UNIVERSIDAD DE MURCIA

ESCUELA INTERNACIONAL DE DOCTORADO

TESIS DOCTORAL

Effect of training and exercise cessation on functional capacity and strength in older adults

Efecto del entrenamiento y su cese sobre la capacidad funcional y fuerza en adultos mayores

D. Ángel Buendía Romero

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Autor: D. Ángel Buendía Romero

Directores: Dr. Jesús García Pallarés y Dr. Javier Courel Ibáñez

UNIVERSIDAD DE MURCIA

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doctorando del Programa de Doctorado en

Ciencias de la Actividad Física y del Deporte

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A mis padres y hermanos

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SCIENTIFIC CONTRIBUTIONS

The current PhD Thesis is a compendium of studies published in scientific journals belong to Journal Citation Reports (*JCR*):

Article 1 Courel-Ibáñez, J., **Buendía-Romero, Á***., Pallarés, J. G., García-Conesa, S., Martínez-Cava, A., & Izquierdo, M. (2022). **Impact of Tailored Multicomponent Exercise for Preventing Weakness and Falls on Nursing Home Residents' Functional Capacity**. *Journal of the American Medical Directors Association*, *23*(1), 98-104. https://doi.org/10.1016/j.jamda.2021.05.037. PMID: 34197791. **JCR D1**

Article 2 **Buendía-Romero, Á.**, Hernández-Belmonte, A., Martínez-Cava, A., García-Conesa, S., Franco-López, F., Conesa-Ros, E., & Courel-Ibáñez, J. (2021). **Isometric knee extension test: A practical, repeatable, and suitable tool for lower-limb screening among institutionalized older adults**. Experimental Gerontology, 155, 111575. https://doi.org/10.1016/j.exger.2021.111575. PMID: 34582970. **JCR Q2**

Article 3 **Buendía-Romero, Á.,** Hernández-Belmonte, A., Franco-López, F., Romero-Borrego, E., Cava, A.M., Pallarés J.G., & Courel-Ibáñez J. (2023) **A sensitive and practical evaluation to detect lower-limb strength changes in geriatrics: the isometric knee extension test**. *Applied Sciences*, *13*(5), 2946. https://doi.org/10.3390/app13052946. **JCR Q2**

Other contributions of the current PhD Thesis presented in scientific conferences:

- **Buendía-Romero, Á.,** Martínez-Cava, A., García-Conesa, S., Pallarés, JG., y Courel-Ibáñez, J. **Effect of short- and long-term detraining on functional capacity and strength in institutionalized older adults**. Oral communication. I International Virtual Congress "Exercise, Aging and Health". Cádiz (Spain), 13-14 May, 2021.

- **Buendía-Romero, Á.,** Hernández-Belmonte, A., García-Conesa, S., Martínez-Cava, A., Franco-López, F., Conesa-Ros, E., Pallarés, J.G., Courel-Ibáñez, J. **Is the isometric knee extension test a repeatable and suitable tool for lower-limb screening among institutionalized older adults?** Oral communication. 26th Virtual Congress of the European College of Sport Science. Colonia (Alemania), 8-10 September 2021.

- **Buendía-Romero, Á.,** Romero-Borrego, E., Hernández-Belmonte, A., Martínez-Cava, A., Franco-López., F, & Pallarés, J.G. **Is the isometric knee extension test a sensible tool for assessing physical condition changes among institutionalised older adults?** Awarded poster. I Congreso Internacional sobre Optimización del Entrenamiento de Fuerza y Rendimiento Neuromuscular. Granada (España), 7-8 October 2022.

- **Buendía-Romero, Á.,** Hernández-Belmonte, A., Romero-Borrego, E., Martínez-Cava, A., Franco-López., F, & Pallarés, J.G. **Does β-hydroxy-β-methylbutyrate (HMB) supplementation produce extra improvements to multicomponent training on functional capacity among older adults?** Oral communication. III

Congreso Internacional de Investigación Aplicada en Ciencias de la Actividad Física y el Deporte. Murcia, 22 October 2022.

