data analysis

The desired sample size was calculated by an external researcher not involved in the procedures, and therefore blind to the intervention. The calculation was based on detecting changes in mobility (2 s) and rectus femoris CSA (1 cm^2), and we selected the larger result from the two calculations, which would provide adequate power for detecting both differences. With a statistical power equal to 80% and an alpha risk of 0.05, a sample size of 22 patients per group was necessary.

The statistical analysis was performed according to intention-to-treat. To compare the success of randomization, preliminary analyses of variance and chi-squared tests were used to determine baseline differences between groups.

Two-way mixed ANOVA tests were used to compare the study effects on TUG, rectus femoris CSA, BBS, hand-grip strength, Barthel Index and 6MWT between groups, with the exercise period serving as the within-group factor and the intervention type as the between-group factor. The data are presented as the mean ± SD. Statistical analyses were performed using SPSS 17.0 for Windows (SPSS Inc., Chicago, Ill). $P < .05$ was considered statistically significant.

3. Results

Baseline descriptive characteristics of all participants are summarized in Table 1. No significant differences were found between groups, indicating successful randomization of participants.

Seventy-eight percent of the participants in the intervention groups attended to complete the 48 planned sessions during the 4-month intervention period. A session was considered completed when 100% of the exercises were successfully performed. In cases of missed sessions, make-up sessions were provided. Reasons for missing sessions were hospitalization, illness, participant choice or others (family visit, medical examination or chiropodist). During the assessment sessions and intervention period, no significant adverse effects were reported by any of the participants.

The results of the two-way ANOVA showed a significant group × time interaction effect for mobility (TUG) ($P = .022$, $\eta_p^2 = .155$, statistical power = .749), rectus femoris CSA ($P = .001$, $\eta_p^2 = .292$, statistical power = .965), and capacity to perform daily tasks (BI) ($P = .05$, $\eta_p^2 = .116$, statistical power = .617). In addition, ANOVA revealed a significant time effect for hand-grip strength (baseline vs 4-month intervention; $P = .044$, $\eta_p^2 = .070$, statistical power = .525) and balance (BBS) ($P = .044$, $\eta_p^2 = .067$, statistical power = .525).

The within-group analysis reported significant improvements in the rectus femoris CSA in all intervention groups (VC .54 cm, 95% confidence interval (CI) = .09–1.00 cm; $P = .02$; NMES 1.00 cm, 95% CI = .53–1.48 cm; $P < .001$; NMES+ 1.31 cm, 95% CI = .88–1.75 cm; $P < .001$). Mobility (TUG) showed significant improvements in the NMES+ group (−2.7 s, 95% CI = −5.0 to −.3 s; $P = .026$), no significant changes in VC and NMES groups, and a significant decrease in the control group (2.5 s, 95% CI = 0–4.9 s; $P = .05$). The capacity to perform daily tasks (BI) improved significantly in all intervention groups (VC 6.4, 95% CI = 2.2–10.6; $P = .003$; NMES 4.4, 95% CI = 0–8.8; $P = .052$; NMES+ 4.7, 95% CI = .6–8.9; $P = .027$) but not in the control group (2.5, 95% CI = −7.6–2.6; $P = .331$).

The time–effect analysis for the hand-grip strength revealed a significant decrease in all groups, with a more pronounced decrease in the control group. Likewise, a significant time effect was found for the balance scores. All intervention groups tended to improve, whereas the control group scores tended to decrease. Finally, the analysis found no significant effects for the aerobic endurance. The 6MWT distance tended to increase in all intervention groups, whereas in the control group it tended to decrease (Table 2).

4. Discussion

To the best of our knowledge, the current study is the first to compare the efficacy of volitional contraction, NMES evoked contraction, and superimposed NMES onto volitional contraction using a low-intensity (40% of 1RM) exercise to improve muscle CSA, physical performance and the capacity to perform daily tasks in older adults. We sought to develop a relatively short-term exercise intervention, safe, accessible, and easy to follow, that would help older adults living in geriatric nursing homes to gradually reduce the age-related decline in their physical condition. This study was demonstrated to be safe, with no major side effects reported during the intervention. Additionally, the mean study attendance rate at 4 months was 78% a rate considerably higher than that for other facility-based individual exercise programs (Hong et al., 2008) suggesting that the exercise was appropriate for and well tolerated by the participants.

Table 1
Baseline characteristics of participants according to study group.

Characteristic	VC (n = 22)	NMES (n = 22)	NMES+ (n = 22)	Control (n = 23)	*P*-value
Age, mean ± SD*	85.5 ± 4.7	82.9 ± 4.3	83.6 ± 3.6	83.6 ± 5.6	.88
Weight, kg, mean ± SD*	65.1 ± 11.3	62.7 ± 7.7	63.6 ± 11.1	64.7 ± 9.8	.87
Height, cm, mean ± SD*	153 ± 7	153 ± 8	155 ± 9	154 ± 7	.79
BMI, kg/m^2, mean ± SD*	27.8 ± 4.6	26.7 ± 2.8	26.6 ± 3.3	27.6 ± 4.5	.80
Female, %,†	68.1	63.6	63.6	65.2	.988

P-values for *one-way analysis of variance for continuous variables, †chi-square test. VC = volitional contraction; NMES = neuromuscular electrical stimulation; NMES+ = neuromuscular electrical stimulation superimposed onto voluntary contraction. SD = standard deviation.

Table 2
Significance by ANOVA of the main effects (group × time).

Variable	Group	*Mean ± standard deviation* Baseline	After 4-month intervention	Analysis of variance (group × time), *P*-value	Effect size[‡]	Post hoc analysis*
Timed up and go test, s	VC	13.01 ± 5.96	10.97 ± 3.09	F = 3.482, .022	.155	NMES+, VC and NMES Control
	NMES	11.92 ± 5.52	11.04 ± 4.22			
	NMES+	13.30 ± 7.61	10.65 ± 4.16			
	Control	9.94 ± 2.21	12.41 ± 7.42			
Rectus femoris perimeter, cm^2	VC	3.33 ± .92	3.97 ± 1.27	F = 6.744, .001	.292	VC, NMES and NMES+ Control
	NMES	3.31 ± 1.80	4.31 ± 1.97			
	NMES+	3.13 ± 1.17	4.44 ± 1.64			
	Control	3.96 ± .1.25	3.97 ± 1.30			
Hand-grip strength, kg	VC	18.82 ± 4.97	18.76 ± 5.73	F = 2.175, .101	.104	
	NMES	19.35 ± 8.77	19.07 ± 10.02			
	NMES+	20.18 ± 8.22	20.00 ± 8.29			
	Control	22.38 ± 7.30	20.15 ± 7.70			
Berg Balance Scale (0–56)	VC	46.64 ± 5.09	48.29 ± 6.61	F = 1.742 .168	.081	
	NMES	47.66 ± 5.74	48.66 ± 5.09			
	NMES+	46.83 ± 5.73	49.27 ± 5.64			
	Control	49.38 ± 4.85	48.53 ± 5.75			
6-Minute Walk Test, m	VC	270.11 ± 105.40	277.88 ± 11.18	F = 1.620, .194	.073	
	NMES	291.31 ± 122.93	304.68 ± 127.14			
	NMES+	305.83 ± 115.38	312.88 ± 128.24			
	Control	311.28 ± 101.63	297.50 ± 111.18			
Barthel Index (0–100)	VC	85.83 ± 12.27	92.22 ± 6.69	F = 2.637, .05	.116	VC, NMES and NMES+ Control
	NMES	90.00 ± 11.97	94.37 ± 6.80			
	NMES+	88.61 ± 12.69	93.33 ± 7.47			
	Control	95.83 ± 5.57	93.33 ± 6.51			

*A post hoc analysis was performed using the Bonferroni method. ‡Partial eta squared ($^{2}_{p}$). VC = volitional contraction; NMES = neuromuscular electrical stimulation; NMES+ = neuromuscular electrical stimulation superimposed onto voluntary contraction.

Our results showed that the rectus femoris CSA and the capacity to perform daily tasks significantly increased in the three intervention groups. Furthermore, our main finding was that the NMES+ group showed the most significant improvement in mobility and a better tendency to improve balance performance.

Three recently published studies have shown that volitional contraction (Van Roie et al., 2013; Watanabe et al., 2013) or NMES evoked contraction exercise (Altubasi, 2012), performed at low and very low intensities (20–40% of 1RM), can result in muscle size gains. These studies reported improvements between 2.6% and 5.8% in the upper leg and quadriceps femoris volume after a 12-week training period. The results of the present study showed a muscle size increase in rectus femoris CSA of 16.3% and 30.4% in the VC and NMES groups, respectively. Nevertheless, the most remarkable gains were observed in the NMES+ group (42.1%). Differences in percentages compared with previous studies could be explained by the amount of muscle volume assessed, the length of the intervention, and the characteristics of the voluntary and electrically evoked contractions. The aforementioned studies assessed the total upper leg muscle volume or the total quadriceps femoris muscle volume using computer tomography (CT) (Van Roie et al., 2013) or magnetic resonance (MG) (Watanabe et al., 2013), while the present study assessed by ultrasonography, only a single part of the whole muscle volume trained. Moreover, the present study lasted 4 weeks longer than previous studies (Altubasi, 2012; Van Roie et al., 2013; Watanabe et al., 2013), which may account for a greater CSA increase.

Additionally, because of the specific characteristics of the electrically evoked contractions, the percentage of muscle volume involved during the exercise was not the same as in the volitional contraction exercises. It has been suggested that NMES would specifically stimulate the superficial fibers of the whole muscle volume (Maffiuletti, 2010; Vanderthommen and Duchateau, 2007). In addition, following Henneman's "size principle", during voluntary contraction, motor units (MUs) are recruited in an orderly fashion from small (slow) to large (fast) in relation to the stimulus intensity (Henneman et al., 1965) whereas, during electrically evoked contraction, the MU recruitment pattern has been defined as a spatially fixed and temporally synchronous (Vanderthommen and Duchateau, 2007). As a consequence, NMES favors the activation of large and small MUs, imposing a contractile activity of both MUs even at relative low intensities (Maffiuletti, 2010). These facts may explain that a superficial muscle such as rectus femoris was more highly activated in both NMES groups as compared to the voluntary contraction group. On the other hand, because of its hip flexor condition, the rectus femoris may not have participated as much in a voluntary exercise protocol using knee extension, in comparison to NMES protocols, where the stimulation was applied regardless of its biomechanics.

Gains in muscle size do not automatically guarantee functional performance improvements (Liu and Latham, 2011; Miszko et al., 2003; Van Roie et al., 2013). Accordingly, and in line with previous low-intensity exercise training studies, significant muscle CSA gains in VC and NMES groups were not accompanied by significant improvements in mobility (Van Roie et al., 2013), aerobic endurance (Seynnes et al., 2004) and balance (Rosie and Taylor, 2007). However, the NMES+ group showed a significant improvement in mobility and better gains in the balance performance, which may be explained by the cumulative effects of both techniques.

Finally, diminished hand-grip strength has been associated with premature mortality, disability and other health-related complications in older adults (Bohannon, 2008; Rantanen et al., 1999). Although our results showed no significant hand-grip improvement (because of the absence of specific upper extremity exercise training), the maintenance of hand-grip strength in all intervention groups compared to the decrease shown in the control group, may represent an attenuation of age-related decline.

This study has several limitations. First, the relatively short duration of the intervention may have truncated the time needed to achieve greater improvements. In addition, it was not possible to assess the long term effect of the intervention because of the absence of follow-up measurements. Second, rectus femoris CSA was assessed using ultrasonography. Muscle volume can be measured using a variety of techniques, including computer tomography (CT) and magnetic resonance (MR). However, such measurements require expensive equipment and specific expertise to interpret the images, and in the first case involve the exposure of the subjects to ionizing radiation (Menon et al., 2012). Ultrasound apparatus, on the other hand, is an easily available, portable, valid, safe and reliable alternative to CT and MG for measuring superficial muscles such as rectus femoris CSA (Sipila and Suominen, 1991; Thomaes et al., 2012). Nevertheless, the rectus femoris only represents a part of the quadriceps femoris. It would have been more appropriate to assess the whole quadriceps muscle volume and/or to measure knee extension strength. Third, experimented experienced PTs motivated to help participants were successful in conducting the exercise sessions. It was evident that participants were highly enthusiastic about the study. Given the simplicity of the training required, less experienced PTs could be equally successful, but that remains to be shown. Fourth, participants were healthy individuals living in a geriatric nursing home, and are therefore not representative of all older adults at large. Consequently, caution should be exercised in generalizing these findings over infirm or diseased older adults.

We conclude that, from a short-term perspective, a low-intensity NMES + exercise program may be useful to improve physical performance, rectus femoris CSA, and the capacity to perform daily tasks in older adults living in a geriatric nursing home. These findings, associated with the characteristics of the program, support the idea that low-intensity NMES + exercises are useful to partially mitigate the age-related consequences in this study population, but further follow-up studies are required to confirm these results.

Conflict of interest

The authors report no personal conflict of interest or any financial support received related to this manuscript.

Author contributions

Study concept and design: V. Benavent-Caballer, JF Lison, P Rosado-Calatayud and JJ Amer-Cuenca and E Segura-Ortí. Acquisition of participants and data: JF Lison, JJ Amer-Cuenca, E Segura-Ortí. Analysis and interpretation of data: V. Benavent-Caballer and JF Lison. Preparation of manuscript: V. Benavent-Caballer, JF Lison, JJ Amer-Cuenca, E Segura-Ortí and P Rosado-Calatayud. All authors approved the final manuscript.

Sponsor's role

None.

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Summary (Spanish)

Efectos de tres programas diferentes de ejercicios realizados a baja intensidad sobre la capacidad funcional, el volumen muscular y las actividades de la vida diaria: Un estudio controlado y aleatorizado.

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Objetivos: Este estudio pretende evaluar los efectos a corto plazo de tres programas de entrenamiento sobre la capacidad funcional, el volumen muscular y la capacidad para realizar actividades de la vida diaria sobre población mayor residente en un centro geriátrico. Los tres programas se basan en la aplicación de una carga que ofrece una resistencia progresiva dentro de unos parámetros de baja intensidad.

Diseño: Se trata de un estudio controlado y aleatorizado, con una intervención de 4 meses de duración.

Dónde se realizó: El estudio ha sido realizado en el centro geriátrico "*Residencia Geriátrica Hermanitas de los Ancianos Desamparados*" de Valencia, España.

Participantes: Un total de ochenta y nueve participantes con edades comprendidas entre los 75 y 96 años, independientes para realizar sus actividades de la vida diaria y sin alteraciones cognitivas, participaron en este estudio.

Intervención: Tras una valoración inicial, los participantes fueron aleatoriamente asignados al grupo control o bien a alguno de los tres grupos de intervención: contracción voluntaria (VC; n=22), estimulación eléctrica neuromuscular (NMES; n=22), o estimulación eléctrica neuromuscular con contracción voluntaria simultánea (NMES+; n=22). La intervención estaba basada en ejercicios de flexo-extensión de rodilla realizados a una intensidad del 40% de la fuerza máxima extensora de cuádriceps medida mediante la prueba 1RM.

Medidas: La variable principal de estudio fue la movilidad, medida mediante la prueba Timed *"Up and Go"* Test. Las variables secundarias fueron el volumen muscular del músculo recto del fémur medido mediante ecografía, el equilibrio a través de la Berg Balance Scale, la resistencia aeróbica mediante el 6-minute Walk Test, la fuerza de agarre de la mano usando un dinamómetro de mano JAMAR y la capacidad para realizar actividades de la vida diaria a través del cuestionario Barthel Index. Todas las medidas fueron realizadas previamente al inicio de la intervención y tras ser completada a los 4 meses.

Resultados: Tras finalizar la intervención, el ANOVA (Modelo de dos factores de medidas repetidas) mostró una mejora significativa (interacción grupo x tiempo) de la movilidad (*P*=.022), el volumen muscular de recto del fémur (*P*=.001) y la capacidad para realizar actividades de la vida diaria (*P*=.05). El análisis intra-grupo mostró un mayor grado de mejora en el grupo NMES+ respecto al resto de grupos. Se apreciaron mejoras significativas en el volumen muscular del recto del fémur y la capacidad para realizar actividades de la vida diaria en todos los grupos que recibieron intervención. La movilidad solo mejoró en el grupo NMES+ (*P*=.026).

Conclusión: En una intervención a corto plazo, el entrenamiento basado en NMES+ y realizado a baja intensidad, puede mejorar la capacidad funcional, aumentar el volumen muscular y mejorar la capacidad para realizar actividades de la vida diaria. Este tipo de entrenamiento puede ayudar a minimizar parcialmente las consecuencias derivadas del envejecimiento.

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The effectiveness of a video-supported group-based Otago exercise programme on physical performance in community-dwelling older adults: a preliminary study

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Abstract

Objectives To evaluate the short-term effects of a video-supported group-based Otago exercise programme (OEP) on physical performance variables in independent community-dwelling older adults.
Design Preliminary randomized controlled trial.
Setting Local senior centre.
Participants Fifty-one adults aged 65 and older with no cognitive impairment.
Intervention Participants were randomly allocated to the intervention group (IG) or to the control group (CG). During 4 months, IG participants performed the exercise routine.
Measurements The primary outcome measure was the Timed 'Up-and-Go' test (TUG). Secondary outcome measurements included functional balance, one-leg balance, lower-limb function and aerobic endurance. All data were collected before and after intervention.
Results TUG scores showed a significant reduction in the performance time in the IG compared to CG after intervention [IG 7.5 (2.0) vs CG 8.8 (1.9), mean difference −1.3 seconds, 95% confidence interval (CI) of the difference −2.3 to −0.1; $P = 0.03$]. Secondary outcomes also showed a significant improvement in the performance of the functional balance [IG 54.9 (2.5) vs CG 51.4 (5.3), mean difference 3.5 points, 95% CI 1.2 to 5.8; $P = 0.003$], one-leg balance [IG 39.1 (21.6) vs CG 15.6 (12.1), mean difference 23.5 seconds, 95% CI 13.3 to 33.7; $P < 0.001$] and lower extremity strength [IG 8.7 (3.8) vs CG 10.9 (3.3), mean difference −2.2 seconds, 95% CI −4.2 to −0.1; $P = 0.035$] in the IG compared to CG.
Conclusion This study shows that, from a short-term perspective, a video-supported group-based OEP programme can significantly improve the levels of mobility, functional balance, one-leg balance and lower extremity strength in community-dwelling older adults.
Trial registration ClincicalTrials.gov ID: NCT02218411.

Keywords: Otago exercise programme; Physical performance; Older adult; Community dwelling; Randomized controlled trial

Introduction

The ageing process is characterized by a progressive decrease in muscle mass and strength that especially accelerates after the sixth decade of life [1,2]. Strength loss may reach up to 1 to 3% per year, showing higher rates in the lower extremities [3,4] even in healthy older adults. These losses, combined with the reduction of physical activity [5], have been associated with a functional decline [6], an increase

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in fall risk [7], the loss of independence [8], institutionalization [9] and, finally, an increase in mortality risk [10]. Therefore, treating or reversing these disabling age-related consequences is of vital importance in the maintenance of health and life expectancy, and an essential public health goal for the 21st century [11].

Different types of exercise programmes have been conducted during the past few decades, focusing on the maintenance and improvement of the functional performance and health-related quality of life in older adults [12–14]. Consequently, it has been widely demonstrated that regular exercise and physical activity provide substantial health benefits and attenuate the ageing phenomenon [15,16]. Furthermore, recent exercise and physical activity guidelines for older adults stress the importance of using multi-modal exercise programmes, which should include strengthening, balance, and cardiovascular exercises [17,18]. The Otago exercise programme (OEP) incorporates all these suggested aspects.

The OEP consists of progressive-resistance strength exercises, balance exercises related to everyday activities, and aerobic exercises supplemented with walking periods [19]. Commonly, it has been conducted at the patients' homes following a written booklet [20–23]. Its effectiveness has been demonstrated by improved muscle strength, functional balance and physical performance in older adults [24–26]. Recently, the group-based modality has been proved to be as effective as the home-based one [27], and it has been recommended for use in conjunction with other group activities [19]. Additionally, engaging a group-based exercise programme provides the opportunity for social interaction during the training sessions of the programme [18], and therefore supports the promotion of physical activity in community-dwelling older adults.

On the other hand, the use of video materials in exercise programmes has reported significant improvements on physical performance [28,29] and physical activity levels [30] in community-dwelling older adults. The use of video can provide accurate visual guidance on how to perform the exercises, in addition to verbal instructions and background music that could be motivational for the participants [28].

To the best of our knowledge, the combination of video-support with a group-based modality has not yet been explored in the OEP. Therefore, the purpose of this study was to evaluate the effects of a video-supported group-based OEP intervention on the mobility and other physical performance variables in community-dwelling adults aged 65 or older.

Methods

Study design

This preliminary randomized controlled study (Clincical-Trials.gov ID: NCT02218411) follows the recommendations of the Consolidated Standards of Reporting Trials [31]. The design, protocols and informed consent procedure of the study were approved by the Bioethics and Clinical Research Committee of UCH-CEU University. All participants included in this study provided written informed consent and were randomly assigned to the intervention group (IG) or to the control group (CG) after baseline assessment. Participants were assessed at baseline and at the end of a 4-month intervention by the same independent assessors. The study was carried out in full compliance with the ethical guidelines of the Declaration of Helsinki.

Study participants and selection criteria

The sample consisted of community-dwelling people, aged 65 years or older, from Valencia, Spain. Fifty-five potential participants were voluntarily recruited through advertisements in the bulletin board of a local community centre as well as through presentation by researchers to community groups. Recruitment started in September 2012 and was completed in January 2013. Fig. S1 shows the participants flowchart through the trial. After an individual interview conducted by a physical therapist (PT) with 25 years of clinical experience in older adults, eligible participants were screened for inclusion. During the interview, all participants received fully explained and comprehensive information of the proposed study, its duration, objectives, benefits, and risks. The inclusion criteria were that the participants should be 65 years of age or older, live in the community, be able to ambulate independently without a walking aid, have no severe medical contraindication for physical activity, be able to communicate, have self-reported visual and auditory capacities to follow the exercises, and would provide a signed informed-consent statement. Those who were unable to ambulate independently or had a Mini-mental state examination score of less than 24 [32], a Barthel Index (BI) score of less than 80 [33], severe visual and auditory disabilities, an unstable cardiovascular disease, a neurological disorder that could compromise them from exercising, or an upper- or lower-extremity fracture in the past year, were excluded. Fifty-one of the 55 eligible participants met the inclusion criteria and completed the baseline assessment.

Supplementary Fig. S1 related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.physio.2015.08.002.

Randomization and blinding

After the baseline assessments, participants were randomly allocated to the IG or to the CG using computer-generated random numbers. The group allocation was concealed to the researchers. The assessors who collected the data were blinded to the group allocation; however, it was not possible to conceal the group assignment from the co-investigators involved in the training procedures.

Primary outcome

Five assessors administered the baseline and post-intervention measurements in two assessment sessions. To accommodate the participants' assessments, all test stations were set up in a large indoor room. General mobility was assessed using the Timed 'Up-and-Go' test (TUG) [34]. The participants were instructed to stand up from a standard chair of 45 cm height, walk 3 metre, turn around a cone, return to the chair, and sit down again in the shortest time possible without running. Two trials were performed, and the quicker time in seconds was recorded.