- **Buendía-Romero, Á.,** Hernández-Belmonte, A., Pallarés, J.G., Courel-Ibáñez., J., Vetrovsky, T. **Exercise training produces standing ability benefits even after an inactivity period in older adults: a systematic review and meta-analysis** Oral communication. III Congreso Internacional de Investigación Aplicada en Ciencias de la Actividad Física y el Deporte. Murcia, 22 October 2022.

Scientific contributions in conferences are presented in Appendix 1

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This PhD project included two research stays in the following destinations:

- **Department of Physiology and Biochemistry of Charles University (Prague, Czech Republic).**

  Supervisor: Michal Steffl, Ph.D. Associate Professor.

  Duration: 3 months (from 15/09/2021 to 16/12/2021)

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Both certificates are presented in Appendix 2

ABSTRACT

Objectives: The current PhD Thesis aimed i) to determine whether the benefits of long and short training programs on functional capacity persist after short and long inactivity periods in institutionalized older adults with sarcopenia and ii) to analyze the repeatability and sensitivity of the field-based isometric knee extension (IKE) test in older adults living in nursing homes, as well as its relationship with functional capacity and body composition. **Method:** Article 1 - Twenty-four institutionalized older adults (87.1 ± 7.1 years, 58.3% women) diagnosed with sarcopenia were allocated into 2 groups: the Long Training-Short Detraining (LT-SD) group completed 24 weeks of supervised Vivifrail training followed by 6 weeks of detraining; the Short Training-Long Detraining (ST-LD) group completed 4 weeks of training and 14 weeks of detraining. Changes in functional capacity (Short Physical Performance Battery [SPPB] and Time Up and Go [TUG]) and handgrip strength were evaluated at baseline and after short and long training and detraining periods. Article 2 - Thirteen institutionalized older adults (87.1 ± 10.9 years, 46% women) were recruited from a nursing home. The variability of maximal isometric force registered in three IKE trials performed on the same day was used to examine intra-session repeatability, whereas inter-session repeatability was analyzed by comparing maximal isometric force from two different days. Standard error of measurement (SEM) was reported in both absolute ($N \cdot kg^{-1}$) and relative terms (coefficient of variation, CV). Furthermore, evaluations of functional capacity (Handgrip, 6-m Gait Speed, TUG, and Sit-to-stand tests) and body composition (appendicular lean mass adjusted by BMI, ALM/BMI) were conducted. Article 3 - Thirty-four institutionalized older adults (84,4 ± 9,7 years, 44% women) completed a 4-week Vivifrail training. Moreover, a subsample of 15 participants (86,0 ± 7,6 years, 40% women) was re-evaluated after a 14-week inactivity period. Changes in functional

capacity, handgrip strength, and IKE test were analyzed. The sensitivity of the IKE test was examined by comparing the changes generated in this test against the repeatability of the protocol. **Results:** Article 1 – The Vivifrail training was highly effective in the short term (4 weeks) in increasing functional and strength performance (effect size, ES= 0.32-1.44; $p < 0.044$), except for handgrip strength in the LT-SD group (ES= 0.48; $p = 0.48$). Continued training for 24 weeks produced 10% to 20% additional functional improvements (ES = 0.80 – 1.90; $p < 0.036$). Benefits after short and long exercise interventions persisted when compared with baseline, especially in SPPB, gait speed, and Sit-to-stand tests ($ES \geq 0.60$; $p < 0.041$). Detraining resulted in a 10% to 25% loss of strength and functional capacity even after 24-week training ($ES \geq 0.24$; $p < 0.039$). Article 2 - High to very high intra-session repeatability was found for both the dominant and non-dominant legs ($CV \leq 6.0\%$). Similarly, both legs showed high inter-session repeatability ($SEM \leq 0.26$ $N \cdot kg^{-1}$). On the other hand, significant relationships were found between Dominant and Non-dominant IKE tests with Gait Speed and ALM/BMI ($r \geq 0.58$). Article 3 – Significant changes ($p < 0.01$; $ES \geq 0.27$) in the IKE strength for both the dominant ($+0.27$ $N \cdot kg^{-1}$) and non-dominant legs ($+0.25$ $N \cdot kg^{-1}$) were produced after the training intervention. Likewise, significant decrements ($p < 0.01$; $ES \geq 0.31$) were detected after the inactive period for the dominant (-0.29 $N \cdot kg^{-1}$) and non-dominant legs (-0.32 $N \cdot kg^{-1}$). All mean changes were found to be superior to the variability threshold of the IKE test for both legs, with superior sensitivity for the non-dominant leg ($\geq 73\%$). **Conclusions and Implications:** This PhD Thesis suggests that i) the gains in strength and functional capacity after multicomponent training were maintained after short and long inactivity periods in institutionalized older adults with sarcopenia, and ii) the field-based IKE test is a repeatable, suitable, sensitive, and practical assessment tool for lower-limb screening in institutionalized older adults.