Secondary outcomes

Functional balance was assessed using the Berg Balance Scale (BBS) [35]. The participants were instructed to perform 14 tasks which included simple movements such as sit-to-stand or transfers, and more difficult ones, such as tandem standing, or a 360° turn. The performance of each task was scored on a five-point scale (0 to 4). A total score from 0 to 56 was recorded, with higher scores representing better performance. Aerobic endurance was assessed using the 6-minute Walk Test (6MWT) [36], which measures the maximum distance covered in 6 minutes. Participants were instructed to walk the maximum distance along a 25 metre indoor corridor from one end to the other. The test was performed under the supervision of an assessor who used encouraging standardized sentences during the test such as 'You are doing well' or 'You are doing a good job'. The total walking distance (in metres) was recorded. One-leg balance was assessed using the One-Leg Stand test (OLS) [37]. Participants were instructed to start the test from a standing position with their eyes open and arms at their sides, choose a leg to stand on, flex the opposite knee, allowing the foot to clear the ground, and stand unassisted on one leg as long as possible. The assessor recorded the time in seconds, and noted whether the participant was able to balance for 5 seconds or longer. The timing was stopped if the participant could maintain balance in excess of 60 seconds. Lower-limb function was assessed using the Short Physical Performance Battery (SPPB) [9]. The SPPB includes an assessment of standing balance, usual gait speed, and lower extremity strength. Each component is scored from 0 to 4 points. Standing balance was assessed using three tests (side-by-side, semi-tandem, and tandem position). The participants were instructed to maintain their feet in these positions, with the maximum score awarded for 10 seconds on balance in each test. Usual gait speed was assessed in a 4-metre walking course. Participants were instructed to walk at their usual pace past the end of the course. This test was repeated twice and the shorter time in seconds was recorded, with higher scores given for faster performance. The lower-extremity strength was assessed using the Chair Stand Test. The participants were instructed to stand from a chair five successive times as quickly as possible without the assistance of their arms. Higher scores were given for shorter times (in seconds) to complete the five chair stands. Additionally, a total score from 0 to 12 was obtained by summing the scores of each SPPB component, with higher scores representing better functioning.

All these measures have been suggested to be valid and reliable in assessing older adults; TUG [38], BBS [38], OLS [39], SPPB [40] and 6MWT [38,40].

Intervention

During 4 months, all participants in the IG enrolled in a three-week non-consecutive exercises programme at the community centre. All exercises were undertaken in a large indoor room equipped with a DVD player, a large screen where the video was projected, and a 45 cm height chair for each participant. The exercise routine performed in each session was based on the Otago exercise programme [19,24].

One week before starting the programme, a trained PT instructed and supervised the IG during three familiarization sessions, to help participants understand the video instructions, the correct use of the ankle cuffs, and to ensure a confident, safe and correct exercise performance. The video content provided safety information, verbal instructions and accurate visual guidance on how to perform the exercises during a total of 45 minutes. Additionally, each IG participant received an exercise booklet which illustrated and described all exercises, and ankle cuff weights (starting at 0.5 kg) to provide resistance during the strengthening exercises.

During the training sessions, the video showed four exercise routines for standing and seated positions. Participants stood in front of the projection screen and followed the exercise instructions. The session started with 7 minutes of moderate warm-up exercises focusing on mobility and flexibility, that included head, neck, trunk, back and ankle movements. Secondly, the strengthening exercises were performed, consisting of knee extensions, knee flexions, hip abductions, ankle plantar flexions, and ankle dorsiflexions. Thirdly, a set of balance exercises were performed, consisting of knee bends, backwards walking, walking and turning around, sideways walking, tandem stance, tandem walk, one-leg stand, heel walking, toe walking, toe to heel walking backwards, sit-to-stand, and stair walking. Fourthly, participants were instructed to walk at their usual pace for at least 10 minutes and return to the exercise room. Finally, there was a 10-minute cool-down period after the session was completed. All strengthening and balance exercises were performed at the appropriate level of difficulty during the 4-month intervention, according to a dedicated publication [19]. Additionally, strategies to incorporate walking times into daily activities were suggested.

The same PT who provided the familiarization sessions returned every week to the community centre to encourage participants to persist in the programme and to make progressive adjustments according to the OEP protocol. A total of 46 sessions were performed during the 4-month intervention. The participants of the CG were asked to

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Table 1
Baseline characteristics of participants according to Study Group.

Characteristic	CG ($n=23$)	IG ($n=28$)	P-value
Age, mean (SD)*	69.0 (3.3)	69.1 (4)	0.89
Weight, kg, mean (SD)*	78.7 (16.1)	71.3 (11.8)	0.07
Height, cm, mean (SD)*	159.7 (9)	156.8 (7.8)	0.24
BMI, kg/m^2, mean (SD)*	30.8 (5.4)	29.0 (4.4)	0.19
Female, %†	69	82	0.292

* P-value for independent t-test for continuous variables.
† P-value for chi-square test.
IG = intervention group, CG = control group, SD = standard deviation, BMI = body mass index.

resume their ordinary daily living, and did not receive any intervention during the length of the programme.

Data analysis

Normal distribution of the data was tested using the Kolmogorov–Smirnov test. The necessary sample size was calculated by an external researcher not involved in the procedures, and therefore blind to the intervention. The calculation was based on the TUG time reduction between the estimated mean and the sampling mean. A 1.5 seconds reduction in the TUG was defined as significant. A statistical power equal to 80% and an alpha risk of 0.05, a minimum sample size of 21 patients per group was necessary.

The statistical analysis was performed based on intention-to-treat. To compare the success of randomization, preliminary independent t-tests and Chi-squared tests were used to determine baseline differences between groups. Two-way mixed ANOVA tests were used to compare the study effects on TUG, BBS, OLS, 6MWT and SPPB and its individual components between the two groups, with the intervention period serving as the within-group factor, and the treatment group as the between-group factor. The data are presented as mean (SD). Statistical analyses were performed using SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA). $P<0.05$ was considered statistically significant.

Results

The baseline descriptive characteristics of the 51 participants in the IG and CG are summarized in Table 1. The participants' level of independence to perform the ADL was very good, with a BI mean score of 99 points out of 100 points in both groups. There were no significant baseline differences between groups for age, weight, height, sex, or body composition. Similarly, no significant differences between groups were found for baseline TUG, BBS, OLS, 6MWT, or SPPB scores, indicating a successful randomization of participants.

Adherence

The exercise group mean attendance throughout the study was 77% of the planned sessions. Attendance during first month was 85%, and at the end of the fourth month it was 70%. A session was considered successfully finished when all exercises were completed.

Intervention effects

Significance by the two-way ANOVA of the main effects (group × time interaction) are shown in Table 2. The between-group analysis reported a significant improvement in the primary outcome (TUG), and in BBS, OLS and Chair stand test. Additionally, the within-group analysis revealed that the IG significantly improved across all the studied variables. In marked contrast, the CG reported no significant changes in any outcome. Data analysis revealed maximum baseline scores in the SPPB Static balance component for the IG and CG (4 points).

4. Discussion

The main novel finding of the current study was that a video-supported group-based Otago exercise programme (OEP) induces significant improvements in the mobility, balance and lower-extremity strength in independent community-dwelling older adults.

The vast majority of studies using the OEP have been conducted at the participant' homes, and most of these studies were focused on reducing falls and related injuries [23]. Because the results of home-based interventions are well documented and fall prevention was beyond the scope of the present study, the emphasis of the discussion below will be on the effects of the video-supported group-based OEP on mobility, balance, physical performance and aerobic endurance.

A measure frequently used to assess general mobility in OEP interventions is the Timed 'Up-and-Go' test (TUG). Previous studies have reported positive effects on mobility after different OEP interventions. However, not all studies have shown significant improvements. Home-based OEP interventions reported non-significant changes in patients with moderate Alzheimer's disease [41], haemophilia and blood disorders [21], or participants with a previous fall incident [22]. Nevertheless, group-based [23] and individually assisted [27] OEP interventions in participants with a previous fall incident or in vision-impaired patients, respectively, have reported significant improvements in general mobility. The results of the current study are in line with these studies, showing a significant reduction in the time needed to perform the TUG. It is encouraging that, given the higher level of mobility shown at baseline (IG 9.3 seconds and CG 9 seconds), the intervention was still able to result in a statistically significant improvement when the two groups were compared.

Recently published studies revealed that OEP interventions significantly improved functional balance in a range between 3.2 and 3.5 points when balance was assessed with

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Table 2
Significance by two-way ANOVA.

Variable	Groups	Mean (SD) pre	Mean (SD) post	Post-hoc analysis[a] Between group (post) Mean difference (95% CI)	P-value	Within-group (IG) Mean difference (95% CI)	P-value	Main effects (group × time) P-value	Effect size[b]
Timed Up and Go, seconds	IG	9.3 (1.7)	7.5 (2)	−1.3 (−2.3 to −0.1)	0.03	−1.8 (−2.2 to −1.4)	<0.001	<0.001	0.367
	CG	9 (1.7)	8.8 (1.9)						
Berg Balance Scale (0 to 56 points)	IG	51.5 (4.3)	54.9 (2.5)	3.5 (1.2 to 5.8)	0.003	3.4 (1.9 to 5)	<0.001	<0.001	0.251
	CG	52.6 (3.2)	51.4 (5.3)						
One Leg Stand, seconds	IG	19.2 (15.5)	39.1 (21.6)	23.5 (13.3 to 33.7)	<0.001	19.8 (14.6 to 25.8)	<0.001	<0.001	0.366
	CG	18.8 (13.5)	15.6 (12.1)						
SPPB (total score, 0 to 12 points)	IG	10.7 (1.6)	11.5 (1.5)	0.3 (−0.5 to 1)	0.527	0.8 (0.4 to 1.1)	<0.001	0.006	0.145
	CG	11.3 (1.1)	11.2 (1.2)						
SPPB Gait speed, seconds	IG	3.9 (0.7)	3.2 (0.8)	−0.2 (−0.7 to 0.2)	0.256	−0.7 (−1 to −0.5)	<0.001	0.006	0.142
	CG	3.7 (0.8)	3.5 (0.7)						
SPPB Chair Stand Test, seconds	IG	12.3 (2.8)	8.7 (3.8)	−2.2 (−4.2 to −0.1)	0.035	−3.6 (−4.5 to −2.7)	<0.001	0.001	0.375
	CG	10.9 (2.9)	10.9 (3.3)						
6 Minute Walk Test, metres	IG	372 (65)	393 (68)	24.9 (−16.7 to 66.7)	0.235	21 (10.8 to 31.2)	<0.001	0.002	0.179
	CG	371 (80)	368 (80)						

[a] A post-hoc analysis was performed using the Bonferroni method.
[b] Partial eta squared (η_p^2).
IG = intervention group, CG = control group, SD = standard deviation, CI = confidence interval, SPPB = short physical performance battery.

the Berg Balance Scale (BBS) [26,27,42]. In agreement with these results, intervention group (IG) showed an improvement of 3.5 points in the total BBS score compared to control group (CG). Despite the similarities between results, baseline BBS scores shown in the current study were considerably higher compared to those established in previous studies. As reported by Rejesky *et al*, baseline values intrinsically affect changes in functional performance, with higher gains obtained in participants with the worst baseline performance [43]. On the other hand, limited OEP interventions have measured static balance using the One-Leg Stand test (OLS). Campbell *et al*. reported improvements when one-leg balance was assessed for 10 seconds [24]. In the present study, the improvements shown by the IG vs CG in the OLS (23.5 seconds) were considerably higher than the Clinically Meaningful Improvement (CMI) reported by Maribo *et al*. (6.8 seconds) [44]. This result suggests that the programme may be effective for enhancing one leg balance on this study population.

Between-groups data analysis showed no significant differences in the total score of the Short Physical Performance Battery (SPPB). Additionally, supplementary data analyses of intervention effects on the individual components of the SPPB were conducted. Given the participants high levels of functioning at baseline, a ceiling effect in the static balance tests (side-by-side, semi-tandem and tandem-stand) was found. Consequently, data analysis revealed no changes in static balance for either group. Chair Stand test data analysis showed a significant reduction of time needed to perform the test -2.2 seconds in favour of the IG when the two groups were compared. This result is consistent with previous studies reporting improvements after a home-based OEP intervention in healthy [24] and mild-balance [45] older adults. Baseline gait speed scores were above the threshold considered for full community ambulance independence in older adults (more than 0.8 m/s) [46]. Between groups analysis reported no significant improvements in the gait speed. However, the within-group analysis showed significant improvements in the IG.

Finally, data analysis revealed a non-significant improvement in the total distance covered in the 6-minute Walk Test (6MWT) when the two groups were compared. However, the within-group analysis of the IG reported a significant improvement (21 metre). On the other hand, and in agreement with previous studies [24], a 10 minute walk at the end of each training session was found to be insufficient for reaching a between-groups significant improvement.

This study has several limitations. Firstly, there was no follow-up performed to determine any long-term effects of the intervention, the adherence to exercises routines, and the maintenance of accrued benefits. Secondly, the participants were predominantly female (76%), although randomization revealed no sex difference between groups. Thirdly, lower-limb strength measures were scarce, and given the range of strengthening exercises in the OEP, the inclusion of more direct and indirect strength measures would have been helpful. Fourthly, the study participants were volunteers who responded to advertisement, well-functioning, and with a high independence level, which characteristics may not be representative of the older adults' population at large. Consequently, care should be taken in generalizing these findings. Finally, the inclusion of a third group receiving a group-based OEP intervention with no video support could have isolated the effects of the video materials.

In summary, this preliminary study shows that a video-supported group-based Otago Exercise Programme programme can significantly improve the levels of mobility, balance and lower-extremity strength in independent community-dwelling older adults compared to the control group. Additionally, this programme has demonstrated to be safe; it reported high levels of attendance (77%); it may effectively promote socialization among the participants. This manner of implementing the Otago Exercise Programme could allow it to reach elderly populations in outlying geographical areas, who would not be able to attend usual physiotherapy care or participate in activity trials conducted at medical centres or universities. These findings could have considerable public-health impact by providing interesting new data on multi-modal exercises programmes even in well-functioning older adults. However, further follow-up programmes designed for older adults using visual support and conducted group-based are required to confirm and develop these findings.

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Summary (Spanish)

Efectividad del *Otago Exercise Programme* realizado en grupo y con apoyo audiovisual sobre la capacidad funcional en adultos mayores residentes en la comunidad: Un estudio preliminar.

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Objetivos: Este estudio pretende evaluar los efectos a corto plazo de un programa de ejercicios basado en el *Otago Exercise Programme* (OEP), realizado en grupo y con apoyo audiovisual sobre variables relacionadas con la capacidad funcional, en una población de adultos mayores independientes que residen en la comunidad.

Diseño: Se trata de un estudio controlado y aleatorizado, con una intervención de 4 meses de duración, entre los meses de Febrero y Mayo de 2013.

Dónde se realizó: El estudio se realizó en el centro social para la tercera edad "*Centro Municipal de Actividades para Personas Mayores Sant Pau*" de Valencia, España.

Participantes: Un total de cincuenta y un participantes con edades comprendidas entre 65 y 82 años independientes para realizar sus actividades de la vida diaria y sin presencia de deterioro cognitivo participaron en este estudio.

Intervención: Tras una valoración inicial, los participantes fueron aleatoriamente asignados al grupo control (CG) o al grupo intervención (IG). Durante 4 meses, los integrantes del IG siguieron una rutina de tres sesiones semanales de 50 minutos de duración en las que realizaron los ejercicios descritos en el *Otago Exercise Programme*, supervisados por un fisioterapeuta y con el apoyo de material audiovisual a través del cual se exponían los ejercicios y su correcta ejecución.

Medidas: La variable principal de estudio fue la movilidad medida mediante la prueba Timed "*Up and Go*" Test (TUG). Además, se estudiaron otras variables secundarias como el equilibrio funcional mediante la Berg Balance Scale (BBS), el equilibrio

unipodal usando el One-leg Stand Test (OLS), la funcionalidad de miembro inferior a través de la Short Physical Performance Battery (SPPB) y la resistencia aeróbica durante la marcha mediante la prueba del 6-minute Walk Test. Todas las medidas fueron realizadas antes de iniciar la intervención y tras finalizarla 4 meses después.

Resultados: El ANOVA (Modelo de dos factores de medidas repetidas) mostró una reducción significativa en el tiempo de ejecución del TUG mostraron en el IG comparado con los valores del CG después de la intervención [GI 7.5 (2.0) vs CG 8.8 (1.9), diferencia de medias -1.3 segundos, P=.03]. Los resultados de las variables secundarias, también mostraron una mejoría significativa de la BBS [IG 54.9 (2.5) vs CG 51.4 (5.3), diferencia de medias 3.5 puntos, P=.003], el OLS [IG 39.1 (21.6) vs CG 15.6 (12.1), diferencia significa 23.5 segundos, P<.001] y la fuerza en las extremidades inferiores [IG 8.7 (3.8) vs CG 10.9 (3.3), la diferencia de medias -2.2 segundos, P=.035] medida mediante la sub-tarea incluida dentro de la batería SPPB Repeated Chair Stand Test, en el IG comparado con el CG.

Conclusión: Este estudio muestra que desde una perspectiva a corto plazo, un programa de ejercicios basado en el OEP cuando se realiza en grupo y tiene apoyo audiovisual puede mejorar significativamente los niveles de movilidad, equilibrio funcional, equilibrio unipodal y la fuerza en las extremidades inferiores, en los adultos mayores independientes que residen en la comunidad.

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Original Article

Factors associated with the 6-minute walk test in nursing home residents and community-dwelling older adults

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Abstract. [Purpose] The main objective of this study was to determine the contributions and extent to which certain physical measurements explain performance in the 6-minute walk test in healthy older adults living in a geriatric nursing home and for older adults dwelling in the community. [Subjects] The subjects were 122 adults aged 65 and older with no cognitive impairment who were independent in their daily activities. [Methods] The 6-minute walk test, age, body mass index, walking speed, chair stand test, Berg Balance Scale, Timed Up-and-Go test, rectus femoris cross-sectional area, Short Physical Performance Battery, and hand-grip strength were examined. [Results] Strong significant associations were found between mobility, lower-limb function, balance, and the 6-minute walk test. A stepwise multiple regression on the entire sample showed that lower-limb function was a significant and independent predictor for the 6-minute walk test. Additionally, lower-limb function was a strong predictor for the 6-minute walk test in our nursing home group, whereas mobility was found to be the best predictor in our community-dwelling group. [Conclusion] Better lower-limb function, balance, and mobility result in a higher distance covered by healthy older adults. Lower-limb function and mobility appeared to best determine walking performance in the nursing home and community-dwelling groups, respectively.

Key words: 6-minute walk test, Physical performance, Older adults

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INTRODUCTION

The life expectancy of the world population is rising[1)]. In developed countries, such as European countries or the U.S., the proportion of older adults has rapidly increased in recent years[2)]. Current estimates project that the number of older adults will double in the next 30 years[3)], changing the structure of the elderly population. The aging process is accompanied by a gradual decrease in exercise capacity and changes in function[4)], which may affect the ability to perform daily tasks and maintenance of personal independence[5, 6)]. The ability to walk has demonstrated important implications in the preservation of function and independence[7)], and it is a key component of health-related quality of life[8)].

The 6-minute walk test (6MWT) is a quick and inexpensive performance-based measure widely used in exercise rehabilitation[9)] and clinical research[10)], both in healthy[11–14)] and impaired[15–18)] older adults. Originally developed by Butland et al. in 1982[19)], the 6MWT measures the total distance walked during a 6-minute period[20)]. The test has established a good reliability[21)], and it is a valid measure for overall physical functional performance[20)] and exercise capacity at levels corresponding to efforts commonly performed during daily tasks[22)]. It has been reported that performance in the 6MWT is determined by a range of factors, including age, gender, height, and weight[11, 23)]. Additionally, correlations between the 6MWT and mobility-related and physical measures have been found in community-dwelling older adults and nursing-home residents[10, 24, 25)]. These observations suggest that performance in the 6MWT may be influenced by different demographic and physical measures. However, to the best of our knowledge, it has not been established which factors better explain 6MWT performance in older adults' populations. It seems important to identify physical-function measures that better explain the capacity to walk so that therapists can include them in the assessment protocol for the aged population and therefore design the most appropriate interventions aimed at mitigating the walking decline associated with age.

The main purpose of the present study was to investigate a range of demographic factors and physical measures for their relative contributions and extent to which they may explain the results of the 6MWT in older adults. A secondary purpose of this study was to compare the factors explaining the 6MWT between older adults dwelling in the community and those living in a geriatric nursing home.

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SUBJECTS AND METHODS

The design of this cross-sectional analysis (ClinicalTrials.gov ID: NCT02218411) and the informed consent procedure were approved by the Bioethics and Clinical Research Committee of UCH-CEU University. All participants provided a signed written informed-consent statement regarding their participation in the study.

The sample for this analysis consisted of healthy nursing home (NH) residents and community-dwelling (CD) older adults aged 65 years or older from Valencia, Spain. The participants were volunteers who were recruited through advertisements on the bulletin boards in a local community center and a geriatric nursing home, as well as through presentations by researchers in both centers. The sample recruitment started in September 2012 and was completed in January 2013. A physical therapist (PT) with 27 years of clinical experience conducted individual interviews to screen all potential participants for inclusion. All participants received detailed information about the purpose of the study and its objectives. Participants who 1) were >65 years of age; 2) were able to ambulate independently without walking aids, 3) had no severe medical contraindications to performance of physical activities, 4) were able to communicate, and 5) provided a signed informed-consent statement were included in the study. Participants who 1) were unable to ambulate independently, 2) had a Mini-Mental State Examination (MMSE) score of <24[26], 3) had a Barthel Index (BI) score <80[27], 4) had an unstable cardiovascular disease or a neurological disorder that could compromise them during the performance of physical activities, or 5) had an upper- or lower-limb fracture in the past year, were excluded. One hundred twenty-two of the 172 eligible participants met the inclusion criteria and were enrolled in the study. Figure 1 shows the flow of the participants through the trial.

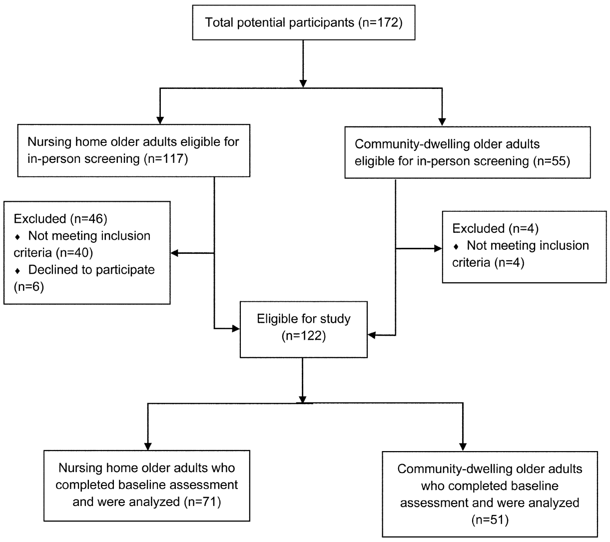

Fig. 1. Flow chart of participants and screening

Five independent assessors recorded all measurements in a single assessment session, except for the rectus femoris cross-sectional area (CSA), which was assessed on a consecutive day. On the first day, participants were assessed for baseline demographics, health status, and physical measures. To enable assessment of the participants, a total of four functional test stations were set up in a large indoor room, except for the 6MWT, which was performed in a long indoor corridor next to the assessment room. Measurements were chronologically organized in order to minimize fatigue, and they were recorded in the following order.

Balance was assessed using the Berg Balance Scale (BBS). This test consists of 14 tasks common in everyday life with varied difficulty of balance (5 static and 9 dynamic). An experienced PT administered the test following the published guidelines[28]. Each task was graded on a 5-point scale of 0 (“unable to perform” or “need assistance”) to 4 (“able to perform independently”) according to the participant’s performance or the time taken to complete the task. At the end of the test, individual task scores were summed for a potential maximal score of 56 points (higher scores representing better performance).

Mobility was assessed using the Timed Up-and-Go test (TUG)[29], which measures the time needed to rise from a chair, walk 3 meters as quickly as possible to reach a plastic cone, turn around the cone, return to the chair, and sit down again. Participants were instructed to start the test seated in a chair with their arms resting on the armrests and feet flat on the floor. One practice trial was conducted before the participants performed three test trials. The assessor recorded the time from the command “go” until the participant’s back touched the backrest of the chair. Although permitted to use walking aids during the test, no participant required them. The quickest time in seconds was recorded.

Hand-grip strength was assessed using a JAMAR hydraulic hand dynamometer (JAMAR, Sammons Preston Rolyan, Chicago, IL, USA). The dominant hand was defined as the hand preferred in performing daily tasks and was chosen for assessment. The second handle position of the dynamometer (at a fixed value of 5.5 cm) was set for all participants measurements[30]. The testing procedure was conducted in accordance with the procedure in a previous report[31], and the mean score of three trials was recorded in kilograms. Finally, body mass index (BMI) was calculated as weight (kg)/height in meters squared (m^2).

Lower-limb function was assessed using the Short Physical Performance Battery (SPPB)[32]. This measure consists of three tasks representing standing balance, walking speed, and repeated chair stands. Each component was scored according to the participant’s performance or the time needed to complete the task on a scale of 0 to 4. Additionally, a total summary score, which ranged from 0 to 12, was determined for the 3 components, with higher scores representing better functioning. To measure standing balance, participants were instructed to stand and maintain their feet in side-by-side (feet together), semi-tandem (heel of one foot against and touching the side of the big toe of the other foot), and tandem stand (heel of one foot in front of and touching the other foot) positions for ≥10 seconds each (maximum score awarded for ≥10 seconds). Walking speed was measured over a 4-m walking course delimited by two tape lines. Participants were instructed to stand with their feet next to the starting point, designated by a plastic cone placed 2 meters behind the first tape line. After the command “go”, participants walked past the end of the course to reach a second cone placed two meters behind the second tape line. Timing started after the first foot of the participant crossed the first tape line and stopped when the same foot completely crossed the second tape line. The shortest time (in seconds) of two trials was recorded (shorter time to complete the task representing better performance) and converted to meters per second. Finally, the repeated chair-stand test (STS-5) measured the time needed to rise from a chair and sit down again five consecutive times without using the arms. Participants were instructed to perform this test as fast as possible while keeping their arms folded across their chest and their feet flat on the floor. Timing started after the command “go” with the participant seated, and the test finished when the participant stood up for the fifth time. The time (in seconds) was recorded, and higher scores were given for shorter performance times.

The 6MWT evaluates the maximum distance that can be covered along a 30-m long corridor during a 6-minute period[33]. Two plastic cones delimited the corridor, and two-meter distance intervals were indicated by pieces of tape. A PT with specific experience administered and supervised the test. Participants were instructed to walk along the walkway as fast as possible, and to stop when needed. The assessor walked alongside the participants to ensure their safety and provided them with standardized verbal encouragement at 1, 3, and 5 min (“you are doing well” and “keep up the good work”). The test ended at the end of the 6-min period, and it was stopped immediately if chest pain, dizziness, or dyspnea was reported by the participant. The total distance covered (in meters) was recorded.

A portable ultrasound unit (Sonosite Inc., Bothell, WA, USA) was used to measure the rectus femoris CSA of each participant’s right leg. The rectus femoris was chosen due to its superficiality, accessibility, and facility with respect to visualization and measurement by ultrasonography[34]. An assessor with 17 years of clinical experience conducted the procedures and instructed the participants to remain in a supine position with their legs extended and relaxed and their toes pointing toward the ceiling. Three consecutive measurements were performed with the transducer placed perpendicularly to the skin surface and positioned midway between the epicondylus lateralis and the greater trochanter of the femur[35]. The mean area of the three measurements was recorded in centimeters.

Data analysis was conducted using SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA). Descriptive statistics (mean ± SD) were generated to summarize demographic, heath-related, and physical measures data for all participants. The Student’s t test or Mann-Whitney U test and χ^2 test were used to determine baseline significant differences between the NH and CD groups. The normality of the distribution of the data was determined with the Kolmogorov-Smirnov test before performing parametric or nonparametric analysis.

In order to determine the independent relationship between the 6MWT and the demographic and physical measures, bivariate correlations were calculated for all participants and for the NH and CD groups (the Pearson product moment correlation coefficient (r) was used for normally distributed data, and Spearman’s rho was used for non-normally distributed data).

Stepwise linear regression analyses were conducted to construct a model for identifying independent contributors to performance in the 6MWT. Analyses were conducted for the whole sample as well as for the NH and CD groups separately. Demographic and physical measures that could be associated with the 6MWT were used as independent variables (age, BMI, walking speed, BBS, TUG, rectus femoris CSA, STS-5, SPPB, and hand-grip strength), and the 6MWT was used as a dependent variable. Furthermore, variable selection was preceded by checking for correlation coefficients between the independent variables and the 6MWT. If a significant correlation was found for a variable, it was chosen for further analysis. The alpha level for significance was set at $p<0.05$.

RESULTS

The complete baseline data are summarized in Table 1. Participants had a mean age of 78 years (SD=8.8) and an age range of 65 to 95 years, and 70% of them were female. The initial sample consisted of 172 participants; however, 50 participants were excluded (n=44, due to not meeting the inclusion criteria) or declined to participate (n=6). Of the final 122 participants, 41.8% were living in their own houses, while 58.2% were living in a geriatric nursing home at the time of inclusion. Based on the mean scores of the BI and MMSE, the sample had high levels of performance in basic daily activities (BI 93.4, SD=10.3) and presented with no cognitive impairment (MMSE ≥24 points). Significant differences were found between the NH and CD groups with regard to demographic and physical measures except for gender, marital status, and heart rate. Data were non-normally distributed except for the 6MWT. During the 6MWT, 8 participants reported fatigue, and two participants reported ankle pain and dizziness.

Associations between the 6MWT and demographics and physical measures for all participants are summarized in Table 2. Spearman’s rho correlation showed a significant strong[36] association between the TUG, SPPB, BBS, and 6MWT in the entire sample (r=0.723 to −0.850, $p\leq0.01$). Additionally, moderate-to-high associations were found between the 6MWT and walking speed, age, hand-grip strength, rectus femoris CSA, and STS-5 (r=−0.435 to 0.657, $p\leq0.01$). Subgroup analyses for the NH and CD groups are summarized in Table 3. Analysis for the participants in the NH group showed significant strong association of the TUG, SPPB, and BBS with the 6MWT (r=0.761 to −0.880, $p\leq0.01$), whereas in the analysis for the participants in the CD group, a higher association with the 6MWT was found for the TUG (r=−0.668, $p\leq0.01$). The 6MWT was not significantly associated with the BMI either in the whole sample or the NH or CD groups. Additionally, in the CD group, an insignificant association was found between the 6MWT and the rectus femoris CSA and hand-grip strength.

The stepwise linear regression analyses are summarized in Table 4. When the whole sample was analyzed, the stepwise multiple regression revealed that the SPPB was a significant and independent predictor for the 6MWT ($AdjR^2$=0.595 β=0.774, $p<0.001$). Model 1 explains over half (59.5%) of

Table 1. Descriptive statistics at baseline

	All participants (N=122) X±SD	Nursing home group (N=71) X±SD	Community-dwelling group (N=51) X±SD
Age (years)$^{\alpha}$ **	78 ± 8.8	84.4 ± 4.9	69.1 ± 3.7
Weight (kg)$^{\alpha}$ **	68.8 ± 13.1	64.6 ± 10.5	74.7 ± 14.2
Height (cm)$^{\alpha}$ *	155.9 ± 8.6	154.2 ± 8.4	158.1 ± 8.4
BMI (kg/m^2)$^{\alpha}$ *	28.3 ± 4.5	27.1 ± 3.8	29.8 ± 4.9
Female †	69.7%	64.8%	76.5%
Marital status †			
Married	21.3%	16.9%	27.5%
Widowed	61.5%	67.6%	54.9%
Single	17.2%	15.5%	17.6%
Barthel Index score (0–100)$^{\alpha}$ **	93.4 ± 10.3	89 ± 11.5	99.7 ± 0.9
6MWT(m)$^{\alpha}$ **	324.7 ± 103.9	290.6 ± 110.7	371.4 ± 71.7
Gait speed (m/s)$^{\alpha}$ **	0.8 ± 0.3	0.6 ± 0.2	1.1 ± 0.2
BBS (0–56)$^{\alpha}$ **	49.1 ± 5.7	46.9 ± 5.8	52 ± 3.9
TUG (s)$^{\alpha}$ **	12.6 ± 6.0	15.2 ± 6.7	9.2 ± 1.7
Rectus femoris CSA (cm^2)$^{\alpha}$ **	4.6 ± 1.9	3.4 ± 1.3	6.2 ± 1.6
STS-5 (s)$^{\alpha}$ **	14.1 ± 6.6	15.9 ± 7.9	11.7 ± 2.9
SPPB (0–12)$^{\alpha}$ **	8.59 ± 2.9	6.8 ± 2.5	10.9 ± 1.5
Hand-grip strength (kg)$^{\alpha}$ **	23.2 ± 8.2	20 ± 7.4	27.7 ± 7.2

BMI: body mass index; 6MWT: 6-min walk test; BBS: Berg Balance Scale; TUG: Timed Up and Go test; CSA: cross-sectional area; STS-5: sit-to-stand test with five repetitions; SPPB: Short Physical Performance Battery total score. $^{\alpha}$Student's t test or Mann-Whitney U test between groups. $^{\dagger}\chi^2$ test. **p≤0.01; *p≤0.05

Table 2. Correlation coefficients for the 6MWT and independent variables in all participants

Variables	Age	BMI	Gait speed	BBS	TUG	Rectus femoris CSA	STS-5	SPPB	Hand-grip strength
6MWT	−0.508**	0.003	0.657^{a}**	0.723**	−0.850**	0.449**	−0.435**	0.752**	0.456**
Age		−0.296**	−0.752**	−0.566**	0.675**	−0.674**	0.402**	−0.705**	−0.507**
BMI			0.199*	0.032	−0.132	0.316**	−0.037	0.235*	0.150
Gait speed				0.684**	−0.860**	0.613**	−0.504**	0.904**	0.550**
BBS					−0.730**	0.461**	−0.419**	0.712**	0.416**
TUG						−0.574**	0.529**	−0.874**	−0.530**
Rectus femoris CSA							−0.315**	0.621**	0.556**
STS-5								−0.615**	−0.313**
SPPB									0.558**

**p≤0.01; *p≤0.05. 6MWT: 6-min walk test; BMI: body mass index; BBS: Berg Balance Scale; TUG: Timed Up and Go test; CSA: cross-sectional area; STS-5: sit-to-stand test with five repetitions; SPPB: Short Physical Performance Battery total score. ^{a}Pearson correlation coefficients

the variation in the 6MWT compared with other variables. The same statistical analysis was conducted for the NH and CD groups. The SPPB ($AdjR^2$=0.684, β=0.831, p<0.001) was revealed to be a strong predictor for the 6MWT when data from the NH group were analyzed. However, in the CD group analysis, the TUG ($AdjR^2$=0.484, β=−0.703 p<0.001) was shown to be the best predictor for the 6MWT. These results indicate that higher lower-limb function, measured with the SPPB (which explains 68.4% of the 6MWT variation in the NH group), and shorter time to complete the TUG (which explains 48.4% of the 6MWT variation in the CD group), are associated with the capacity to cover longer distances in the 6MWT in older adults dwelling in the community or in a geriatric nursing home.

DISCUSSION

We found that all physical measurement results were significantly lower in older adults living in a geriatric nursing home compared with those of older adults dwelling in the community. In the bivariate analyses, more distance covered in the 6MWT was associated with better results in the BBS, TUG, and SPPB (higher in the NH group compared with the CD group), better walking speed and hand-grip strength, and

Table 3. Correlation coefficients for the 6MWT and independent variables in the nursing home and community-dwelling groups

Variables	Group	Age	BMI	Gait speed	BBS	TUG	Rectus femoris CSA	STS-5	SPPB	Hand-grip strength
6MWT	Nursing home	−0.338[a]**	−0.158[a]	0.697[a]**	0.761**	−0.880**	0.262*	−0.255*	0.807**	0.442**
	Community dwelling	−0.315*	−0.118	0.500[a]**	0.521**	−0.668**	0.159[a]	−0.483[a]**	0.372**	−0.010[a]
Age	Nursing home		−0.112[a]	−0.357[a]*	−0.402**	0.321**	−0.144	0.032	−0.362**	−0.181
	Community dwelling		−0.231	−0.108	−0.185	0.076	−0.335*	0.193	−0.179	−0.158
BMI	Nursing home			−0.021[a]	−0.038	0.103	0.116	0.199	−0.059	−0.060
	Community dwelling			−0.056	−0.210	0.075	0.314*	−0.150	0.187	0.130
Gait speed	Nursing home				0.645**	−0.761**	0.430**	−0.148	0.813**	0.508**
	Community dwelling				0.425**	−0.660**	−0.283	−0.737**	0.761**	−0.096
BBS	Nursing home					−0.749**	0.225	−0.274*	0.768**	0.380**
	Community dwelling					−0.470**	−0.017	−0.400**	0.348*	−0.108
TUG	Nursing home						−0.305*	0.287*	−0.820**	−0.461**
	Community dwelling						0.114	0.550**	−0.522**	0.077
Rectus femoris CSA	Nursing home							−0.134	0.324*	0.485**
	Community dwelling							0.039	−0.087	0.090
STS-5	Nursing home								−0.343**	−0.216
	Community dwelling								−0.917**	−0.057
SPPB	Nursing home									0.425**
	Community dwelling									0.003

**p≤0.01; *p≤0.05. 6MWT: 6-min walk test; BMI: body mass index; BBS: Berg Balance Scale; TUG: Timed Up and Go test; CSA: cross-sectional area; STS-5: sit-to-stand test with five repetitions; SPPB: Short Physical Performance Battery total score. [a]Pearson correlation coefficients

Table 4. Multiple stepwise linear regression analyses with the 6MWT as a dependent variable

	6-min walk test				
Independent variables	R^2	Adjusted R^2	R^2 change	Unstandardized β coefficient (standard error)	Standardized β coefficient
All participants					
Model 1	0.599	0.595	145.069		
SPPB				26.597 (2.208)	0.774**
Model 2	0.639	0.631	10.521		
SPPB				18.448 (3.279)	0.537**
TUG				−5.080 (1.566)	−0.310*
Nursing home group					
Model 1	0.690	0.684	122.484		
SPPB				35.738 (3.229)	0.831**
Model 2	0.717	0.707	5.235		
SPPB				32.258 (3.463)	0.750**
Hand-grip strength				2.784 (1.217)	0.184*
Community-dwelling group					
Model 1	0.495	0.484	0.495		
TUG				−29.192 (4.216)	−0.703**

**β significance p≤0.01; *β significance p≤0.05. TUG: Timed Up and Go test; SPPB: Short Physical Performance Battery total score

a higher rectus femoris CSA. After adjusting for age, rectus femoris CSA, hand-grip strength, BBS, walking speed, and STS-5, the SPPB and TUG were independently related to the 6MWT. The SPPB explained 59.5% of the change in the distance covered during the test. When the NH group was analyzed separately, both the SPPB and hand-grip strength were independently related to the 6MWT, while in the CD group, only the TUG was independently associated with the 6MWT. Therefore, in the light of these results, a lower SPPB score explains less distance covered in the 6MWT in the elderly population. The TUG appears to be an important measure for those individuals dwelling in the community.

The data analysis showed a significant difference in the 6MWT between the study groups. We found that the distance covered by the CD group was very similar to that reported in a prior study on well-functioning community-dwelling older adults (65±2 yrs)[37]. On the other hand, participants in the NH group reported a lower distance covered (290.6 ± 110.7 m) compared with the CD group (371.4 ± 71.7 m). Additionally, a considerable range in distance covered (ranging 49 to 645 m in the NH group and 172 to 508 m in the CD group) was found in both study groups. This variability between groups was probably due to differences in age[38–40] or baseline values for the physical measures[20, 25]. Heterogeneity in health status is a characteristic of the older adults' population. "Apparently healthy" elderly persons could present with a large diversity in health status, and their exercise capacities could be substantially influenced[22].

Although previous studies have assessed the implications of physical measures on 6MWT performance in older adults, their target populations (suffering from multiple sclerosis or strokes)[17, 41–44] or methods (non-standardized procedures for balance or lower-limb function)[10, 12, 22, 25] were somewhat different, making direct comparison difficult, and factors explaining the differences in 6MWT performance between two different geriatric groups (older adults living in a geriatric home and those dwelling in the community) have not been previously reported.

Moderate to high (r between 0.5 and >0.7)[36] correlations between the 6MWT and age, walking speed, BBS, TUG, and SPPB were found, but the correlations were lower with the rectus femoris CSA, STS-5 and hand-grip strength (r <0.5). In agreement with previous research, there was a negative correlation between age and 6MWT[11, 45] and a positive correlation between physical performance and 6MWT distance[10, 25, 41, 43, 44]. Hence, Harada et al.[25] observed significant correlations between related individual tasks from the SPPB (standing balance r=0.52, gait speed r=0.73, and chair stands r=0.67) and the 6MWT in a sample of healthy older adults living in retirement homes or dwelling in the community. Additionally, Lord et al.[10] reported that overall mobility (which included balance, sensorimotor, and lower-limb strength measures) was significantly associated with the 6MWT in a sample of older adults living in retirement villages. Furthermore, other studies have reported similar observations in impaired older adults. Wetzel et al.[44] reported significant correlations between the 6MWT and static balance (r=0.39) and the multiple sit-to-stand test (r=0.57) in community dwelling individuals who had moderate disabilities and had been diagnosed with multiple sclerosis. Langhammer et al.[41] observed a strong correlation between the 6MWT and TUG in a sample of older adults with acute stroke. Finally, Kluding et al.[43] observed a significant correlation with the BBS (r=0.67) in a sample of patients who had a mean age 57.6 years and were suffering from chronic stroke. Despite differences in the characteristics of the samples in the various studies, these results support the importance of physical performance on the walking ability when covering long distances, especially in low-functioning older adults. Therefore, the present study confirms and extends the findings reported by previous research concerning demographic and physical measures explaining 6MWT performance in a samples of healthy older adults.

Although our study was cross-sectional, the inclusion of participants across the spectrum of aging yielded some interesting observations that might shed some light on the main functional aspects that influence walking distance among older adults. Multivariate analyses showed different results depending on the subgroup analysis. While the 6MWT was independently associated with the SPPB in the NH group, it was associated with the TUG in the CD group. The walking ability of older adults living in a geriatric nursing home is better explained by the SPPB than by age, rectus femoris CSA, or other physical performance variables. To the best of our knowledge, no study has investigated the variance of the 6MWT with the SPPB as a single measure. However, a previous study[25] showed that the three individual tasks of the SPPB (balance, gait speed, and chair stands) explained 69% of the variance in the 6MWT in healthy older adults dwelling in the community and living in retirement homes. While Harada et al. analyzed the results for a mixed-population sample from community centers and retirement homes the two types of populations were also analyzed separately in our study. Differences in the variance may be accounted for by other disparities in the analysis of measures and samples of the studies. This finding reveals that the capacity to perform daily activities such as walking, standing up from a chair, or maintaining standing balance, may be reflected by the ability to walk a certain distance. Therefore, the SPPB could be used to evaluate lower-limb functioning as well as walking ability in older adults, with special attention to populations living in geriatric nursing homes. Regarding CD older adults, the TUG was the variable that better explained the variance in the 6MWT. The absence of studies examining the extent to which the TUG influences the 6MWT in healthy older adults prevents us from comparing our results with previous research. However, one study[10] reported that overall mobility appeared to provide a measure of 6MWT in a sample of community-dwelling older adults. The regression model of this study (which included age, lower-limb strength, simple reaction time, and postural sway and balance range) explained 52.5% of the variance in the 6MWT. These results are in agreement with our study, which explained 48.4% of the variance in the 6MWT with the TUG. However, care should be taken in comparing these results because of the differences between study populations and assessment measures. The positive correlation between the TUG and 6MWT is not surprising because during the 6MWT, participants walked as far as possible and the test included "turns around a cone" at the end of the corridor. According to our results, it seems that, in lower-functioning older adults, balance and SPPB components are of high importance to improvement of walking distance, while in higher-functioning samples, walking distance relies on mobility and walking speed. Hence, these results suggest that, to improve walking performance in healthy older adults, an intervention could focus on enhancement of balance, mobility, and lower-limb function. This will need to be confirmed in prospective and longitudinal studies.

This study has several limitations. Firstly, the study participants were volunteers and relatively healthy older adults, a sample that may not represent the characteristics of people living in a geriatric nursing home or dwelling in the community. A possible selection bias may explain differences in the participants' levels of physical performance. The wide inclusion criteria lend support to the external validity of these results when making comparisons to typical older adults living in nursing homes or in the community. Secondly, although we assessed some components of lower-limb physical performance, the measured variables may not cover all physical information that explains the variability in the 6MWT. To confirm the results of this study, future analyses should consider other physical measures, such as the ability to modify balance while walking in the presence of external demands (Dynamic Gait Index)[46], fast walking speed (10-Meter Walk Test)[47], or muscle strength and CSA of other muscles involved in walking performance, like the vastus medialis. These factors may play an important role in the 6MWT and walking performance. Thirdly, the sample size was relatively small (NH; n=71, CD; n=51). Consequently, caution is warranted when interpreting or generalizing the results of this study, especially to frail or impaired older adults.

In conclusion, the findings of the present study revealed that higher lower-limb function, balance, and mobility are associated with better walking ability and distance covered in healthy older adults. The SPPB is the test that best determines the walking performance in low-functioning older adult populations, while the TUG best determines the walking performance in community-dwelling older adults. Future studies should clarify if improving the results of the SPPB and TUG results in an increased distance in the 6MWT in older adults.

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Summary (Spanish)

Factores asociados con la prueba 6-minute Walk Test en adultos mayores residentes en un centro geriátrico y en la comunidad.

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Objetivos: El principal objetivo de este estudio fue determinar la contribución y extensión en la que ciertas variables físicas explican la distancia recorrida durante la prueba 6-minute Walk Test, en adultos mayores sanos que residen en un centro geriátrico o que habitan en la comunidad.

Diseño: Se trata de un estudio transversal con un único registro para evaluar todas las variables físicas y demográficas seleccionadas.

Dónde se realizó: El estudio ha sido realizado en el centro social para la tercera edad "*Centro Municipal de Actividades para Personas Mayores Sant Pau*", además de en el centro geriátrico "*Residencia Geriátrica Hermanitas de los Ancianos Desamparados*", ambos centros en Valencia, España.

Participantes: Un total de ciento veintidós sujetos mayores de 65 años fueron seleccionados para participar en el estudio, tras ser evaluados mediante los cuestionarios Mini-mental State Examination y Barthel Index, y no mostrar signos de deterioro cognitivo, además de ser independientes para realizar las actividades básicas de la vida diaria.

Medidas: La variable principal del estudio fue la prueba del 6-minute Walk Test (6MWT). Además, se estudiaron otras variables como la edad, el índice de masa corporal, la velocidad de la marcha mediante la prueba Gait Speed Test, la fuerza de miembros inferiores a través de la prueba Repeated Chair Stand Test, el equilibrio funcional usando la Berg Balance Scale (BBS), la movilidad mediante la prueba Timed

"Up and Go" Test (TUG), el volumen muscular del músculo recto femoral mediante ecografía, la capacidad funcional de los miembros inferiores a través de la batería de pruebas Short Physical Performance Battery (SPPB) y la fuerza de agarre de la mano medida mediante un dinamómetro de mano JAMAR.

Resultados: El análisis de las correlaciones entre las variables estudiadas mostró asociaciones significativas sólidas entre la movilidad (TUG), la capacidad funcional de los miembros inferiores (SPPB), el equilibrio funcional (BBS) y la prueba del 6-minute Walk Test. El análisis de regresión múltiple realizado en toda la muestra, mostró que la capacidad funcional de los miembros inferiores (SPPB) fue la variable que predecía en mayor medida los resultados del 6-minute Walk Test. Además, el SPPB demostró ser la variable que predecía en mayor medida los resultados del 6-minute Walk Test cuando el análisis de regresión fue realizado en la muestra de sujetos que residían en un centro geriátrico, mientras que el TUG fue el mejor predictor cuando se analizó a la muestra de sujetos que residían en la comunidad.

Conclusión: Una mejor capacidad funcional de los miembros inferiores (SPPB), un mejor equilibrio funcional (BBS) y una mejor movilidad (TUG) resultan en una mayor distancia recorrida durante la prueba del 6-minute Walk Test en adultos mayores sanos. La capacidad funcional de los miembros inferiores (SPPB) y la movilidad (TUG) son las variables que mejor determinan la capacidad de la marcha en sujetos sanos que residen en un centro geriátrico o habitan en la comunidad, respectivamente.

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Feature Article

Physical factors underlying the Timed "Up and Go" test in older adults

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ABSTRACT

The purpose of this study was to investigate a range of selected physical measures for their relative contributions and extent to which they may explain the performance of the Timed "Up and Go" test (TUG) in a sample of healthy older adults. The participants where 194 adults aged 65 and older with no cognitive impairment and independent in their daily activities from local senior centres and a geriatric nursing home in Valencia, Spain. Age, body mass index (BMI), TUG, Berg balance scale (BBS), One-leg stand test (OLS), grip strength, chair stand test (STS-5), knee extension strength and rectus femoris cross-sectional area (CSA) where measured. Moderate to high significant associations were found between the TUG performance and BBS and knee extension strength ($r = -.561$ and $-.397$). A stepwise multiple regression analysis showed that the BBS was a significant and independent predictor ($AdjR^2 = .373$) for the TUG performance. The TUG is highly correlated with the BBS score and knee extension strength, measures that represent common performance tasks in everyday life. The BBS was demonstrated to be the most significant factor explaining the TUG performance. The TUG is demonstrated to be a useful tool for predicting changes in functional balance measured with the BBS. The mobility decline may be better explained as the sum of deficits across multiple domains rather than as a single entity. Clinicians would benefit of those findings by a better understanding of the physical measures, in addition to designing more accurate interventions focusing on the enhancement of mobility.

Introduction

The aging process is accompanied by a gradual and steady reduction of muscle size[1,2] and strength that affects the lower-limb muscles to a greater extent[3]; The reduction accelerates by the 6th decade of life and reaches up to a 2–3% loss per annum even in healthy individuals.[2,4] This progressive muscle weakening has important functional consequences with regard to the maintenance of personal independence and the ability to perform daily tasks such as stair climbing, rising from a chair or getting out of bed, keeping balance or walking a distance,[5–8] ultimately resulting in reduced health-related quality of life and increases in health care costs.[9]

During the last three decades, functional performance-based tests have been developed to demonstrate sensitivity to a therapeutic intervention or as screening tools to identify older adults at risk of functional decline.[10] These physical measures, mainly focusing on balance, walking ability, lower-limb function, strength or mobility, are key components of the geriatric assessment. It has been reported that, when studying physical mobility by using a performance-based measure, balance and gait maneuvers used in everyday life should be included.[11] The Timed "Up-and-Go" test (TUG)[11] is a quick performance-based measure of mobility,

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extensively studied in both impaired[12,13] and in healthy[14,15] older adults, that incorporates those recommended maneuvers. Additionally, the TUG has demonstrated a high reliability (ICC = .98) and validity supported by studies among healthy older adults.[11,16,17] When using the test, the subject is observed and timed while performing different subtasks that comprise the TUG, including transitions, straight-line walking, and turning.[18] The TUG differs from other tests in that it measures mobility as a continuous entity (over time), and not as the sum of the scores of its subtasks.

The TUG has been demonstrated to predict health decline and disability in the activities of daily living.[19] However, to the best of our knowledge, it has not been made clear whether physical factors, such as muscle strength (STS-5; Chair stand test), functional balance (BBS; Berg balance scale, OLS; One-leg stand test), knee extension strength and muscle cross-sectional area (CSA) may explain the TUG performance. Therefore, the purpose of the present study was to investigate a range of selected physical measures for their relative contributions and extent to which they may explain the performance of the TUG in a sample of institutionalized and community-dwelling older adults.

Material and methods

Study design

The design, the protocol, and the informed-consent procedure of this cross-sectional analysis were approved by the Bioethics and Clinical Research Committee of the UCH-CEU University. All participants provided a signed written informed-consent statement regarding their participation in the study. All participants included in this study were evaluated by the same independent assessors.

Study participants and selection criteria

The sample for this analysis consisted of apparently healthy community-dwelling and institutionalized older adults without any short-term-medical conditions, living in the urban areas of Valencia, Spain. Two-hundred seventy-three potential participants were voluntarily recruited through advertisements in the bulletin boards of different local senior centers and geriatric nursing homes, as well as through presentations by researchers in all centers, and by word of mouth. Recruitment started in October 2014 and was completed in May 2015. Fig. 1 shows the participants' selection flow chart. All participants received fully detailed and comprehensive information about the proposed study, its objectives, duration and risks during an individual interview conducted by a physiotherapist. Additionally, all potential participants were screened for inclusion by a medical doctor with 24 years of clinical experience who determined possible unstable cardiovascular diseases, neurological disorders or mobility limitations that could represent a risk for the participants during the assessment sessions. Inclusion criteria for the present analysis were as follows: participants who 1) were aged >65 yr.; 2) had no severe medical contraindications to performing physical activities; 3) provided a signed informed-consent statement; 4) were able to ambulate independently (i.e., without a walking aids); 5) were able to communicate and follow simple commands; and 6) had self-reported visual and auditory capacities to follow the measures procedure. Participants who 1) were unable to ambulate independently; 2) had a Barthel Index (BI) score <80[20]; 3) had a Mini-Mental State Examination (MMSE) score <24[21]; 4) had an unstable cardiovascular disease or a neurological disorder that could compromise them during the performance of physical activities; 5) reported moderate to severe pain while walking; and 6) had an upper- or lower-limb fracture in the past year, were excluded. A total of one-hundred ninety-four participants met the inclusion criteria and were eligible for the study.

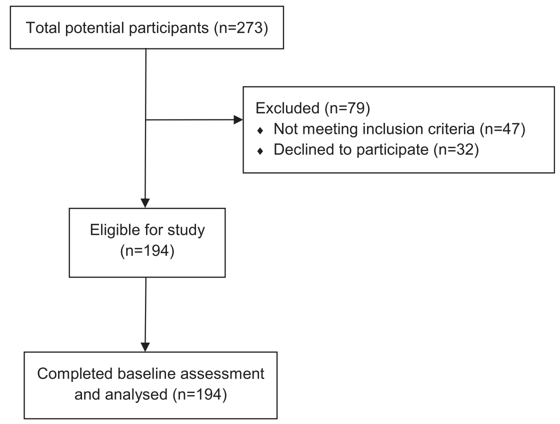

Fig. 1. Flow chart of participants and screening.

Outcome measures

All measures performed have been determined from the literature to be valid and reliable in assessing mobility,[22] balance,[23] knee extension strength,[24] lower-limb strength,[25] and upper-body strength[26] in older adults. Data collection was carried out by six experienced independent assessors (physiotherapists). To accommodate the participants' assessment, a total of four functional test stations were set in a large indoor room. All measurements were administered in a single session, except the rectus femoris CSA, which was assessed on a consecutive day. In order to standardize the data collection schedule, all tests were conducted between 10 am and 2 pm. During the first day, data collection was chronologically organized in order to minimize fatigue, and then completed in the following order: BMI, TUG, BBS, OLS, knee extension strength, grip strength and STS-5. A 5 min resting period in a seated position was permeated between measures. Furthermore, to avoid the possible fatigue between the two lower-limb strength tests, knee extension strength was assessed before the grip strength assessment, which provided an extra period to the participants in a seated position, and then the STS-5 was conducted. Finally, the rectus femoris CSA was determined to be measured in a consecutive day to avoid a possible muscle changes as a consequence of the administration of the previous tests, which could alter the rectus femoris CSA measured by ultrasonography. The descriptive characteristics of outcome measures are summarized in Table 2.

Body mass index

Height and body mass were recorded using a portable stadiometer and balance weighing scales, respectively. Body mass index (BMI) was calculated using the standard formula: mass (kg)/height^2 (m).

Timed "Up and Go" test

Mobility was assessed using the TUG, which measures the time needed to rise from a chair, walk 3 m at a comfortable and safe pace to reach a plastic cone, turn around the cone, return to the chair,

Table 1
Descriptive characteristics at baseline ($n = 194$).

Characteristics	Mean ± SD
Age, yr.	75.7 ± 8.4
Weight, kg	68.7 ± 12.8
Height, cm	156.2 ± 8.3
BMI, kg/m^2	28.1 ± 4.4
Female, %	77.8%
Marital status	
Married, %	32.4%
Single, %	16.4%
Widowed, %	51.2%
TUG, s	11.1 ± 5.3
Barthel index score, (0–100 points)	95.4 ± 8.9
BBS (0–56 points)	50.5 ± 5.4
One-leg stand, s	12.3 ± 14.7
Grip strength, kg	20.6 ± 8.7
STS-5, s	12.9 ± 6.1
Rectus femoris CSA, cm^2	4.6 ± 1.9
Knee extension strength, kg	16.2 ± 5.8

SD; Standard deviation, BMI; Body mass index, TUG; Timed "Up-and-Go" test, BBS; Berg balance scale, STS-5; Sit-to-stand test with five repetitions, CSA; Cross sectional area, s; seconds.

and sit down again. Participants were instructed to start the test seated in a chair with arms resting in the armrests and feet flat on the floor. One practice trial was conducted before the participants performed the two test trials so that the participants understood how to properly perform the test. The time was recorded, using a stopwatch, from the command "go" until the participant's back was positioned against the back of the chair after sitting down. The quickest time in seconds was recorded, and shorter times indicated better performance.[11]

Berg balance scale

Balance was assessed using the BBS following the published guidelines.[23] The test consisted of 14 different tasks common in everyday life with varied difficulty of balance (e.g. tandem standing, reaching, 360° turning, standing with eyes closed or stepping). Each task was graded on a 5-point scale of 0 ("unable to perform" or "need assistance") to 4 ("able to perform independently") according to the participant's performance, or the time taken to complete the task. When the test was completed, individual task scores were summed for a potential maximal score of 56 points, which represents perfect balance.

One-leg stand

One-leg balance was assessed using the OLS.[27] Participants were instructed to start the test from a standing position with their eyes open and arms at their sides, choose a leg to stand on, flex the opposite knee, allowing the foot to clear the ground, and stand unassisted on one leg as long as possible. Participants performed two test trials, and the best time in seconds was recorded (longer times in balance represented better performance). The timing was stopped if the participant could maintain balance in excess of 60 s.

Table 2
Descriptive characteristics of outcome measures.

Outcome	Performance	Score
BMI	One test trial	kg/m^2
TUG	One practical trial + two tests trials	Time, seconds
BBS	One test trial (each of the 14 tasks)	Scale, 0 points (min.) to 56 points (max.)
One-leg stand	Two test trials	Time, seconds (60 s max.)
Knee extension strength	Three test trials	Mean, kg
Grip strength	Three test trials	Mean, kg
STS-5	One test trial	Time, seconds
Rectus femoris CSA	Three measurements	Mean area, cm^2

BMI; Body mass index, TUG; Timed "Up-and-Go" test, BBS; Berg balance scale, STS-5; Sit-to-stand test with five repetitions, CSA; Cross sectional area.

Knee extension strength

The maximal voluntary isometric knee extension strength of the dominant leg was measured using a fixed strain gauge (TESYS 400®, Globus Italia, Italy) attached to the extensor chair lever arm and the chair legs. Participants were seated on a knee extension chair in a straight-back position, with the knee and hip joints at 90° of flexion.[28] Adjustable straps were placed on the pelvis and the distal thigh to stabilize the participants, and the lever arm of the extensor chair was placed on the ankle above the malleoli. Participants were instructed to push as hard as possible for 5 s of isometric contraction. Strong verbal encouragement was used during the test. Three test trials were performed, with a 90 s of resting period between trials.[29] The mean score of the three trials was recorded (in kilograms).

Hand grip strength

Grip strength of the dominant hand was measured using a JAMAR hydraulic hand dynamometer (JAMAR, Sammons Preston Rolyan, Chicago, Illinois, USA). The second handle position of the dynamometer (at a fixed value of 5.5 cm) was set for all participants' measurements.[30] The testing procedure was conducted according to a dedicated publication.[31] The mean score of three trials was recorded (in kilograms).

Chair stand test

Lower-limb strength was assessed using the repeated STS-5 test[32] which measures the time needed to rise from a chair and sit down again five consecutive times without using the arms. Participants were instructed to perform this test as fast as possible while keeping their arms folded across their chest and their feet flat on the floor. Timing started after the command "go" with the participant seated, and the test finished when the participant stood up for the fifth time. The time (in seconds) was recorded, and higher scores were given for shorter performance times.

Rectus femoris cross sectional area

To finish the assessment, a portable ultrasound unit (Sonosite Inc., Bothell, WA, USA) was used to measure the rectus femoris CSA of each participant's right leg. The rectus femoris was chosen due to its superficiality, accessibility and facility to visualize and measure by ultrasonography.[33] An assessor with 16 years of clinical experience conducted the procedures and instructed the participant's to remain in supine position, with legs extended and relaxed, and toes pointing to the ceiling. Three consecutive measurements were performed with the transducer placed perpendicularly to the skin surface, and positioned midway between the epicondylus lateralis and the greater trochanter of the femur.[34] The mean area of the three measurements was recorded (in cm^2).

Data analyses

Data analysis was conducted using SPSS 17.0 for Windows (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics (mean ± SD) were generated to summarize demographic, heath-related and physical measures data for the whole sample. The normality distribution of the data was determined with the Kolmogorov–Smirnov test before using parametric or non-parametric analysis. In order to determine the independent relationship between the TUG and the selected physical measures, partial correlations adjusted for age and gender were calculated for both, nursing home residents and community-dwelling participants.

Stepwise linear regression analyses were conducted to construct a model for identifying independent contributors to the TUG. TUG was determined as a dependent variable, and the selected physical measures that could be associated with the TUG were used as independent variables (BBS and knee extension strength). The variable selection was preceded by checking for correlation coefficients between the independent variables and the TUG. If a significant correlation was found for a variable, it was chosen for further analysis. The alpha level for significance was set at $P < .05$.

Results

The complete baseline characteristics of the data are summarized in Table 1. The mean age of the 194 study participants was 75.7 ± 8.4 yr (range: 65–96 yr), and 77.8% of them were female. The sample of this study consisted of a higher proportion of community-dwelling older adults ($n = 123$; 63% of the whole sample) in order to reflect the general population of older adults in Spain.[35] The initial sample consisted of 273 potential participants; however, 79 participants were excluded ($n = 47$), due to not meeting the inclusion criteria; $n = 32$ declined to participate. According to the BI mean score, the sample had high levels of performance in the basic daily activities (BI 95.4 ± 8.9). MMSE mean score indicated that the cohort did not present signs of dementia or marked cognitive impairment (>24).

The data were non-normally distributed for the BBS, grip strength, knee extension strength and rectus femoris CSA, and were normally distributed for age, BMI, OLS, and STS-5. Associations between the TUG, age and selected physical measures are summarized in Table 3. No statistically significant group related differences (community-dwelling vs. nursing home residents) were found in any of the studied measures, so data were pooled for subsequent partial correlational analysis including the whole sample. The correlation analyses showed a significant high[36] association between the TUG and BBS ($r = -.561$) and knee extension strength ($r = -.397$). The TUG was not significantly associated with the BMI, OLS, STS-5, rectus femoris CSA or grip strength.

The stepwise linear regression analyses are summarized in Table 4. Interestingly, the analyses revealed that the BBS was a significant and independent predictor for the TUG (AdjR^2 = .373 $\beta = -.618$, $P < .001$). Model 1 explained 37.3% of the variation in the TUG compared to other variables. Model 2 included the knee extension strength to the BBS and explained 45.1% of the variation in the TUG. These results indicate that a higher functional balance measured with the BBS is associated with the mobility performance in older adults.

Discussion

This study confirms and extends the findings reported by previous research examining the relationships between the TUG performance and physical measures in older adult's populations. As far as we know, this is the first study that compares the factors explaining the TUG performance by including muscle CSA. The main findings of the current analysis are (1) that BBS score and knee extension strength were highly correlated with the TUG ($r = -.561$ and $-.397$). In the partial correlation analyses, shorter times to complete the transitions, straight-line walking, and turnings included in the TUG were associated with better results in the BBS and higher knee extension strength. Moreover, (2) following the stepwise linear regression, the functional balance measured with the BBS was demonstrated to be the most significant factor explaining the TUG performance. A higher BBS score explains shorter performance times to complete the TUG.

Baseline sample characteristics showed that the mean TUG performance (11.1 ± 5.3 s) was in consonance with published values for well-functioning older adults.[37,38] Additionally, it was below the cut-off point reported for a normal TUG in community-dwelling or institutionalized older adults,[38,39] and 76% of the sample performed the test in <12 s, confirming that the sample was composed by healthy and freely mobile individuals.[39] On the other hand, a considerable range in the time taken to perform the TUG was found (ranging from 5.9 to 38.3 s). This variability may be explained by differences in age[22,40] as well as through differences in baseline values in the physical capacities.[41] We found that the TUG performance time gradually increases as age increases. For individuals aged 65–75 yr ($n = 106$), a mean TUG performance of 8.6 s was recorded, while for individuals aged 76–85 yr ($n = 60$), a mean TUG performance of 12.4 s was recorded. Finally, for individuals aged >85 yr ($n = 28$), a mean TUG performance of 17.2 s was recorded. This observation is in agreement with a recent study reporting similar TUG performance times in the same three age categories, in a sample of apparently healthy adults aged 60–96 yr[38] Hence, age has been demonstrated to be an important factor for the TUG performance in older adults. As an "apparently healthy" elder person grows older, exercise capacity could be substantially influenced by the concomitant mobility decline.[42]

High significant correlation coefficients between the TUG and BBS score and knee extension strength ($r = -.561$ and $-.397$) were reported. These results are in consonance with previous research reporting a significant negative correlation between the TUG performance and functional balance[43] and knee extension strength[44,45] in apparently healthy and independent older adults. Our results suggest that the TUG performance correlated with many physical performance tasks present during everyday life,

Table 3
Correlation coefficients for the TUG and independent variables.

	BMI	BBS	One-leg stand	Grip strength	STS-5	Knee extension strength	Rectus femoris CSA
TUG	.076	−.561[a]	.082	.027	.089	−.397[a]	−.096
BMI		−.198[a]	−.190[a]	.139	.079	.036	.118
BBS			.273[a]	−.012	−.122	.357[a]	−.016
One-leg stand				.178[b]	−.108	.149	.128
Grip strength					−.072	.436[a]	.182
STS-5						−.143	−.181
Knee extension strength							.366[a]

BMI; Body mass index, BBS; Berg balance scale, TUG; Timed "Up-and-Go" test, STS-5; Sit-to-stand test with five repetitions, CSA; Cross sectional area.
[a] Correlation is significant at the $P < .01$ level.
[b] Correlation is significant at the $P < .05$ level.

Table 4
Multiple stepwise linear regression analyses with the TUG as a dependent variable.

Independent Variables	Timed "Up-and-Go" test					
	R^2	Adjusted R^2	R^2 change	Unstandardized β coefficient (standard error)	Standardized β coefficient	β significance
All participants						
Model 1	.382	.373	.382	48.815 (5.225)		
BBS				−.717 (.111)	−.618	<.001
Model 2	.467	.451	.085	47.188 (4.915)		
BBS				−.554 (.115)	−.478	<.001
Knee extension strength				−.370 (.113)	−.323	.002

BBS; Berg balance scale.

such as keeping in balance, sitting and standing from a chair, reaching forward, retrieve an object from the floor or turning. As it has been reported previously, the functional decline may be related with the accumulation of deficits in the functional capacities.[10] Consequently, the mobility decline may be better explained as the sum of deficits across multiple domains rather than as a single entity. Due to its multi-task design,[11] it seems clear that the TUG performance does not focus on a single independent variable, but reflects the performance of many daily life activities.[39] This observation favors the understanding that the BBS score was the variable that better correlated with the TUG performance. An unexpected result in the correlational analyses was the absence of significant correlation between the TUG and the rectus femoris CSA. Coordination between lower-limb muscles plays an important role in the performance of the TUG. Measuring a single portion of the muscle may not reflect the necessary coordination involved in a multi-task mobility test as the TUG.

Furthermore, we observed that the multivariate analyses reported that the BBS was independently related to the TUG performance. The BBS score explained 37.3% of the change in the time needed to complete the TUG, while the sum of the BBS and knee extension strength explained 45.1% of the change. Previous studies have reported that the BBS appears to be an independent predictor of the TUG performance in subjects with chronic stroke.[46] However, care should be taken in comparing these results because of the differences between study populations. Our analyses showed that the BBS score was the most significant factor explaining the TUG performance in our study sample (Table 4). The TUG incorporates a series of motor tasks including sit-to-stand, walking, turning and stand-to-sit[47] which requires efficient postural responses to perform the test quickly and as safe as possible. Four of the 14 items that composes the BBS are components of the TUG test (sitting to standing, standing unsupported, standing to sitting and turning 360°) which may explain why the BBS score describes a large proportion of variance in the TUG performance, and the close relation between the TUG performance and the BBS score. On the other hand, BBS score and knee extension strength explained 45.1% of the change in the TUG performance (Table 4). Previous studies have reported that knee extension strength is a significant determinant of the TUG performance in apparently healthy independent women[45] and community-dwelling[44] older adults. Maximal voluntary isometric knee extension strength is a reflection of the forces a muscle can produce, which are necessary for completing activities of daily living, such as rising from a chair.[48] As the TUG involves muscle activity, it is not surprising that our results showed that knee extension strength explained a relevant proportion of the changes in the TUG performance. Hence, future interventional studies should incorporate a focus on balance and muscle strengthening to clarify if improving those variables may result in a better TUG performance.

In the light of these results, the TUG performance, besides considered a reliable instrument to measure mobility, appears to be an appropriate measure for the clinical assessment of functional balance, and a useful tool for predicting the muscle weakness in lower-limb muscles. In addition, given the absence of a ceiling effect, its fine design and its quick and easy implementation, the TUG demonstrates apparent advantages over other performance-based tests when studying the functional decline or the benefits of a therapeutic intervention in healthy older adults. Our study findings have clinical importance in that they suggest that TUG performance may be improved by exercise programs aimed at the enhancing of balance and muscle strength, with particular attention to those individuals identified as mobility impaired, elders who perform the TUG in >12 s.[39] Therefore, nurses, physiotherapist and other health providers, as key components of the assessment and treatment of elder populations, will benefit from those findings by a better understanding of the physical measures, in addition to designing more accurate interventions focusing on the enhancement of mobility. However, this will need to be confirmed in prospective and longitudinal studies and, future analyses should consider additional and more demanding physical measures for high functioning elder populations, such as the ability to modify balance while walking in the presence of external demands (Dynamic gait index),[38] fast walking speed (10-meter walk test),[49] or muscle strength and CSA of other muscles involved in walking performance, like vastus medialis. Those factors may play an important role in the TUG performance.

There are several limitations to this study. Firstly, the participants were volunteers and relatively healthy older adults, a sample that may not represent the characteristics of people living in a geriatric nursing home or dwelling in the community, therefore these findings should not be extended to frail or impaired older adults. A possible selection bias may explain differences in the participants' levels of physical performance. The wide inclusion criteria lend support to the external validity of these results when comparing to the typical older adults living in the nursing home or in the community. Secondly, although we assessed some components of lower-limb physical performance, the measured variables may not cover all physical information that explains the variability in the TUG performance. Thirdly, the sample size was relatively small ($n = 194$). Consequently, caution is warranted when interpreting or generalizing the results of this study, especially to frail or impaired older adults.

Conclusions

In conclusion, the TUG performance is highly correlated with the BBS score and knee extension strength, measures that represent numerous physical performance tasks common in everyday life, such as keeping in balance, sitting and standing from a chair, reaching forward, retrieve an object from the floor or turning. The BBS reported to be the most significant factor explaining the TUG performance. The TUG was demonstrated to be a useful tool for predicting changes in functional balance. A higher BBS score explains shorter performance times to complete the TUG. The mobility decline may be better explained as the sum of deficits across multiple domains rather than as a single entity. Clinicians would benefit of those findings by a better understanding of the physical measures, in addition to designing more accurate interventions focusing on the enhancement of mobility.

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Summary (Spanish)

Factores físicos determinantes de la prueba Timed "*Up and Go*" Test en adultos mayores.

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Objetivos: El objetivo principal de este estudio fue investigar la contribución de una batería de variables físicas y el grado en el que éstas pueden llegar a explicar la ejecución de la prueba Timed *"Up and Go"* Test (TUG), en una población de adultos mayores sanos.

Diseño: Se trata de un estudio transversal con un único registro para evaluar todas las variables físicas y demográficas seleccionadas.

Dónde se realizó: El estudio ha sido realizado en diferentes centros para la tercera edad; "*Centro Municipal de Actividades para Personas Mayores Sant Pau*", "*Centro Municipal de Actividades para Personas Mayores Malvarrosa*", "*Centro Municipal de Actividades para Personas Mayores Giorgeta*" y "*Centro Municipal de Actividades para Personas Mayores Trafalgar*", además de en el centro geriátrico "*Residencia Geriátrica Hermanitas de los Ancianos Desamparados*". Todos los centros localizados en Valencia, España.

Participantes: Un total de ciento noventa y cuatro sujetos mayores de 65 años que tras ser evaluados mediante los cuestionarios Mini-mental State Examination y Barthel Index, no mostraron signos de deterioro cognitivo y eran independientes para realizar las actividades básicas de la vida diaria.

Medidas: La variable principal del estudio fue la movilidad medida mediante la prueba Timed *"Up and Go"* Test (TUG). Además, se estudiaron otras variables como la edad, el índice de masa corporal, el equilibrio funcional usando la Berg Balance Scale (BBS), el equilibrio unipodal mediante la prueba del One-leg Stand Test (OLS), la fuerza de miembros inferiores a través de la prueba Repeated Chair Stand Test (STS-5), la fuerza isométrica máxima de extensión de rodilla de la pierna dominante mediante una dinamometría de miembro inferior, la fuerza de agarre de mano medida mediante un dinamómetro de mano JAMAR y el volumen muscular del músculo recto femoral a través de un registro ecográfico.

Resultados: El análisis de las correlaciones entre las variables estudiadas mostró asociaciones significativas entre el TUG y la BBS (*r*=-.561), y el TUG y la fuerza isométrica máxima de extensión de rodilla (*r*=-.397). El análisis de regresión múltiple realizado en toda la muestra, mostró que la BBS fue la variable que predecía en mayor medida los resultados del Timed *"Up and Go"* Test (AdjR2=.373).

Conclusión: El Timed *"Up and Go"* Test (TUG) está altamente correlacionado con el equilibrio funcional (BBS) y la fuerza isométrica máxima de extensión de rodilla. Ambas medidas representan la capacidad para realizar tareas comunes en la vida diaria. El BBS ha demostrado ser el factor más importante para explica la ejecución de la prueba TUG. El TUG demuestra ser una herramienta útil para la predicción de cambios en el equilibrio funcional medidos mediante el BBS. La disminución de la movilidad podría explicarse mejor como la suma de los déficits en múltiples factores y no solo como consecuencia de un único factor. El personal sanitario que trate con personas mayores se beneficiaría de esas conclusiones gracias a una mejor comprensión de las medidas físicas estudiadas, además de permitirles diseñar intervenciones más precisas y mejor enfocadas al desarrollo de la movilidad en la población de avanzada edad.

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APPENDIX

To the best of our knowledge, this study is the first to compare the efficacy of volitional contractions, NMES evoked contractions, and superimposed NMES onto volitional contractions using a low intensity (40% of 1RM) exercise to improve muscle CSA, physical performance and the capacity to perform daily tasks in older adults. We sought to develop a relatively short-term exercise intervention, safe, accessible, and easy to follow, that would help older adults living in geriatric nursing homes to gradually reduce the age-related decline in their physical condition. This study was demonstrated to be safe, with no major side effects reported during the intervention. Additionally, the mean study attendance rate at 4 months was 78% a rate considerably higher than that for other facility-based individual exercise programs (Seung-Youn et al., 2008) suggesting that the exercise was appropriate for and well tolerated by the participants.

Our results showed that the rectus femoris CSA and the capacity to perform daily tasks significantly increased in the three intervention groups. Furthermore, our main finding was that the NMES+ group showed the most significant improvement in mobility and a better tendency to improve balance performance.

Three recently published studies have shown that volitional contraction (Van Roie et al., 2013; Watanabe et al., 2013) or NMES evoked contraction exercise (Altubasi, 2012), performed at low and very low intensities (20–40% of 1RM), can result in muscle size gains. These studies reported improvements between 2.6% and 5.8% in the upper leg and quadriceps femoris volume after a 12-week training period. The results of the present study showed a muscle size increase in rectus femoris CSA of 16.3% and 30.4% in the VC and NMES groups, respectively. Nevertheless, the most remarkable gains were observed in the NMES+ group (42.1%). Differences in percentages compared with previous studies could be explained by the amount of muscle volume assessed, the length of the intervention, and the characteristics of the voluntary and electrically evoked contractions. The aforementioned studies assessed the total upper leg muscle volume or the total quadriceps femoris muscle volume using computer tomography (CT) (Van Roie et al., 2013) or magnetic resonance (MG) (Watanabe et al., 2013), while the present study assessed by ultrasonography, only a single part of the whole muscle volume trained. Moreover, the present study lasted 4 weeks longer than previous studies (Altubasi, 2012; Van Roie et al., 2013; Watanabe et al., 2013), which may account for a greater CSA increase.

Additionally, because of the specific characteristics of the electrically evoked contractions, the percentage of muscle volume involved during the exercise was not the same as in the volitional contraction exercises. It has been suggested that NMES would specifically stimulate the superficial fibers of the whole muscle volume (Maffiuletti, 2010; Vanderthommen and Duchateau, 2007). In addition, following Henneman's "*size principle*", during voluntary contraction, motor units (MUs) are recruited in an orderly fashion from small (slow, type I) to large (fast, type II) in relation to the stimulus intensity (Henneman et al., 1965) whereas, during electrically evoked contraction, the MU recruitment pattern has been defined as a spatially fixed and temporally synchronous (Vanderthommen and Duchateau, 2007). As a consequence, NMES favours the activation of large and small MUs, imposing a contractile activity of both MUs even at relative low intensities (Maffiuletti, 2010). These facts may explain that a superficial muscle such as rectus femoris was more highly activated in both NMES groups as compared to the voluntary contraction group. On the other hand, because of its hip flexor condition, the rectus femoris may not have participated as much in a voluntary exercise protocol using knee extension, in comparison to NMES protocols, where the stimulation was applied regardless of its biomechanics.

Gains in muscle size do not automatically guarantee functional performance improvements (Liu and Latham, 2011; Miszko et al., 2003; Van Roie et al., 2013). Accordingly, and in line with previous low intensity exercise training studies, significant muscle CSA gains in VC and NMES groups were not accompanied by significant improvements in mobility (Van Roie et al., 2013), aerobic endurance (Seynnes et al., 2004) and balance (Rosie and Taylor, 2007). However, the NMES+ group showed a significant improvement in mobility and better gains in the balance performance, which may be explained by the cumulative effects of both techniques.

Finally, diminished hand-grip strength has been associated with premature mortality, disability and other health-related complications in older adults (Bohannon, 2008; Rantanen et al., 1999). Although our results showed no significant hand-grip improvement (because of the absence of specific upper extremity exercise training), the maintenance of hand-grip strength in all intervention groups compared to the decrease shown in the control group, may represent an attenuation of age-related decline.

This study has several limitations. First, the relatively short duration of the intervention may have truncated the time needed to achieve greater improvements. In addition, it was not possible to assess the long term effect of the intervention because of the absence of follow-up measurements. Second, rectus femoris CSA was assessed using ultrasonography. Muscle volume can be measured using a variety of techniques, including computer tomography (CT) and magnetic resonance (MR). However, such measurements require expensive equipment and specific expertise to interpret the images, and in the first case involve the exposure of the subjects to ionizing radiation (Menon et al., 2012). Ultrasound apparatus, on the other hand, is an easily available, portable, valid, safe and reliable alternative to CT and MG for measuring superficial muscles such as rectus femoris CSA (Sipila and Suominen, 1991; Thomaes et al., 2012). Nevertheless, the rectus femoris only represents a part of the quadriceps femoris. It would have been more appropriate to assess the whole quadriceps muscle volume and/or to measure knee extension strength. Third, experimented physiotherapists motivated to help participants were successful in conducting the exercise sessions. It was evident that participants were highly enthusiastic about the study. Given the simplicity of the training required, less experienced physiotherapists could be equally successful, but that remains to be shown. Fourth, participants were healthy individuals living in a geriatric nursing home, and are therefore not representative of all older adults at large. Fifthly, sample size calculation may have considered the minimal detectable change for the TUG and rectus femoris CSA in a sample of healthy older adults. Consequently, caution should be exercised in generalizing these findings over infirm or diseased older adults.

The effectiveness of a video-supported group-based Otago Exercise Programme on physical performance in community-dwelling older adults: A preliminary study.

The main novel finding of the current study was that, if a multi-modal exercise program such as the Otago Exercise Programme (OEP) is video-supported and conducted on a group basis, it induces significant improvements in the balance, mobility, physical performance and aerobic endurance in community-dwelling older adults.

The vast majority of studies using the OEP have been conducted at the participant's homes, and most of these studies were focused on reducing falls and related injuries (Thomas et al., 2010). Because the results of home-based interventions are well documented and fall prevention was beyond the scope of the present study, the emphasis of the discussion below will be on the effects of the video-supported group-based OEP on balance, mobility, physical performance and aerobic endurance.

A measure frequently used to assess general mobility in OEP interventions is the Timed "*Up-and-Go*" Test (TUG). Previous studies have reported positive effects on mobility after different OEP interventions. However, not all studies have shown significant improvements. Home-based OEP interventions reported non-significant changes in patients with moderate Alzheimer's disease (Suttanon et al., 2013), haemophilia and blood disorders (Hill et al., 2010), or participants with a previous fall incident (Liu-Ambrose et al., 2008). Nevertheless, group-based (Thomas et al., 2010) and individually assisted (Kyrdalen et al., 2014) OEP interventions in participants with a previous fall incident or in vision-impaired patients, respectively, have reported significant improvements in general mobility. The results of the current study are in line with these studies, showing a significant reduction in the time needed to perform the TUG. It is encouraging that, given the higher level of mobility shown at baseline (IG 9.3 s and CG 9 s), the intervention was still able to result in a statistically significant improvement when the two groups were compared.

Recently published studies revealed that OEP interventions significantly improved functional balance in a range between 3.2 and 3.5 points when balance was assessed with the Berg Balance Scale (BBS) (Yoo et al., 2013; Kyrdalen et al., 2014; Kovács et al., 2012). In agreement with these results, intervention group (IG) showed an improvement of 3.5 points in the total BBS score compared to control group (CG). Despite the similarities between results, baseline BBS scores shown in the current study were considerably higher compared to those established in previous studies. As reported by Rejesky *et al.*, baseline values intrinsically affect changes in functional performance, with higher gains obtained in participants with the worst baseline performance (Rejeski et al., 2011). On the other hand, limited OEP interventions have measured static balance using the One-leg Stand Test (OLS). Campbell *et al*. reported improvements when one-leg balance was assessed for 10 s (Campbell et al., 1997). In the present study, the improvements shown by the IG vs CG in the OLS (23.5 s) were considerably higher than the Clinically Meaningful Improvement (CMI) reported by Maribo *et al.* (6.8 s) (Maribo et al., 2009). This result suggests that the programme may be effective for enhancing one leg balance on this study population. Between-groups data analysis showed no significant differences in the total score of the Short Physical Performance Battery (SPPB). Additionally, supplementary data analyses of intervention effects on the individual components of the SPPB were conducted. Given the participants high levels of functioning at baseline, a ceiling effect in the static balance (side-by-side, semi-tandem and tandem-stand) was found. Consequently, data analysis revealed no changes in static balance for either group. Repeated Chair Stand Test data analysis showed a significant reduction of time needed to perform the test -2.2 s in favour of the IG when the two groups were compared. This result is consistent with previous studies reporting improvements after a home-based OEP intervention in healthy (Campbell et al., 1997) and mild-balance (Jing Yang et al., 2012) older adults. Baseline gait speed scores were above the threshold considered for full community ambulance independence in older adults (more than .8 m/s) (Schmid et al., 2007). Between groups analysis reported no significant improvements in the gait speed. However, the within-group analysis showed significant improvements in the IG. Finally, data analysis revealed a non-significant improvement in the total distance covered in the 6-minute Walk Test (6MWT) when the two groups were compared. However, the within-group analysis of the IG reported a significant improvement (21 m). On the other hand, and in agreement with previous studies (Campbell et al., 1997), a 10 minute walk at the end of each training session was found to be insufficient for reaching a between-groups significant improvement.

This study has several limitations. Firstly, there was no follow-up performed to determine any long-term effects of the intervention, the adherence to exercises routines, and the maintenance of accrued benefits. Secondly, the participants were predominantly female (76%), although randomization revealed no sex difference between groups. Thirdly, lower-limb strength measures were scarce, and given the range of strengthening exercises in the OEP, the inclusion of more direct and indirect strength measures would have been helpful. Fourthly, the study participants were volunteers who responded to advertisement, well-functioning, and with a high independence level, which characteristics may not be representative of the older adult´s population at large. Fifthly, sample size calculation may have considered the minimal detectable change for the TUG in a sample of healthy older adults. Consequently, care should be taken in generalizing these findings. Finally, the inclusion of a third group receiving a group-based OEP intervention with no video support could have isolated the effects of the video materials.

Factors associated with the 6-minute Walk Test in nursing home residents and community-dwelling older adults.

We found that all physical measurement results were significantly lower in older adults living in a geriatric nursing home compared with those of older adults dwelling in the community. In the bivariate analyses, more distance covered in the 6MWT was associated with better results in the BBS, TUG, and SPPB (higher in the NH group compared with the CD group), better walking speed and hand-grip strength, and a higher rectus femoris CSA. After adjusting for age, rectus femoris CSA, hand-grip strength, BBS, gait speed, and STS-5, the SPPB and TUG were independently related to the 6MWT. The SPPB explained 59.5% of the change in the distance covered during the test. When the NH group was analysed separately, both the SPPB and hand-grip strength were independently related to the 6MWT, while in the CD group, only the TUG was independently associated with the 6MWT. Therefore, in the light of these results, a lower SPPB score explains less distance covered in the 6MWT in the elderly population. The TUG appears to be an important measure for those individuals dwelling in the community.

The data analysis showed a significant difference in the 6MWT between the study groups. We found that the distance covered by the CD group was very similar to that reported in a prior study on well-functioning community-dwelling older adults (65±2 yr.) (Thaweewannakij et al., 2013). On the other hand, participants in the NH group reported a lower distance covered (290.6±110.7 m) compared with the CD group (371.4±71.7 m). Additionally, a considerable range in distance covered (ranging 49 to 645 m in the NH group and 172 to 508 m in the CD group) was found in both study groups. This variability between groups was probably due to differences in age (Rikli and Jones, 1999; Steffen et al., 2002; Tveter et al., 2014) or baseline values for the physical measures (Rikli and Jones, 1998; Harada et al., 1999). Heterogeneity in health status is a characteristic of the older adult´s population. “Apparently healthy” elderly persons could present with a large diversity in health status, and their exercise capacities could be substantially influenced (Bautmans et al., 2004).

Although previous studies have assessed the implications of physical measures on 6MWT performance in older adults, their target populations (suffering from multiple sclerosis or strokes) (Langhammer et al., 2006; Danielsson et al., 2011; Kluding and Gajewski, 2009; Wetzel et al., 2011; Enright and Sherrill, 1998) or methods (non-standardized procedures for balance or lower-limb function) (Lord and Menz, 2002; Camarri et al., 2006; Bautmans et al., 2004; Harada et al., 1999) were somewhat different, making direct comparison difficult, and factors explaining the differences in 6MWT performance between two different geriatric groups (older adults living in a geriatric home and those dwelling in the community) have not been previously reported.

Moderate to high (*r* between .5 and .7) (Fleiss, 1986) correlations between the 6MWT and age, gait speed, BBS, TUG, and SPPB were found, but the correlations were lower with the rectus femoris CSA, STS-5 and hand-grip strength (r<.5). In agreement with previous research, there was a negative correlation between age and 6MWT (Troosters et al., 1999; Shumway-Cook et al., 1997) and a positive correlation between physical performance and 6MWT distance (Lord and Menz, 2002; Harada et al., 1999; Langhammer et al., 2006; Kluding and Gajewski, 2009; Enright and Sherrill, 1998). Hence, Harada *et al.* (Harada et al., 1999) observed significant correlations between related individual tasks from the SPPB (standing balance r=.52, gait speed test r=.73, and the Repeated Chair Stand Test r=.67) and the 6MWT in a sample of healthy older adults living in retirement homes or dwelling in the community. Additionally, Lord *et al.* (Lord and Menz, 2002) reported that overall mobility (which included balance, sensorimotor, and lower-limb strength measures) was significantly associated with the 6MWT in a sample of older adults living in retirement villages. Furthermore, other studies have reported similar observations in impaired older adults. Wetzel *et al.* (Wetzel et al., 2011) reported significant correlations between the 6MWT and static balance (r=.39) and the multiple sit-to-stand test (r=.57) in community dwelling individuals who had moderate disabilities and had been diagnosed with multiple sclerosis. Langhammer *et al.* (Langhammer et al., 2006) observed a strong correlation between the 6MWT and TUG in a sample of older adults with acute stroke. Finally, Kluding *et al.* (Kluding and Gajewski, 2009) observed a significant correlation with the BBS (*r*=.67) in a sample of patients who had a mean age 57.6 years and were suffering from chronic stroke. Despite differences in the characteristics of the samples in the various studies, these results support the importance of physical performance on the walking ability when covering long distances, especially in low-functioning older adults. Therefore, the present study confirms and extends the findings reported by previous research concerning demographic and physical measures explaining 6MWT performance in a sample of healthy older adults.

Although our study was cross-sectional, the inclusion of participants across the spectrum of aging yielded some interesting observations that might shed some light on the main functional aspects that influence walking distance among older adults. Multivariate analyses showed different results depending on the subgroup analysis. While the 6MWT was independently associated with the SPPB in the NH group, it was associated with the TUG in the CD group. The walking ability of older adults living in a geriatric nursing home is better explained by the SPPB than by age, rectus femoris CSA, or other physical performance variables. To the best of our knowledge, no study has investigated the variance of the 6MWT with the SPPB as a single measure. However, a previous study (Harada et al., 1999) showed that the three individual tasks of the SPPB (balance, gait speed, and chair stands) explained 69% of the variance in the 6MWT in healthy older adults dwelling in the community and living in retirement homes. While Harada *et al.* analysed the results for a mixed-population sample from community centres and retirement homes the two types of populations were also analysed separately in our study. Differences in the variance may be accounted for by other disparities in the analysis of measures and samples of the studies. This finding reveals that the capacity to perform daily activities such as walking, standing up from a chair, or maintaining standing balance, may be reflected by the ability to walk a certain distance. Therefore, the SPPB could be used to evaluate lower-limb functioning as well as walking ability in older adults, with special attention to populations living in geriatric nursing homes. Regarding to the community-dwelling older adults, the TUG was the variable that better explained the variance in the 6MWT. The absence of studies examining the extent to which the TUG influences the 6MWT in healthy older adults prevents us from comparing our results with previous research. However, one study (Lord and Menz, 2002) reported that overall mobility appeared to provide a measure of 6MWT in a sample of community-dwelling older adults.

The regression model of this study (which included age, lower-limb strength, simple reaction time, and postural sway and balance range) explained 52.5% of the variance in the 6MWT. These results are in agreement with our study, which explained 48.4% of the variance in the 6MWT with the TUG. However, care should be taken in comparing these results because of the differences between study populations and assessment measures. The positive correlation between the TUG and 6MWT is not surprising because during the 6MWT, participants walked as far as possible and the test included "turns around a cone" at the end of the corridor. According to our results, it seems that, in lower-functioning older adults, balance and SPPB components are of high importance to improvement of walking distance, while in higher-functioning samples, walking distance relies on mobility and walking speed. Hence, these results suggest that, to improve walking performance in healthy older adults, an intervention could focus on enhancement of balance, mobility, and lower-limb function. This will need to be confirmed in prospective and longitudinal studies.

This study has several limitations. Firstly, the study participants were volunteers and relatively healthy older adults, a sample that may not represent the characteristics of people living in a geriatric nursing home or dwelling in the community. A possible selection bias may explain differences in the participant´s levels of physical performance. The wide inclusion criteria lend support to the external validity of these results when making comparisons to typical older adults living in nursing homes or in the community. Secondly, although we assessed some components of lower-limb physical performance, the measured variables may not cover all physical information that explains the variability in the 6MWT. To confirm the results of this study, future analyses should consider other physical measures, such as the ability to modify balance while walking in the presence of external demands

(Dynamic Gait Index) (Shumway-Cook et al., 1997), fast walking speed (10-Meter Walk Test) (Peters et al., 2013), or muscle strength and CSA of other muscles involved in walking performance, like the vastus medialis. These factors may play an important role in the 6MWT and walking performance. Thirdly, the sample size was relatively small (NH; n=71, CD; n=51). Consequently, caution is warranted when interpreting or generalizing the results of this study, especially to frail or impaired older adults.

This study confirms and extends the findings reported by previous research examining the relationships between the TUG performance and physical measures in older adult’s populations. As far as we know, this is the first study that compares the factors explaining the TUG performance by including muscle CSA. The main findings of the current analysis are (1) that BBS score and knee extension strength were highly correlated with the TUG (r=-.561 and -.397). In the partial correlation analyses, shorter times to complete the transitions, straight-line walking, and turnings included in the TUG were associated with better results in the BBS and higher knee extension strength. Moreover, (2) following the stepwise linear regression, the functional balance measured with the BBS was demonstrated to be the most significant factor explaining the TUG performance. A higher BBS score explains shorter performance times to complete the TUG.

Baseline sample characteristics showed that the mean TUG performance (11.1±5.3 s) was in consonance with published values for well-functioning older adults (Thaweewannakij et al., 2013; Medley and Thompson, 2015). Additionally, it was below the cut-off point reported for a normal TUG in community-dwelling or institutionalized older adults (Medley and Thompson, 2015; Bischoff et al., 2003), and 76% of the sample performed the test in <12 s, confirming that the sample was composed by healthy and freely mobile individuals (Bischoff et al., 2003). On the other hand, a considerable range in the time taken to perform the TUG was found (ranging from 5.9 to 38.3 s). This variability may be explained by differences in age (Steffen et al., 2002; Rikli and Jones, 1999) as well as through differences in baseline values in the physical capacities (Duncan et al., 1993). We found that the TUG performance time gradually increases as age increases. For individuals aged 65 to 75 yr. (n=106), a mean TUG performance of 8.6 s was recorded, while for individuals aged 76 to 85 yr. (n=60), a mean TUG performance of 12.4 s was recorded. Finally, for individuals aged >85 yr. (n=28), a mean TUG performance of 17.2 s was recorded. This observation is in agreement with a recent study reporting similar TUG performance times in the same three age categories, in a sample of apparently healthy adults aged 60 to 96 yr. (Medley and Thompson, 2015). Hence, age has been demonstrated to be an important factor for the TUG performance in older adults. As an "apparently healthy" elder person grows older, exercise capacity could be substantially influenced by the concomitant mobility decline (Bautmans et al., 2004).

High significant correlation coefficients between the TUG and BBS score and knee extension strength (*r*=-.561 and -.397) were reported. These results are in consonance with previous research reporting a significant negative correlation between the TUG performance and functional balance (Herman et al., 2011) and knee extension strength (Kwan et al., 2011; Shimada et al., 2010) in apparently healthy and independent older adults. Our results suggest that the TUG performance correlated with many physical performance tasks present during everyday life, such as keeping in balance, sitting and standing from a chair, reaching forward, retrieve an object from the floor or turning. As it has been reported previously, the functional decline may be related with the accumulation of deficits in the functional capacities (Donoghue et al., 2014). Consequently, the mobility decline may be better explained as the sum of deficits across multiple domains rather than as a single entity. Due to its multi-task design (Podsiadlo and Richardson, 1991), it seems clear that the TUG performance does not focus on a single independent variable, but reflects the performance of many daily life activities (Bischoff et al., 2003). This observation favours the understanding that the BBS score was the variable that better correlated with the TUG performance. An unexpected result in the correlational analyses was the absence of significant correlation between the TUG and the rectus femoris CSA. Coordination between lower-limb muscles plays an important role in the performance of the TUG. Measuring a single portion of the muscle may not reflect the necessary coordination involved in a multi-task mobility test as the TUG.

Furthermore, we observed that the multivariate analyses reported that the BBS was independently related to the TUG performance. The BBS score explained 37.3% of the change in the time needed to complete the TUG, while the sum of the BBS and knee extension strength explained 45.1% of the change. Previous studies have reported that the BBS appears to be an independent predictor of the TUG performance in subjects with chronic stroke (Ng, 2011). However, care should be taken in comparing these results because of the differences between study populations. Our analyses showed that the BBS score was the most significant factor explaining the TUG performance in our study sample. The TUG incorporates a series of motor tasks including sit-to-stand, walking, turning and stand-to-sit (Wall et al., 2000) which requires efficient postural responses to perform the test quickly and as safe as possible. Four of the 14 items that composes the BBS are components of the TUG test (sitting to standing, standing unsupported, standing to sitting and turning 360°) which may explain why the BBS score describes a large proportion of variance in the TUG performance, and the close relation between the TUG performance and the BBS score. On the other hand, BBS score and knee extension strength explained 45,1% of the change in the TUG performance (Table 11). Previous studies have reported that knee extension strength is a significant determinant of the TUG performance in apparently healthy independent women (Shimada et al., 2010) and community-dwelling (Kwan et al., 2011) older adults. Maximal voluntary isometric knee extension strength is a reflection of the forces a muscle can produce, which are necessary for completing activities of daily living, such as rising from a chair (Marmon et al., 2014). As the TUG involves muscle activity, it is not surprising that our results showed that knee extension strength explained a relevant proportion of the changes in the TUG performance. Hence, future interventional studies should incorporate a focus on balance and muscle strengthening to clarify if improving those variables may result in a better TUG performance.

In the light of these results, the TUG performance, besides considered a reliable instrument to measure mobility, appears to be an appropriate measure for the clinical assessment of functional balance, and a useful tool for predicting the muscle weakness in lower limb muscles. In addition, given the absence of a ceiling effect, its fine design and its quick and easy implementation, the TUG demonstrates apparent advantages over other performance-based tests when studying the functional decline or the benefits of a therapeutic intervention in healthy older adults. Our study findings have clinical importance in that they suggest that TUG performance may be improved by exercise programs aimed at the enhancing of balance and muscle strength, with particular attention to those individuals identified as mobility impaired, elders who perform the TUG in >12 seconds (Bischoff et al., 2003). Therefore, nurses, physiotherapist and other health providers, as key components of the assessment and treatment of elder populations, will benefit from those findings by a better understanding of the physical measures, in addition to designing more accurate interventions focusing on the enhancement of mobility. However, this will need to be confirmed in prospective and longitudinal studies and, future analyses should consider additional and more demanding physical measures for high functioning elder populations, such as the ability to modify balance while walking in the presence of external demands (Dynamic gait index) (Medley and Thompson, 2015), fast walking speed (10-Meter walk test) (Peters et al., 2013), or muscle strength and CSA of other muscles involved in walking performance, like vastus medialis. Those factors may play an important role in the TUG performance.

There are several limitations to this study. Firstly, the participants were volunteers and relatively healthy older adults, a sample that may not represent the characteristics of people living in a geriatric nursing home or dwelling in the community, therefore these findings should not be extended to frail or impaired older adults. A possible selection bias may explain differences in the participant´s levels of physical performance. The wide inclusion criteria lend support to the external validity of these results when comparing to the typical older adults living in the nursing home or in the community. Secondly, although we assessed some components of lower-limb physical performance, the measured variables may not cover all physical information that explains the variability in the TUG performance. Thirdly, the sample size was relatively small (n=194). Consequently, caution is warranted when interpreting or generalizing the results of this study, especially to frail or impaired older adults.

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1. From a short-term perspective, a low-intensity NMES+ exercise program may be useful to improve physical performance, rectus femoris CSA, and the capacity to perform daily tasks in older adults living in a geriatric nursing home. These findings, associated with the characteristics of the program, support the idea that low intensity NMES+ exercises are useful to partially mitigate the age-related consequences in this study population.

2. A video-supported group-based Otago Exercise Programme can significantly improve the levels of balance, mobility and physical performance in older adults.

3. A higher lower-limb function, balance, and mobility are associated with better walking ability and distance covered in healthy older adults. The SPPB is the test that best determines the walking performance in low-functioning older adult populations, while the TUG best determines the walking performance in community-dwelling older adults.

4. The TUG performance is highly correlated with the BBS score and knee extension strength, measures that represent numerous physical performance tasks common in everyday life, such as keeping in balance, sitting and standing from a chair, reaching forward, retrieve an object from the floor or turning. The BBS reported to be the most significant factor explaining the TUG performance. The TUG was demonstrated to be a useful tool for predicting changes in functional balance. A higher BBS score explains shorter performance times to complete the TUG.

5. The capacity to walk for a distance and mobility decline may be better explained as the sum of deficits across multiple domains rather than as a single entity. Clinicians would benefit of those findings by a better understanding of the physical measures, in addition to designing more accurate interventions focusing on the enhancement of mobility and the walking capacity.

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Effects of three different low-intensity exercise interventions on muscle CSA, physical performance and activities of daily living: A randomized controlled trial.

Study concept and design: Vicent Benavent Caballer, Juan Francisco Lisón Párraga, Pedro Rosado Calatayud, Juan José Amer Cuenca and Eva Segura Ortí.

Acquisition of participants and data: Juan Francisco Lisón Párraga, Juan José Amer Cuenca and Eva Segura Ortí.

Analysis and interpretation of data: Vicent Benavent Caballer and Juan Francisco Lisón Párraga.

Preparation of manuscript: Vicent Benavent Caballer, Juan Francisco Lisón Párraga, Juan José Amer Cuenca, Eva Segura Ortí and Pedro Rosado Calatayud.

*All authors approved the final manuscript.

The effectiveness of a video-supported group-based Otago Exercise Programme on physical performance in community-dwelling older adults: A pilot randomized controlled trial.

Study concept and design: Vicent Benavent Caballer, Juan Francisco Lisón Párraga, Pedro Rosado Calatayud and Juan José Amer Cuenca and Eva Segura Ortí.

Acquisition of participants and data: Juan Francisco Lisón Párraga, Juan José Amer Cuenca, Eva Segura Ortí and Pedro Rosado Calatayud.

Analysis and interpretation of data: Vicent Benavent Caballer and Juan Francisco Lisón Párraga.

Preparation of manuscript: Vicent Benavent Caballer, Juan Francisco Lisón Párraga, Juan José Amer Cuenca, Eva Segura Ortí and Pedro Rosado Calatayud.

*All authors approved the final manuscript.

Factors explaining the 6-minute Walk Test in nursing home residents and community-dwelling older adults.

Study concept and design: Vicent Benavent Caballer, Eva Segura Ortí, Juan Francisco Lisón Párraga, Juan José Amer Cuenca and Pedro Rosado Calatayud.

Acquisition of participants and data: Juan Francisco Lisón Párraga, Juan José Amer-Cuenca, Eva Segura Ortí and Pedro Rosado Calatayud.

Analysis and interpretation of data: Vicent Benavent Caballer and Eva Segura Ortí.

Preparation of manuscript: Vicent Benavent Caballer, Eva Segura Ortí, Juan Francisco Lisón Párraga, Juan José Amer Cuenca, and Pedro Rosado Calatayud.

*All authors approved the final manuscript.

Physical factors underlying the Timed "*Up and Go*" Test in older adults.

Study concept and design: Vicent Benavent Caballer, Alejandro Sendín Magdalena, Pedro Rosado Calatayud, Eva Segura Ortí, Pablo Salvador-Coloma, Juan José Amer Cuenca and Juan Francisco Lisón Párraga.

Acquisition of participants and data: Alejandro Sendín Magdalena, Juan Francisco Lisón Párraga, Pablo Salvador Coloma, Juan José Amer Cuenca, Eva Segura Ortí and Pedro Rosado Calatayud.

Analysis and interpretation of data: Vicent Benavent Caballer and Eva Segura Ortí.

Preparation of manuscript: Vicent Benavent Caballer, Juan Francisco Lisón, Alejandro Sendín Magdalena, Pedro Rosado Calatayud, Pablo Salvador Coloma, Juan José Amer Cuenca and Eva Segura Ortí.

*All authors approved the final manuscript.

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The ability to minimize age-related physical decline has been widely supported by the evidence shown in different studies and previous publications. Within this vast literature is included those studies based on neuromuscular electrical stimulation programs, volitional contractions exercises and multimodal exercise programs carried out individually or as a group. However, given the heterogeneity of the elderly population, their pluripathology and the differences between individuals regarding to their place of residence, it seems necessary to continue studding the implications of these techniques and programs based on the physical exercise. Future research lines should take into account in their interventions an analytical approach in its exercises structure, trying to keep the best possible conditions of those structures that may be limiting the functional capacity of the elderly, as well a as a global point of view through interventions aimed at improving the functional capacity and the development of commonly performed tasks in their daily life. In addition, those interventions should not overlook the new technological advances in the health field market that arises almost daily, and along with the programs and techniques already known, those technological advances could represent a great support for improving the quality of life in older adult's populations.

Future studies, should confirm the effectiveness of using low-intensity neuromuscular electrical stimulation programs in elderly subjects by using functional exercises close to those developed during the activities of the daily life, such as sitting and rising from a chair, climbing stairs or walk for a distance. It´s possible that new proposals that have recently appeared massively in the consumer market, such as electro-stimulation vests, may be an interesting research line in the near future, appearing as a good training complement or as a single tool for the enhancement of the functional capacity in older adults. However in a research like this, it shouldn't been forgotten the individual characteristics of this population, paying special attention to their comorbidities (osteoarticular, vascular, cognitive impairment and even the presence of overweight). In addition, those interventions should include activities that promote socialization between participants, as it would help to minimize the social isolation that older adults sometimes suffer.

On the other hand, structured and systematized exercises programs as the *Otago Exercise Programme*, have proven to be effective to improve functional capacity in the short- and medium-term. This program has enabled to improve balance, mobility, strength and the walking capacity in both healthy and impaired subjects. Even it has proven to be effective in reducing the risk of falls and improving the mood of its participants. The efficacy shown by the *Otago Exercise Programme* invites us to continue working on this tool, including different populations that haven´t been studied so far, or would be likely to benefit from its application. Examples such as institutionalized populations living in geriatric nursing homes or patients affected by knee or hip osteoarthritis, Alzheimer's disease or patients who have received chemotherapy or radiation therapy as a consequence of cancer treatment, are susceptible populations to be studied in future interventions.

In addition, we now know that physical decline is closely linked to inactivity. Keep on developing more effective and attractive interventions, that suit the characteristics and needs of its participants, must be one of the main objectives of the primary prevention, in which physiotherapists are key components. Interventions such as those shown in this compendium of publications, demonstrate a very high percentage of adherence, very affordable equipment, a reduced cost in its implementation and a high level of motivation in the participants. From a public health point of view, programs such as those exposed may have the ability to reduce the health spending as well as promote the quality of life in older adults.

Finally, the results presented in this compendium of publications, shown a progress in the knowledge related to the physical factors that determine and explain the assessment tests designed for older adults. It has been demonstrated the importance of the lower-limb function (SPPB), the functional balance (BBS) and the mobility (TUG) for improving the walking capacity. Additionally, it has also been proven that mobility performance (TUG) is closely related to the functional balance (BBS). These results, beyond the understanding of the factors that explain a physical quality, invite us to develop and improve interventions aimed to increase the walking capacity and mobility performance. Future studies should consider those physical factors in order to design better interventions that result in higher improvements. Furthermore, despite the better understanding of these variables, it seems necessary that future studies consider other physical measures, such as the ability to modify balance while walking in the presence of external demands, the fast walking speed, or the muscle CSA of muscles involved in walking performance that may play an important role in the walking capacity and mobility.

The results of this collection of publications have opened up different research lines that are already underway, such as the *Otago Exercise Programme* conducted home-base in both healthy and impaired (suffering knee osteoarthritis) subjects, or the use of unstable footwear for the enhancement of balance and gait in institutionalized older adults.

Finally, before ending this section of future perspectives, I would like to share a brief and simple experiment that after its reading awakened in me an optimistic, motivating and inspiring reflection for future studies. For this, I will go back to the second century B.C. where Eratosthenes, who was the chief librarian for years at the Library of Alexandria, showed through an experiment of great beauty and simplicity how is possible to achieve great results with minimal equipment. The experiment has a starting point on the study of the Earth in which we live. The fact that the earth is round or almost round was already known at the time of Eratosthenes. However, it was not known how big or small could be. To calculated the circumference of the Earth, Eratosthenes only needed four things; a wooden stick, a group of merchants who covered the distance between Alexandria and Aswan (a town in southern Egypt), the sunshine light, and finally an extraordinary observation capacity. With these four elements Eratosthenes determined with an outstanding accuracy the size of the circumference of the earth, establishing its magnitude with an error lower than 1% compared to the data known nowadays (40.008 km). Eratosthenes not only calculated the size of Earth, but also demonstrated that even using very basic equipment it´s possible to make great contributions to the knowledge. Back again to 2016 and unlikely the years of Eratosthenes, we fortunately have an unprecedented access to technology, equipment, and information via databases. Therefore, with all my respect to Eratosthenes, it´s necessary to say that even if we don't have his intelligence, capacity of observation and insight, I am sure that with our current resources, all who have participated in this compendium of publications will try to keep contributing to enrich the physiotherapy as a discipline every day. This attitude will revert directly to the benefit of all groups that make up our society.

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Introducción

El envejecimiento es una experiencia maravillosa que cada ser humano vivencia de manera única, pero que nadie llega plenamente a entender. Esta aproximación al proceso de envejecimiento muestra sus aspectos positivos y recuerda las carencias respecto a su plena comprensión. Aun así, el proceso de envejecimiento resulta en su totalidad extraordinario (Ashford et al., 2005). El envejecimiento no debería asociarse a la última etapa de la vida, puesto que tiene su inicio en el comienzo mismo de nuestra existencia. Este proceso continúa progresivamente con el paso de los años, representando los cambios fisiológicos que experimenta nuestro organismo y no solo la presencia de la patología en mayor o menor medida (Bower y Atwood, 2004). Además, el proceso de envejecimiento trasciende más allá de la persona como individuo, al ejercer una profunda influencia sobre las características y necesidades de nuestra sociedad, llegando incluso a moldear la estructura de la población mundial (Christensen et al., 2009).

Un punto de partida comúnmente empleado para acercarnos a la comprensión del proceso de envejecimiento es la categorización de los individuos en función del número de años vividos desde su nacimiento. Este criterio cronológico establece que los individuos con edades superiores o iguales a 65 años, sean asignados a la categoría conocida como “adulto mayor” (Nelson et al., 2007). Sin embargo, esta clasificación resulta una medida ajena a los cambios fisiológicos, psicológicos y sociales que forman parte inherente del proceso de envejecimiento (Borkan y Norris, 1980). Obviamente, no todos envejecemos al mismo ritmo, ni tampoco experimentamos los mismos cambios con el paso del tiempo. Sin duda, la singularidad del individuo es la norma durante este proceso (White et al., 2013). Por tanto, tratar de comprender el proceso de envejecimiento desde una perspectiva exclusivamente cronológica resulta en cierto modo incompleto, lo que hace necesario el uso de medidas adicionales para establecer objetivamente las diferencias que el paso del tiempo produce entre individuos, considerando los aspectos físicos, psicológicos y sociales (Bautmans et al., 2004).

Sin embargo, los análisis poblacionales basados en la edad cronológica han sido de gran utilidad para los estudios demográficos. Estos estudios representan los cambios ocurridos en el tamaño, composición y distribución de la población a lo largo de las últimas décadas, además de permitirnos establecer proyecciones futuras. De acuerdo con sus resultados, sabemos que la proporción de adultos mayores está creciendo en los países de Europa occidental y que posiblemente llegará a duplicarse a lo largo de los próximos 30 años (Christensen et al., 2009; Caffrey et al., 2011). En España, un país con una población de 46.5 millones de habitantes, el 18.2% (8.4 millones) es ≥65 años (INE, 2014), una proporción que podría incrementarse hasta alcanzar el 24.9% (un aumento de 2.9 millones) en el año 2029 (INE, 2014). Del mismo modo, se estima que los países vecinos de España experimentarán una proyección similar a lo largo de los próximos años; Francia alcanzará el 22.4% de población ≥65 años en el año 2030 (INSEE, 2010), Alemania el 29% en 2030 (FSO, 2010) y Reino Unido el 23% en 2035 (ONS, 2012).

Por otra parte, y dejando a un lado las proyecciones demográficas, al analizar las características del adulto mayor en el contexto actual, uno de los aspectos más destacados es su heterogeneidad en términos de patología, nivel socio-cultural, económico e incluso su lugar de residencia. Analizando este último punto, actualmente más del 70% de los adultos mayores residen en zonas urbanas (USCB, 2011) (Grimley et al., 2003), dividiéndose esta proporción principalmente en dos grupos; (1) adultos mayores que viven en residencias y centros geriátricos, y (2) adultos mayores que habitan en la comunidad. Un elevado número de adultos mayores con edades comprendidas entre los 65 y los 75 años, con suficiente nivel de independencia para llevar a cabo la mayor parte de las actividades de la vida diaria, viven en sus casas y desarrollan sus actividades y relaciones con otros grupos sociales dentro de la comunidad. Sin embargo, cuando los adultos mayores superan la edad de 80 años, el número de individuos que vive en residencias y centros geriátricos aumenta notablemente (Grimley et al., 2003). Esta circunstancia se explica principalmente como resultado de la relación directa entre el aumento de la edad y el progresivo deterioro de la capacidad funcional, que puede llegar a resultar en la necesidad de institucionalización o cuidados de larga duración (Benavent-Caballer et al., 2015). A modo de ejemplo, el 11.8% de los hombres y el 18.1% de las mujeres españolas con edades ≥90 años viven en residencias y centros geriátricos, mientras que solo en el 1.8% de las mujeres y en el 2.1% de los hombres con edades comprendidas entre los 65 y 69 años se da esta circunstancia (INE, 2013).

Además de analizar la población de adultos mayores desde una perspectiva cronológica o de acuerdo a su lugar de residencia, es posible hacerlo basándonos en criterios asociados a su condición física. Esta clasificación permite integrar desde individuos sanos y activos, hasta individuos frágiles y enfermos. Nuevamente, esta circunstancia demuestra la gran heterogeneidad y variabilidad individual entre los adultos mayores (Serra-Rexach et al., 2011). Diferentes estudios sobre el deterioro físico como consecuencia de la edad demuestran que el proceso de envejecimiento afecta a todos nuestros sistemas corporales, incluyendo el sistema cardio-vascular, el respiratorio, el músculo-esquelético o el nervioso, resultando en una pérdida de capacidad pulmonar, una reducción en la resistencia aeróbica o una disminución de la masa muscular y la fuerza (Watsford et al., 2007; Janssens et al., 1999; Daubney y Culham, 1999; Lindle et al., 1997). La magnitud en el deterioro de cada uno de estos sistemas varía entre los individuos; sin embargo, ciertos cambios biológicos y funcionales están reconocidos como marcadores comunes al proceso de envejecimiento humano.

Uno de estos cambios se manifiesta en la modificación de la composición corporal, caracterizado por un aumento progresivo de la masa grasa y una reducción gradual y constante del área de sección transversal muscular (CSA) (Lexell, 1995; Ikezoe et al., 2011). Estos cambios no se manifiestan exclusivamente en individuos de avanzada edad, sino que tiene su punto de partida en la tercera década de vida, progresando con el paso de los años hasta alcanzar una pérdida total del 25% al 40% de la CSA (Klitgaard et al., 1990; Lexell et al., 1988). Estos cambios en el porcentaje de masa grasa y CSA se consideran como los principales responsables de la pérdida de la capacidad funcional, disminución de la independencia y aumento de la fragilidad en los adultos mayores (Roubenoff, 2001; Roubenoff y Hughes, 2000; Doherty, 2003).

Los mecanismos fisiológicos propuestos para explicar la progresiva pérdida de CSA indican que se produce como consecuencia de una reorganización de las unidades motoras (UM) que inervan las fibras musculares (Doherty y Brown, 1993). Durante este proceso, se produce una denervación selectiva de las fibras musculares tipo I y II (especialmente fibras musculares tipo II) (Lexell et al., 1988; Nilwik et al., 2013) seguida de una reinervación a cargo de las UM yuxtapuestas, lo que se traduce en un incremento del tamaño de las UM existentes y del número de fibras musculares inervadas por cada UM (Wang et al., 1999). Debido al aumento en el número de fibras musculares por UM se produce una disminución progresiva en la capacidad para su activación (Doherty y Brown, 1993; Ling et al., 2009) y, en consecuencia, el tamaño de las mismas disminuye, especialmente las fibras musculares tipo II, contribuyendo a su progresiva atrofia. Finalmente, esta pérdida en el tamaño de las fibras musculares se ve reflejada en una disminución de la CSA (Nilwik et al., 2013). El relativo mantenimiento del tamaño de las fibras musculares tipo I podría explicarse gracias al "*size principle*" o patrón de reclutamiento fibrilar de las UM propuesto por Henneman *et al*. Este principio indica que durante una contracción muscular voluntaria las UM se reclutan de manera ordenada, empezando por las fibras lentas tipo I y continuando con las fibras rápidas tipo II, ello en relación al incremento de la intensidad del estímulo (Henneman et al., 1965). Debido a la reorganización de las UM las fibras tipo I se mantienen en uso de manera regular, mientras que las fibras tipo II, sujetas a estímulos de mayor intensidad, raramente se reclutan y por tanto presentan mayor atrofia como consecuencia del desuso (Nilwik et al., 2013).

De manera similar a la reducción de la CSA, la fuerza muscular, entendida como la cantidad de energía que un músculo es capaz de generar durante una contracción máxima, experimenta una pérdida comprendida entre el 20% y el 40% a lo largo de la vida (Larsson et al., 1979; Murray et al., 1985; Murray et al., 1980; Young et al., 1985). La pérdida de fuerza comienza durante la quinta década de vida y continúa a un ritmo anual del 1% al 2% (Skelton et al., 1994; Vandervoort y Duchateau, 2002), afectando en mayor medida a los músculos de las extremidades inferiores (Beneka et al., 2005; Rosenberg, 1997; Janssen et al., de 2000), donde el porcentaje de pérdida puede llegar a incrementarse hasta el 3% anual (Ikezoe et al., 2011; Goodpaster et al., 2006). Esta pérdida de fuerza puede verse agravada debido a una conducta sedentaria (Doherty, 2003; Park et al., 2010; Ikezoe et al., 2011) o a una reducción prolongada de la actividad física (Sandler et al., 1991; Hunter et al., 2004).

La disminución de la fuerza ha demostrado ser un factor determinante para entender la pérdida de capacidad funcional e independencia en los adultos mayores (Rantanen et al., 2002; Fiatarone et al., 1990). A medida que envejecemos la capacidad para realizar actividades de la vida diaria (AVD) puede verse mermada (Brill et al., 2000) (Lauretani et al., 2003; Salem et al., 2000), especialmente aquellas actividades relacionadas con las extremidades inferiores (Visser et al., 2002) tales como caminar, levantarse o sentarse de una silla, levantarse de la cama o mantener el equilibrio (Guralnik et al., 1995; Janssen et al., 2002; Janssen et al., 2004; Moreland et al., 2004). En ocasiones, los adultos mayores realizan las AVD generando fuerzas próximas a su capacidad máxima. Es por tanto necesario que cada individuo cuente con un nivel mínimo de condición física que le permita alcanzar el umbral funcional ("*Functional Performance Threshold*"), a fin de realizar las AVD con plenas garantías (Thompson, 2000). Si la capacidad máxima se encuentra justo por encima del umbral funcional, tan solo es necesario un leve descenso en su condición física para pasar de ser "capaz", es decir independiente, a ser "incapaz", y por tanto necesitar de una ayuda externa para realizar las AVD.

Revertir el deterioro físico asociado con la edad mediante el mantenimiento de la calidad de vida relacionada con la salud (HRQOL) es uno de los principales objetivos de la salud pública para el siglo XXI (Baker et al., 2007). Durante las últimas décadas, estudios basados en la práctica de ejercicio físico en población de avanzada edad han demostrado su eficacia para la mejora de la capacidad funcional y la HRQOL (Liu y Latham, 2009; Kalapotharakos et al., 2005; Cyarto et al., 2008; McAuley et al., 2013;

Gillespie et al., 2012; Sherrington et al., 2008; Chandler y Hadley, 1996). En consecuencia, la práctica regular de ejercicio físico puede considerarse como una de las actividades más importantes que podemos hacer para mantenernos saludables a medida que envejecemos (Peterson et al., 2010; Chodzko-Zajko et al., 2009; Teri et al., 2001).

Un método frecuentemente utilizado para realizar ejercicio físico es el entrenamiento progresivo de la resistencia (PRT). Los sujetos que practican esta modalidad de entrenamiento realizan contracciones musculares frente a una resistencia externa que incrementa progresivamente su carga a medida que la fuerza de los sujetos aumenta (Latham et al., 2004; Hunter et al., 2004). Dos técnicas basadas en el PRT que han demostrado su eficacia para el fortalecimiento muscular en poblaciones de avanzada edad son: (1) contracciones musculares voluntarias (VC) y (2) estimulación eléctrica neuromuscular (NMES). La NMES consiste en la aplicación de una corriente eléctrica sobre una musculatura normalmente inervada mediante electrodos de superficie, con el objetivo de mejorar la fuerza muscular a través de contracciones musculares evocadas eléctricamente (Maffiuletti, 2010; Vanderthommen y Duchateau, 2007). Ambas técnicas, tanto la VC como la NMES, ofrecen una resistencia que debe aumentar progresivamente a lo largo de las sucesivas sesiones de entrenamiento debido a que la intensidad del ejercicio es un factor determinante para alcanzar resultados positivos (Latham et al., 2004; Liu y Latham, 2009; Maffiuletti, 2010). Y cuanto mayor sea la resistencia a superar por la VC, mayores serán las ganancias en el tamaño muscular y su fuerza (Hunter et al., 2004) (Peterson et al., 2010). Del mismo modo, cuanto mayor sea la intensidad de la NMES, mayores serán las ganancias en el tamaño muscular y su fuerza (Maffiuletti, 2010; Miller y Thepaut-Mathieu, 1993). Sin embargo, es necesario recordar que dada la heterogeneidad y variabilidad individual en el estado de salud y los niveles de funcionalidad de la población de avanzada edad, debemos prestar especial cuidado y supervisión individual a aquellos sujetos que participan en intervenciones basadas en VC o NMES, a fin de reducir el posible riesgo de lesión y sus efectos adversos (Pollock et al., 1991; Vincent et al., 2002).

Uno de los factores limitantes a tener en cuenta cuando se aplica la NMES o se realizan ejercicios basados en VC a intensidades altas son las molestias asociadas a la estimulación eléctrica y el aumento de riesgo de lesión, respectivamente (Maffiuletti, 2010; Stevens-Lapsley et al., 2012). Sin embargo, la aplicación de NMES a baja intensidad se muestra como una alternativa segura y eficaz que evita las molestias asociadas y logra un aumento del tamaño muscular y la fuerza (Galvao y Taaffe, 2005; Kalapotharakos et al., 2005; Taaffe et al., 1996; Vincent et al., 2002; Takano et al., 2010). Del mismo modo, los ejercicios basados en la VC realizados a baja intensidad podrían considerarse una buena recomendación para la práctica de ejercicio físico en personas de avanzada edad, al favorecer la participación y adherencia al ejercicio, minimizar el dolor muscular y reducir la tasa de lesiones (Galvao y Taaffe, 2005; Vincent et al., 2002). Sin embargo, que tengamos constancia y hasta la fecha, no se ha realizado ningún estudio que compare la eficacia de varios programas de ejercicios de baja intensidad (40% de la 1RM) basados en 1) VC, 2) NMES y 3) NMES superpuesta a contracciones voluntarias (NMES+), sobre la CSA, la capacidad funcional y capacidad para realizar las AVD en adultos mayores.

Por otra parte, la práctica de ejercicio físico basado en programas de ejercicios multi-modales se considera una buena alternativa para reducir la debilidad muscular y mejorar la capacidad funcional en una población de avanzada edad. Como apuntan recientes guías de ejercicios y recomendaciones de actividad física orientada a los adultos mayores, los programas multi-modales deberían incluir ejercicios orientados al fortalecimiento muscular, mejora del equilibrio y ejercicios para la mejora cardio-vascular (Cress et al., 2005; Chodzko-Zajko et al., 2009). El *Otago Exercise Programme* (OEP) incorpora todos estos aspectos sugeridos.

El OEP consiste en una batería de ejercicios de intensidad, resistencia y dificultad progresiva, orientados a la mejora de la fuerza muscular, el equilibrio, la capacidad aeróbica y la marcha (Gardner et al., 2001). La eficacia del OEP en sus diferentes modalidades ha quedado ampliamente demostrada a lo largo de diferentes publicaciones (Campbell et al., 1997; Robertson et al., 2002; Liu-Ambrose et al., 2011;

Kyrdalen et al., 2013). Habitualmente se ha realizado en la modalidad *home-based*, donde el participante realiza la batería de ejercicios en su domicilio, siguiendo un cuaderno de ejercicios ampliamente detallado. Sin embargo, recientemente la modalidad *group-based*, donde el participante realiza los ejercicios en grupo y en un lugar diferente a su domicilio bajo la supervisión de un instructor, ha demostrado ser tan eficaz como la modalidad *home-based* (Kyrdalen et al., 2013). Ante esta situación, se plantea la posibilidad de incorporar materiales audio-visuales que mejoren la comprensión y ejecución de los ejercicios a un programa OEP en su modalidad *group-based*. Las instrucciones verbales, la representación visual de los ejercicios y la música de fondo podrían servir de motivación a los participantes mientras realizan la batería de ejercicios (Vestergaard et al., 2008). Además, un programa OEP en la modalidad *group-based* podría favorecer la interacción social entre los participantes durante las sesiones de ejercicios, convirtiéndose en una buena recomendación para adultos mayores en riesgo de exclusión social. Sin embargo, por lo que respecta a nuestro conocimiento, ningún OEP en la modalidad *group-based* se ha llevado a cabo utilizando apoyo audio-visual en una población de avanzada edad.

Por otro lado, un aspecto metodológico a tener en cuenta durante el diseño de una intervención basada en el OEP o en ejercicios con VC, NMES, NMES+, es la selección de las medidas de evaluación para los participantes. La selección de estas medidas debe estar basada en su idoneidad para el propósito que persigue la intervención, además de demostrar su validez y fiabilidad para la evaluación de las capacidades que se pretenden medir en la población de estudio (Steffen et al., 2002).

La capacidad para la deambulación o marcha, tiene gran relación con el mantenimiento de la independencia (Tinetti et al., 1995) y es un componente clave de la HRQOL en los adultos mayores (Guralnik et al., 1989). Existen diferentes medidas para la evaluación de la marcha; distancia recorrida (Rikli y Jones, 1998), velocidad de la marcha habitual y máxima (Peters et al., 2013), o la funcionalidad de la marcha (Shumway-Cook et al., 1997). Originalmente desarrollado por Butland *et al*. (Butland et al., 1982), el 6-minute Walk Test (6MWT) es una prueba que mide la distancia recorrida por un sujeto durante un período de 6 minutos (Rikli y Jones, 1998). Esta prueba se utiliza habitualmente en centros de rehabilitación (Alison et al., 2012) e investigación clínica (Lord y Menz, 2002), tanto en sujetos sanos (Troosters et al., 1999; Camarri et al., 2006; Benavent-Caballer et al., 2014), como en sujetos que presentan patología (Esg et al., 2002; Mossberg, 2003; Savci et al., 2005; Cahalin et al., 1996). En el caso de los adultos mayores, el número de metros recorridos durante el 6MWT viene determinado por una serie de factores físicos y demográficos, entre los que se incluyen la edad, el género, la altura y el peso (Troosters et al., 1999; Enright et al., 2003). Además, la distancia recorrida por esta población durante el 6MWT ha demostrado correlacionar significativamente con medidas asociadas a la movilidad y la condición física (Duncan et al., 1993; Harada et al., 1999; Lord y Menz, 2002).

Otra prueba ampliamente utilizada como herramienta para la detección de adultos mayores en riesgo de deterioro funcional es la prueba Timed "*Up and Go*" Test (TUG) (Podsiadlo y Richardson, 1991). El TUG es una prueba de movilidad que puede ser utilizada tanto en población sana (Benavent-Caballer et al., 2014; Storer et al., 2008) como en sujetos con patología (Matinolli et al., 2009; Swanenburg et al., 2014), que incluye subtareas relacionadas con la ejecución de las AVD, el equilibrio, la fuerza o la marcha (Podsiadlo y Richardson, 1991). Durante la prueba, un evaluador cronometra y observa como un sujeto ejecuta las diferentes subtareas; levantarse y sentarse de una silla, caminar en línea recta y rodear un cono (Mirelman et al., 2014). A diferencia de otras pruebas, el TUG mide la ejecución de las tres subtareas de manera continua, expresando el resultado en tiempo y no como la suma de las puntuaciones individuales de cada subtarea.

Sin embargo, por lo que respecta a nuestro conocimiento, se desconocen los factores físicos que podrían explicar en mayor medida la ejecución del 6MWT y del TUG en los adultos mayores. Identificar las medidas físicas que explican la capacidad para la deambulación o la movilidad, sería de gran importancia para fisioterapeutas y otros profesionales de la salud al permitirles incluirlas como parte de sus protocolos de evaluación, además de diseñar intervenciones adecuadas para reducir la pérdida de capacidad funcional como consecuencia de la edad.

Objetivos

Se realizaron dos intervenciones de corta duración basadas en la práctica de ejercicio físico seguro, accesible y fácil de seguir para los participantes. Las dos intervenciones pretendían minimizar la pérdida de condición física asociada con la edad, en una muestra de adultos mayores que habitan en la comunidad o viven en residencias y centros geriátricos. Además, se llevaron a cabo dos análisis tratando los factores demográficos y medidas físicas que podrían explicar en mayor medida la capacidad para la deambulación y la movilidad en adultos mayores que habitan en la comunidad o residen en un centro geriátrico.

Los objetivos de esta tesis están divididos en tres puntos. (1) Evaluar los efectos de tres programas diferentes de entrenamiento progresivo de la resistencia (VC, NMES y NMES+) realizados a baja intensidad sobre la capacidad funcional, la CSA y la capacidad para realizar AVD, en una muestra de adultos mayores que residen en un centro geriátrico. (2) Evaluar los efectos de un programa de ejercicios basado en el OEP en la modalidad *group-based* utilizando apoyo audio-visual sobre el equilibrio, la movilidad, la capacidad funcional y la resistencia aeróbica en una muestra de adultos mayores que habitan en la comunidad. (3) Investigar la contribución de una serie de factores demográficos y medidas físicas para explicar los resultados de las pruebas 6MWT y TUG en una muestra de adultos mayores que habitan en la comunidad y residen en un centro geriátrico.

Diseño de los Estudios

Todos los estudios (ClinicalTrials.gov ID:NCT01086592) (ClincicalTrials.gov ID:NCT02218411) fueron diseñados cumpliendo con las recomendaciones de la *Consolidated Standards of Reporting Trials Statements* (Altman et al., 2001), el Comité de Bioética e Investigación Clínica de la Universidad CEU-Cardenal Herrera y las directrices éticas marcadas por la Declaración de Helsinki. Todos los participantes firmaron un consentimiento informado donde se detallaban los objetivos, las medidas utilizadas y una descripción de las intervenciones. Se realizaron un total de 4 estudios, dos estudios prospectivos (RCT) y dos estudios descriptivos transversales. Los participantes de los estudios con intervención fueron asignados aleatoriamente a los grupos intervención o control tras realizar una evaluación inicial y fueron evaluados nuevamente transcurridos 4 meses. Por otra parte, los participantes de los estudios transversales realizaron una única evaluación.

Población de Estudio

La muestra de los estudios estaba compuesta por adultos mayores con edades ≥65 años residentes en un centro geriátrico (n=117) o que habitan en la comunidad (n=156). Todos los participantes fueron reclutados voluntariamente a través de carteles informativos en los tablones de anuncios de diferentes centros municipales de actividades para personas mayores y en un centro geriátrico, así como a través de charlas y presentaciones por parte de los investigadores en todos los centros. El reclutamiento de la muestra se inició en septiembre de 2012 y finalizó en mayo de 2015. Un fisioterapeuta realizó una entrevista individual a todos los potenciales participantes durante la que eran informados acerca de las características y objetivos de los estudios, además de aplicarse el cribado para su inclusión. Los participantes 1) ≥65 años, 2) capaces de deambular de forma independiente sin ayuda, 3) que no presentaran contraindicaciones médicas para realizar actividad física, 4) sin dificultades para la comunicación y 5) que hubieran firmado el consentimiento informado, fueron incluidos en los estudios. Los participantes 1) incapaces de deambular de forma independiente, 2) con una puntuación <24 puntos en el Mini-mental State Examination (Folstein et al., 1975), 3) con una puntuación <80 puntos en el Barthel Index (Wade y Collin, 1988), 4) con presencia de enfermedad cardio-vascular inestable o un trastorno neurológico que pudiera comprometerlos para realizar actividad física y 5) que hubieran sufrido una fractura en las extremidades superiores o inferiores durante el último año, fueron excluidos de los estudios.

Medidas

6-minute Walk Test

El 6-minute Walk Test (6MWT) es una prueba que evalúa la distancia recorrida caminando durante un período de 6 minutos (Rikli y Jones, 1999). Dos conos delimitan los límites de un pasillo de 30 m de longitud subdividido en intervalos de 2 m. El participante se sitúa en uno de los extremos del pasillo y al escuchar la señal "*Ya*" comienza a caminar recorriendo el pasillo tantas veces como le sea posible. En caso de ser necesario, el participante puede detener la marcha y sentarse en una de las sillas situadas a lo largo del recorrido. Un evaluador camina junto al participante a fin de garantizar su seguridad, mientras le proporciona un refuerzo verbal positivo mediante los comandos "*Lo está haciendo bien*" y "*Siga así*" en los minutos 1, 3 y 5. La prueba finaliza transcurridos los 6 minutos o en caso de que el participante reporte dolor en el pecho, mareos o disnea. La distancia total recorrida expresada en metros se consideraba la puntuación de la prueba 6MWT.

Berg Balance Scale

La Berg Balance Scale (BBS) es una batería de tareas para la evaluación del equilibrio funcional basada en la ejecución de actividades de la vida diaria (Berg et al., 1992). Las 14 tareas que componen esta escala evalúan tanto el equilibrio estático como el dinámico. El participante es evaluado mientras mantiene la bipedestación con los ojos abiertos y cerrados, mantiene la bipedestación con los pies en posición de side-by-side, semi-tándem o tándem, realiza un apoyo unipodal, realiza una transferencia entre sillas, ejecuta una inclinación frontal, realiza un giro de 360°, recoge un objeto del suelo, o coloca alternativamente sus pies sobre un step. Cada una de estas tareas es evaluada en una escala de 5 puntos; 0 puntos indica "incapaz para realizar la tarea" o "necesidad de ayuda" y 4 puntos indica "capacidad para realizar la tarea de manera independiente". La suma de las puntuaciones individuales de las 14 tareas corresponde a la puntuación final de la BBS, pudiendo alcanzarse una puntuación máxima de 56 puntos.

Timed “Up-and-Go” Test

El Timed “*Up-and-Go*” Test (TUG) es una prueba para la evaluación de la movilidad basada en el tiempo necesario para levantarse de una silla, caminar 3 m, rodear un cono y volver a la silla para sentarse nuevamente (Podsiadlo y Richardson, 1991). En el área de evaluación se sitúa una silla con el respaldo en contacto con una pared, una cinta adhesiva en la base de la silla indicando la línea de partida del recorrido, y un cono a una distancia de 3 m desde esta línea. El participante parte desde una posición de sedestación con la espalda apoyada contra el respaldo de la silla y los brazos descansando sobre los reposabrazos. Al escuchar la señal “*Ya*” inicia la prueba levantándose de la silla, recorriendo los 3 m hasta alcanzar el cono, rodeándolo y volviendo a sentarse en la silla. Un evaluador situado en todo momento cerca del participante contabiliza el tiempo transcurrido desde la señal de inicio hasta que la espalda del participante toca nuevamente el respaldo de la silla. El menor tiempo necesario para completar la prueba expresado en segundos tras realizarse tres intentos corresponde a la puntuación final del TUG.

Área de Sección Transversal Muscular

La ecografía es una técnica basada en el análisis de una imagen, utilizada en este caso con la finalidad de evaluar los cambios producidos en el área de sección transversal muscular (CSA). La ecografía proporciona una imagen bidimensional del músculo que permite identificar y medir su CSA. El recto femoral del miembro inferior derecho fue el músculo elegido para su análisis debido a su superficialidad, accesibilidad y facilidad para visualizar (Bemben, 2002). Para su registro fue necesario un equipo de ultrasonidos portátil B-mode (Sonosite Inc., Bothell, WA, USA) con un transductor de sonda lineal de 80 mm, gel conductor de ultrasonidos y una camilla. Durante el registro, el participante permanece en posición decúbito supino sobre la camilla, con las piernas extendidas y relajadas. Un evaluador realiza tres mediciones consecutivas sobre la zona de registro con el transductor colocado perpendicularmente sobre la superficie de la piel (e Lima et al., 2012). Las imágenes se analizan en el mismo equipo de ultrasonido y el área media de las tres mediciones expresada en cm^2 se considera como la CSA del recto femoral.

Short Physical Performance Battery

La Short Physical Performance Battery (SPPB) es una batería de pruebas diseñada para la evaluación de la capacidad funcional de los miembros inferiores (Guralnik et al., 1994). Esta medida está dividida en tres subtareas asociadas al equilibrio estático, la velocidad de la marcha y la fuerza de los miembros inferiores. Para realizar la SPPB se dispone un pasillo de 4 m de longitud delimitado por dos líneas de cinta adhesiva, una silla sin reposabrazos con el respaldo en contacto con una pared y una zona libre de puntos de apoyos y obstáculos. La subtarea asociada al equilibrio estático evalúa la capacidad del participante para mantener la bipedestación con los pies colocados en posición side-by-side, semi-tándem y tándem durante al menos 10 s cada una sin utilizar ningún tipo de apoyo. La subtarea asociada a la velocidad de la marcha evalúa el tiempo necesario para recorrer un pasillo de 4 m de longitud. Al escuchar la señal "*Ya*", el participante situado en un extremo del pasillo inicia la marcha y recorre la totalidad del pasillo caminando a su velocidad habitual hasta traspasar la línea de cinta adhesiva situada en el extremo contrario. Un evaluador registra el tiempo desde el inicio de la prueba hasta que el participante cruza la segunda línea, y la prueba se realiza en dos ocasiones consecutivas. Por último, la subtarea asociada a la fuerza de los miembros inferiores se evalúa mediante la prueba Repeated Chair Stand Test (STS-5), que registra el tiempo necesario para levantarse y sentarse en una silla cinco veces consecutivas sin utilizar la ayuda de los brazos. El participante realiza la prueba tan rápido como le sea posible manteniendo los brazos cruzados a la altura del pecho y los pies apoyados sobre el suelo. Un evaluador registra el tiempo necesario para completar la prueba desde la señal "*Ya*" hasta que el participante se pone de pie por quinta vez. Durante la ejecución de las tres subtareas, un evaluador se sitúa en todo momento cerca del participante a fin de garantizar su seguridad y evitar una posible caída. Cada una de las tres subtareas se evalúa en una escala de 0 a 4 puntos en función de la ejecución o tiempo necesario para ser completada. Puntuaciones máximas corresponden a: mantener la bipedestación ≥10 segundos en cada una de las tres posiciones de equilibrio descritas, recorrer el pasillo de 4 m en un tiempo inferior a 4.83 s y realizar la prueba STS-5 en menos de 11.19 s. Además, el cálculo de la puntuación total del SPPB se establece mediante la suma de las puntuaciones individuales de las tres subtareas, pudiendo alcanzarse una puntuación máxima de 12 puntos.

Hand-Grip Strength

El dinamómetro hidráulico de mano JAMAR (JAMAR, Sammons Preston Rolyan, Chicago, Illinois, USA) es una herramienta para la medición de la fuerza máxima de agarre. Antes de realizar la prueba, se define la mano dominante del participante y se ajusta la empuñadura del dinamómetro (Ruiz-Ruiz et al., 2002). Durante la prueba, el participante permanece sentado en una silla sin reposabrazos con el hombro en aducción y rotación neutra, el codo flexionado 90° y el antebrazo y la muñeca con una desviación cubital y flexión dorsal entre 0° y 15°. El participante sujeta el dinamómetro con su mano dominante mientras un evaluador situado frente a él sujeta la base del dinamómetro mirando su esfera de lectura (Mathiowetz et al., 1983). Tras una demostración, el participante aprieta la empuñadura del dinamómetro tan fuerte como le sea posible durante un periodo de 3 a 5 s. Durante el registro, el evaluador utiliza estímulos verbales como "*Fuerte, fuerte, fuerte!... Más Fuerte!... y Relax*". Tras tres registros no consecutivos con cada mano, el evaluador establece las puntuaciones medias expresadas en kg como la fuerza máxima de agarre para la mano dominante y la no dominante (Mathiowetz et al., 1983).

One-leg Stand

El One-leg Stand (OLS) es una prueba para la evaluación del equilibrio unipodal (Vellas et al., 1997). Antes de realizar la prueba, el participante elige la pierna sobre la que mantener el equilibrio. El participante inicia la prueba desde la bipedestación y con los ojos abiertos, a continuación se sitúa sobre la pierna seleccionada y flexiona la rodilla contraria permitiendo que el pie se despegue del suelo. El participante mantiene el apoyo unipodal el mayor tiempo posible, pudiendo utilizar el movimiento de sus brazos con el fin de reequilibrarse. Un evaluador se situa cerca del participante a fin de garantizar su seguridad y evitar una posible caída registra el tiempo que el participante permanece en apoyo unipodal. La prueba finaliza cuando el participante toca el suelo con el pie que permanecía elevado o transcurrido un periodo de 60 s. El tiempo total en apoyo unipodal expresado en s corresponde a la puntuación final de la prueba OLS.

Fuerza Extensora de Rodilla

La fuerza extensora de rodilla se define como la capacidad para producir una fuerza máxima durante la contracción isométrica de los músculos extensores de rodilla (Crockett et al., 2013). Para su registro fue necesario un medidor de tensión (TESYS 400®, Globus Italia, Italia) unido al brazo de un banco de cuádriceps que registró la fuerza extensora de rodilla expresándola en kg. Antes de realizar la prueba se define la pierna dominante del participante. La prueba se inicia con el participante sentado en un banco de cuádriceps con la espalda apoyada sobre el respaldo, la rodilla y cadera flexionadas 90° (Newman et al., 2003) y el brazo del banco de cuádriceps situado sobre los maléolos del tobillo de la pierna evaluada. Al escuchar la señal "*Ya*" el participante realiza una contracción isométrica máxima tratando de extender la rodilla durante un periodo de 5 s. Tras realizar 3 registros consecutivos con 90 s de descanso entre registros (Sillanpää et al., 2014), se establece la puntuación media de la fuerza extensora de rodilla expresada en kg.

Barthel Index

El Barthel Index (BI) es un cuestionario de 10 ítems que evalúa el grado de independencia para realizar actividades básicas de la vida diaria (Mahoney y Barthel, 1965). Las actividades se agrupan de acuerdo a las categorías: cuidados personales (higiene personal, alimentación, control de esfínteres y vestimenta) y movilidad (deambulación, subir-bajar escaleras y realizar transferencias) (Wade y Collin, 1988).

Un evaluador administra el cuestionario directamente al participante recordándole que debe responder a las preguntas en función de cómo realiza la actividad y no en base a cómo podría llegar a realizarla. Cada ítem se evalúa en función de la cantidad de ayuda necesaria para realizar la tarea en una escala de 0 puntos “no puede realizar la actividad” o “necesitar ayuda para realizar la actividad” a 5, 10 o 15 puntos “capaz de realizar la actividad de forma independiente”. La suma de las puntuaciones individuales de los 10 ítems corresponde a la puntuación final del BI, pudiendo alcanzarse una puntuación máxima de 100 puntos.

Mini-mental State Examination

El Mini-mental State Examination (MMSE) es una herramienta para la evaluación de la función cognitiva. El cuestionario consta de 11 ítems a través de los que se evalúa la orientación, la memoria, la atención, la capacidad para reconocer objetos, la capacidad para seguir órdenes, la escritura o la reproducción de un dibujo con formas geométricas (Folstein et al., 1975). Un evaluador administra el cuestionario directamente al participante y asigna una apuntación a cada ítem en función de la respuesta a la pregunta o la ejecución de la tarea. La suma total de los resultados individuales de los 11 ítems corresponde a la puntuación final del MMSE, pudiendo alcanzarse una puntuación máxima de 30 puntos.

Índice de Masa Corporal

Un evaluador registra la altura y la masa corporal del participante utilizando un estadiómetro y una báscula. El índice de masa corporal (BMI) se calcula utilizando la fórmula: Peso(kg)/altura^2(m).

One repetition máximum (1RM)

La 1RM de la musculatura extensora de rodilla corresponde a la cantidad máxima de peso que puede levantar un participante hasta alcanzar la extensión completa de rodilla en una sola repetición. El participante permanece sentado en un banco de cuádriceps en una posición de 90° de flexión de cadera y rodilla. A continuación, un evaluador coloca un lastre de 0.5 a 1 kg sobre los maléolos del tobillo de la pierna evaluada y el participante realiza una extensión completa de rodilla. En caso de realizar correctamente la extensión de rodilla y, a criterio del evaluador, se añaden nuevos lastres de 0.5 y 1 kg de peso al tobillo del participante antes de realizar la siguiente repetición. El procedimiento se repite hasta que el participante no es capaz de completar la extensión completa de rodilla. El mayor peso elevado expresado en kg en una repetición correctamente realizada corresponde al valor de la 1RM de la musculatura extensora de rodilla.

Intervenciones

Effects of three different low-intensity exercise interventions on physical performance, muscle CSA and activities of daily living: A randomized controlled trial.

La muestra de este estudio fue aleatoriamente dividida entre los grupos intervención (VC, NMES y NMES+) y grupo control. Todos los participantes asignados a los grupos de intervención realizaron un total de 48 sesiones a lo largo de un periodo de 16 semanas. De manera individual, los participantes realizaron las sesiones bajo la supervisión de dos fisioterapeutas que les orientaron e instruyeron acerca de cómo realizar correctamente los ejercicios. Cada sesión tuvo una duración aproximada de 35 minutos.

Contracciones Musculares Voluntarias (VC)

Los participantes asignados al grupo VC realizaron ejercicios de extensión de rodilla contra una resistencia externa (lastre) situada sobre el tobillo, correspondiente al 40% de la 1RM de su musculatura extensora de rodilla. Los participantes realizaron los ejercicios sentados con 90° de flexión de rodilla y cadera. Los ejercicios consistían en; (1) un movimiento de extensión de rodilla hasta alcanzar la extensión completa (fase concéntrica), (2) mantenimiento de la extensión completa de rodilla (fase isométrica) y (3) flexión de rodilla (fase excéntrica) hasta volver a la posición de partida. Todos los participantes realizaron un total de tres series de quince repeticiones cada una en ambas piernas, con un periodo de descanso entre series de 3 minutos.

NMES y NMES+

Los participantes asignados a los grupos estimulación eléctrica neuromuscular (NMES) y NMES superpuesta a contracciones voluntarias (NMES+), incorporaron a los ejercicios de extensión de rodilla contra resistencia descritos en el grupo VC la NMES y NMES+, realizando contracciones musculares involuntarias o voluntarias respectivamente. La técnica NMES consiste en la aplicación de un estímulo eléctrico con el fin de generar una contracción muscular. El estímulo eléctrico se aplicó a través de la piel utilizando electrodos adhesivos de superficie conectados a un dispositivo portátil (TensMed S82). Los electrodos se situaron sobre el extremo distal, medial y proximal lateral de la musculatura extensora de rodilla. La forma de onda utilizada fue bidireccional rectangular simétrica, con una frecuencia constante de 50 Hz y una amplitud de impulso de 400 µ. La intensidad del estímulo se incrementaba hasta producir una contracción involuntaria capaz de superar la resistencia externa (40% de la 1RM del participante) y alcanzar la extensión completa de rodilla. El grupo NMES+ seguía el mismo protocolo de extensión de rodilla que los grupos VC y NMES, incorporando simultáneamente la contracción muscular voluntaria a la estimulación eléctrica neuromuscular durante la ejecución de los ejercicios.

Grupo Control

Los participantes asignados al grupo control no recibieron ningún tipo de intervención y continuaron con su vida diaria, sin participar en otros programas de ejercicio durante las 16 semanas de duración del estudio.

The effectiveness of a video-supported group-based Otago Exercise Programme on physical performance in community-dwelling older adults: A preliminary study.

La muestra de este estudio fue aleatoriamente dividida en los grupos intervención (IG) y control. Los participantes asignados al IG realizaron un programa de ejercicios basado en el *Otago Exercise Programme* (Campbell et al., 1997), con un total de 48 sesiones durante un periodo de 16 semanas. Todos los ejercicios se realizaron en una sala interior equipada con un reproductor DVD, un proyector, una gran pantalla y una silla asignada a cada uno de los participantes. Cada sesión tuvo una duración aproximada de 45 minutos y se realizó bajo la supervisión de un fisioterapeuta.

Grupo Intervención

Los participantes del IG realizaban conjuntamente 3 sesiones de ejercicios semanales no consecutivas. Previamente al inicio del programa, cada participante recibía un cuaderno con una descripción de cada uno de los ejercicios y un lastre que proporcionaba resistencia externa durante la ejecución de los ejercicios de fortalecimiento. Durante cada una de las sesiones, un video mostraba cuatro rutinas de ejercicios en bipedestación y sedestación, además de proporcionar instrucciones verbales y orientación visual acerca de cómo realizar los ejercicios. Los participantes permanecían frente a la pantalla de proyección y seguían las instrucciones en cada uno de los ejercicios. Todas las sesiones estaban estructuradas siguiendo la misma rutina; (1) ejercicios de calentamiento centrados en la movilidad y la flexibilidad de cuello, tronco y tobillo. (2) ejercicios de fortalecimiento basados en extensiones y flexiones de rodilla, separación de cadera y flexión plantar y dorsal de tobillo, (3) ejercicios para la mejora del equilibrio basados en la marcha lateral, marcha en tándem, marcha sobre talón y puntas de los pies, marcha hacia atrás, marcha con cambios de dirección, apoyo unipodal, sentarse y levantarse de una silla y subir y bajar escaleras, (4) 10 minutos de marcha a velocidad habitual fuera de la sala de ejercicios y (5) una vuelta a la calma tras finalizar la sesión.

Grupo Control

Los participantes asignados al grupo control no recibieron ningún tipo de intervención y continuaron con su vida diaria, sin participar en otros programas de ejercicio durante las 16 semanas de duración del estudio.

Factors associated with the 6-minute Walk Test in nursing home residents and community-dwelling older adults.

Physical factors underlying the Timed "Up and Go" Test in older adults.

En estos dos estudios transversales todos los participantes fueron evaluados mediante una batería de variables antropométricas y pruebas funcionales. Con el fin de estandarizar el horario de recogida de datos, todas las pruebas se realizaron entre las 10h y las 14h. La evaluación de los participantes se realizó en una amplia sala interior, a excepción de la prueba 6-minute Walk Test (6MWT), que se realizó en un pasillo cubierto situado junto a la sala. La evaluación de los participantes en ambos estudios se organizó con el fin de minimizar su fatiga durante los registros siguiendo el siguiente orden: 1) Índice de Masa Corporal (BMI), Berg Balance Scale (BBS), Timed "*Up and Go*" Test (TUG), fuerza máxima de agarre (Hand-grip), Short Physical Performance Battery (SPPB) y 6MWT y 2) BMI, TUG, BBS, One-leg Stand (OLS), fuerza extensora de rodilla, Hand-grip y Repeated Chair Stand Test (STS-5). A lo largo de la primera sesión de recogida de datos todos los participantes realizaron un descanso 5 minutos entre pruebas. Por último, para evitar posibles cambios en la musculatura del recto femoral como consecuencia de la realización de las pruebas anteriores, la medición del CSA mediante ecografía se realizó un día después de la administración de las medidas antropométricas y las pruebas funcionales en ambos estudios.

Effects of three different low-intensity exercise interventions on physical performance, muscle CSA and activities of daily living: A randomized controlled trial.

Los resultados del ANOVA mostraron una interacción significativa (efectos principales Grupo × Tiempo) en las variables movilidad (TUG) (P=.022, ηp^2=.155, potencia estadística =.749), CSA del recto femoral (P=.001, ηp^2=.292, potencia estadística =.965) y capacidad para realizar actividades básicas de la vida diaria (Barthel Index) (P=.05, ηp^2=.116, potencia estadística =.617). Además, el ANOVA mostró una mejora significativa (efectos principales Factor Tiempo) para las variables fuerza máxima de agarre (Hand-grip) (P=.044, ηp^2=.070, potencia estadística =.525) y equilibrio funcional (BBS) (P=.044, ηp^2=.067, potencia estadística =.525). El análisis intra-grupos mostró mejoras significativas en la CSA del recto femoral en todos los grupos con intervención (VC .54 cm, 95% intervalo de confianza (IC) =.09 – 1.00 cm; P=.02; NMES 1.00 cm, 95% IC =.53 – 1.48 cm; P<.001; NMES+ 1.31 cm; 95% IC =.88 – 1.75 cm; P<.001). Sin embargo, el TUG solo mostró cambios significativos en el grupo NMES+ (-2.7 s, 95% IC =-5.0 – -.3 s; P=.026), mientras que no mostró cambios significativos en los grupos VC y NMES. Finalmente, la puntuación del Barthel Index mejoró significativamente en todos los grupos con intervención (VC 6.4 puntos, 95% IC =2.2 – 10.6, P=.003; NMES 4.4 puntos, 95% IC =.0 – 8.8; P=.052; NMES+ 4.7 puntos, 95 IC % =.6 – 8.9; P=.027).

The effectiveness of a video-supported group-based Otago Exercise Programme on physical performance in community-dwelling older adults: A preliminary study.

Los resultados del ANOVA mostraron una interacción significativa (efectos principales Grupo × Tiempo) en todas las variables estudiadas; equilibrio funcional (BBS), apoyo unipodal (OLS), movilidad (TUG), capacidad funcional de los miembros inferiores (SPPB), velocidad de la marcha (SPPB Gait Speed), fuerza miembros inferiores (STS-5) y distancia recorrida caminando (6MWT). El análisis entre-grupos mostró una mejora significativa en el grupo intervención (IG) en las variables BBS en 3.5 puntos (P<.001, 95% intervalo de confianza (IC) =1.9 – 5), OLS en 19.9 s (P<.001; 95% IC =14.6 – 25.8), TUG en -1.8 s (P<.001; 95% IC =-2.2 – -1.4), SPPB en .7 por puntos (P<.001; 95% IC = .4 – 1.1), SPPB Gait Speed en -.7 s (P<.001; 95% IC = -1 – -.5), STS-5 en -3.6 s (P<.001; 95% IC =-4.5 – -2.7) y 6MWT en 21 m (P<.001; 95% IC =10.8 – 31.2). Por el contrario, el grupo control (CG) no mostró cambios significativos en ninguna variable analizada.

Factors associated with the 6-minute Walk Test in nursing home residents and community-dwelling older adults.

Los resultados del análisis de correlaciones bivariadas mostraron asociaciones significativas entre las variables movilidad (TUG), capacidad funcional de los miembros inferiores (SPPB), equilibrio funcional (BBS), y distancia recorrida caminando (6MWT) cuando la totalidad de la muestra fue analizada (r=.723 – -.850, P≤.01). Además, el análisis mostró asociaciones moderadamente altas entre 6MWT y velocidad de la marcha, edad, fuerza máxima de agarre (Hand-grip), CSA del recto femoral y fuerza de miembros inferiores (STS-5) (r=-.435 – .657, P≤.01). Respecto a los análisis realizados por grupos (grupo NH: residentes en un centro geriátrico; grupo CD: residentes en la comunidad), los participantes del grupo NH mostraron asociaciones significativas entre las variables TUG, SPPB, BBS y 6MWT (r= .761 – -.880, P≤.01), mientras que los participantes del grupo CD mostraron como asociación más destacada la comprendida entre TUG y 6MWT (r=-.668, P≤.01), además de una asociación significativa entre 6MWT, CSA del recto femoral y Hand-grip.

El análisis de regresión lineal realizado sobre toda la muestra reveló que la puntuación total del SPPB fue el mejor predictor para el resultado del 6MWT (AdjR2=.595, β=.774, P<.001). Así, la puntuación total del SPPB explicó más de la mitad de la variación en el 6MWT (59.5%) en comparación con otras variables. El mismo análisis estadístico se llevó a cabo en los grupos NH y CD. La puntuación total del SPPB (AdjR2=.684, β=.831, P<.001) demostró ser el mejor predictor para el resultado del 6MWT cuando se analizaron los datos del grupo NH. Por otro lado, el TUG (AdjR2=.484, β=-.703 P<.001) demostró ser el mejor predictor para el resultado del 6MWT cuando se analizaron los datos del grupo CD. Estos resultados indican que una buena capacidad funcional de los miembros inferiores medida mediante la batería SPPB (explica el 68.4% de la variación 6MWT en el grupo NH), y un tiempo reducido al completar la prueba TUG (explica el 48.4% de la variación 6MWT en el grupo de CD), están asociados a la capacidad para recorrer una mayor distancia en la prueba 6MWT en adultos mayores que residen en un centro geriátrico o que habitan en la comunidad respectivamente.

Physical factors underlying the Timed "Up and Go" Test in older adults.

Los resultados del análisis de correlaciones bivariadas mostraron asociaciones significativas entre la variable movilidad (TUG) y las variables equilibrio funcional (BBS) (*r*=-.561) y fuerza extensora de rodilla (*r*=-.397). El TUG no mostró asociaciones significativas con las variables Índice de Masa Corporal (BMI), apoyo unipodal (OLS), fuerza miembros inferiores (STS-5), CSA del recto femoral o fuerza máxima de agarre (Hand-grip).

El análisis de regresión lineal mostró que la puntuación total de la BBS se comportó como el mejor predictor para el resultado del TUG (AdjR2=.373, β=-.618, *P*<.001). Así, el modelo 1 que incluía la puntuación total de la BBS explicó el 37.3% de la variación en el TUG en comparación con otras variables. El modelo 2, que incluía la fuerza extensora de rodilla además de la BBS, explicó el 45.1% de la variación del TUG. Estos resultados indican que un mayor equilibrio funcional medido mediante la BBS está asociado con la movilidad de los adultos mayores.

Conclusiones

1. Un programa de 16 semanas de duración basado en la aplicación de ejercicios de extensión de rodilla con NMES+ a baja intensidad mejora la capacidad funcional, la sección transversal del recto femoral y la capacidad para realizar actividades básicas de la vida diaria en adultos mayores que residen en un centro geriátrico.

2. Un programa de ejercicios *Otago Exercise Programme* realizado en formato *group-based* y suplementado con material audio-visual, mejora el equilibrio, la movilidad y capacidad funcional en adultos mayores que habitan en la comunidad.

3. Unos mayores niveles de equilibrio, capacidad funcional en los miembros inferiores y movilidad, están asociados a una mejor capacidad para la deambulación en los adultos mayores. La batería SPPB es la prueba que determina en mayor grado la capacidad para la deambulación en poblaciones de adultos mayores con bajo nivel de funcionalidad, mientras que el TUG es la prueba que determina en mayor medida la capacidad para la deambulación en adultos mayores que habitan en la comunidad.

4. La prueba TUG tiene una buena correlación con la puntuaciones de la BBS y de la fuerza extensora de rodilla, medidas que representan la ejecución de numerosas tareas de la vida diaria, como mantener el equilibrio, levantarse y sentarse de una silla, realizar una inclinación frontal, recoger un objeto del suelo o realizar un giro. La BBS es la prueba que explica en mayor grado la ejecución del TUG en poblaciones de adultos mayores.

5. El deterioro de la capacidad para la deambulación y la movilidad pueden explicarse como resultado de la suma de déficits en diferentes capacidades, y no como consecuencia del deterioro de una única capacidad. Este hallazgo favorece la comprensión de las medidas físicas empleadas durante la evaluación de adultos mayores, además de contribuir al diseño de intervenciones para la mejora de la movilidad y la capacidad para la deambulación en esta población.

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APPENDIX

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INTRODUCTION

OBJETIVES

METHODS

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DISCUSSION

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AUTHOR CONTRIBUTIONS

FUTURE PERSPECTIVES

THESIS SUMMARY WRITTEN IN SPANISH

REFERENCES

APPENDIX

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TRINITY COLLEGE

SCHOOL OF MEDICINE
DISCIPLINE OF PHYSIOTHERAPY

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2nd February 2011

TO WHOM IT MAY CONCERN

Re: Mr Vincent Benavent Caballer

Mr Benavent spent in excess of 4 months in the post graduate research section of the Discipline of Physiotherapy in The University of Dublin, Trinity College as part of his PhD programme. Mr Benavent was here from October 1st 2010 until February 2nd 2011 inclusive.

Should you require anything further please do not hesitate to contact me.

Yours sincerely,

Dr. Juliette Hussey
Senior Lecturer
Head of Physiotherapy

Schools of the Faculty: Medicine, Dental Science, Nursing and Midwifery, Pharmacy and Pharmaceutical Sciences

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Professor Tom Mercer
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tmercer@qmu.ac.uk

March 23rd 2016

To whom it may concern

Re: Vicent Caballer Benevente, teacher from the Physiotherapy Department of the Universidad CEU Cardenal Herrera. NIF: 22578756-R

This letter confirms that Vicent Caballer Benevente (Physiotherapy Department of the Universidad CEU Cardenal Herrera. NIF: 22578756-R) completed a four week research study visit at Queen Margaret University from 21 July 2014 until 18 August 2014, inclusive.

Vicent was hosted within the Division of Dietietics, Nutrition and Biological Sciences, Podiatry, Physiotherapy and Radiography. During this time I, as research director for Rehabilitation Sciences and Physiotherapy, was personally responsible for the supervision of Vicent's research study visit. I can confirm that Vicent was engaged in research activity throughout his time with us and also that it was a pleasure to host him during this period.

Yours faithfully,

T. Mercer

Tom Mercer, PhD FBASES
Director of the Centre for Health, Activity and Rehabilitation Research

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ugr | Universidad de Granada

Dª. Carmen Moreno Lorenzo con DNI 75.354.068-L. , Directora del Departamento de Fisioterapia. Facultad Ciencias de la Salud de la Universidad de Granada (España), HACE CONSTAR QUE:

D. Vicent Benavent Caballer, (DNI 22578756-R) profesor del Departamento de Fisioterapia de la Universidad CEU Cardenal Herrera, ha realizado una estancia en este Centro, de un mes de duración, durante el mes de Marzo de 2014. Durante la misma ha llevado a cabo las siguientes actividades dentro del ámbito investigador:

- Planificación de líneas de investigación comunes dentro del ámbito de la Fisioterapia Geriátrica desde un enfoque multidisciplinar.
- Participación en labores docentes dentro del área del ámbito de la fisioterapia comunitaria y la salud pública.

En todo momento, durante esta estancia, ha mostrado gran interés y ha desarrollado sus actividades a plena satisfacción de esta dirección.

Y para que conste, y a petición del interesado, firmo la presente a treinta de marzo de 2014.

Sello y Firma

Fdo. Carmen Moreno Lorenzo
Director del Departamento de Fisioterapia.
Facultad de Ciencias de la Salud.
Granada (España)

Registration Clinical Trials

Effects of a program of physical exercise and electrotherapy on muscle strength in subjects of the fourth age

https://clinicaltrials.gov/ct2/show/NCT01086592

ClinicalTrials.gov
A service of the U.S. National Institutes of Health

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Home > Find Studies > Study Record Detail   Text Size

Effects of a Program of Physical Exercise and Electrotherapy on Muscle Strength in Subjects of the Fourth Age

This study has been completed.

Sponsor:
Cardenal Herrera University

Information provided by:
Cardenal Herrera University

ClinicalTrials.gov Identifier:
NCT01086592

First received: March 9, 2010
Last updated: July 2, 2010
Last verified: June 2010
History of Changes

Full Text View | Tabular View | No Study Results Posted | Disclaimer | How to Read a Study Record

Purpose

The purpose of this study is to determine whether neuromuscular electrical stimulation, strengthening exercises, or combination of both over lower limbs are effective in the improvement of the stability fundamentally against falls, greater independence and, therefore, better quality of life in elderly over 75 years.

Condition	Intervention	Phase
Geriatric Assessment Muscle Strength Postural Balance Body Mass Index	Other: No intervention Other: Strong progressive strengthening exercises of lower limbs Other: Electrotherapy Other: Electrotherapy+weights	Phase 0

Study Type: Interventional
Study Design: Allocation: Randomized

Video-supported group-based Otago Exercise Programme on physical performance in older adults.

https://clinicaltrials.gov/ct2/show/study/NCT02218411

ClinicalTrials.gov
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Home > Find Studies > Study Record Detail — Text Size

Video-supported Group-based Otago Exercise Programme on Physical Performance in Older Adults.

This study has been completed.

Sponsor:
Cardenal Herrera University

Information provided by (Responsible Party):
Eva Segura Ortí, Cardenal Herrera University

ClinicalTrials.gov Identifier:
NCT02218411

First received: July 14, 2014
Last updated: August 14, 2014
Last verified: August 2014
History of Changes

Full Text View | Tabular View | No Study Results Posted | Disclaimer | How to Read a Study Record

Purpose

The purpose of this study was to evaluate the effects of a video-supported group-based Otago exercise programme intervention on balance, mobility, physical performance and aerobic endurance in community-dwelling older adults 65+ years old.

Condition	Intervention	Phase
Healthy Aging	Other: Exercise training	Phase 1

Study Type: Interventional
Study Design: Endpoint Classification: Efficacy Study
Intervention Model: Parallel Assignment
Masking: Double Blind (Subject, Investigator, Outcomes Assessor)
Primary Purpose: Treatment

TESIS POR COMPENDIO DE PUBLICACIONES

EN MODALIDAD DE LENGUA EXTRANJERA

TÍTULO

THE EFFECTIVENESS OF EXERCISE INTERVENTIONS AND THE FACTORS ASSOCIATED WITH THE PHYSICAL PERFORMANCE IN OLDER ADULTS.

AUTOR

D. Vicent Benavent Caballer

DIRECTORES

Dr. D. Juan Fco.Lisón Párraga **Dr. D. Pedro Pablo Rosado Calatayud** **Dra. Dña. Eva Segura Ortí**

Departamento de Fisioterapia

Universidad CEU Cardenal Herrera

Valencia, 2016