RESUMEN

ARTÍCULO 1

Título: Impacto del ejercicio multicomponente individualizado para prevenir la debilidad y caídas de adultos mayores que viven en hogares de atención geriátrica

Los programas de ejercicio físico multicomponente individualizados son la mejor forma de mejorar la capacidad funcional, masa muscular y estado de salud entre los adultos mayores frágiles e institucionalizados. Aunque es probable que los adultos mayores sufran eventos adversos u hospitalizaciones que interrumpan temporalmente cualquier programa de ejercicio físico. Estudios previos han demostrado que las mejoras relacionadas con el ejercicio puedes persistir después de periodos cortos y largos de cese de ejercicio. No obstante, la información disponible sobre el efecto protector o residual de programas de ejercicios después de periodos de desentrenamiento entre adultos mayores institucionalizados es escasa, Por tanto, el objetivo del presente estudio fue determinar si los beneficios de programas de entrenamiento largos (24 semanas) y cortos (4 semanas) persisten después de periodos cortos (6 semanas) y largos (14 semanas) de inactividad en adultos mayores con sarcopenia que viven en residencias de atención geriátrica. Veinticuatro adultos con sarcopenia y una edad ≥ 75 años que viven en residencias geriátricas fueron asignados a 2 grupos experimentales: el grupo Largo Entrenamiento-Corto Desentrenamiento (LE-CD) (84,0 ± 10,5 años; 54,5% mujeres) realizó 24 semanas de entrenamiento seguido de 6 semanas de cese del ejercicio, mientras que el grupo Corto Entrenamiento – Largo Desentrenamiento (CE-LD) (87,2 ± 7,6 años; 58,3% mujeres) llevó a cabo 4 semanas de entrenamiento y 14 semanas de desentrenamiento. La condición de sarcopenia fue identificada de acuerdo con el diagnóstico de la *Foundation for the National Institutes of Health.* Todos los participantes

realizaron el programa de entrenamiento Vivifrail de manera supervisada con una frecuencia semanal de 5 días. Este programa de ejercicio se individualizó en 4 regímenes de entrenamiento de acuerdo con los niveles de capacidad funcional de los adultos mayores. La capacidad funcional, usando la batería de test *Short Physical Performance Battery* (SPPB) y la prueba *Time Up-and-Go,* y la fuerza de agarre manual fueron evaluadas al inicio de la intervención (T0), tras el programa de entrenamiento (T1) y después del periodo de desentrenamiento (T2). Se realizó una prueba t de medidas repetidas para evaluar los efectos del entrenamiento y desentrenamiento en cada grupo. El tamaño del efecto (TE) fue calculado para estimar la magnitud de las diferencias entre los diferentes puntos temporales (i.e., T0-T1-T2). Un análisis de covarianza, usando los valores iniciales como covariable, fue realizado para determinar si las diferencias en los marcadores de capacidad funcional y fuerza fueron diferentes entre los dos grupos en los periodos de entrenamiento y desentrenamiento.

Los resultados revelan que ambos grupos mejoraron de manera significativa su capacidad funcional y fuerza de agarre después de 4 semanas de entrenamiento multicomponente Vivifrail (TE = 0,32 – 1,44; $p < 0,05$), excepto la fuerza de agarre en el grupo LE-CD. Además, la extensión de 20 semanas de entrenamiento del grupo LE-CD supuso unas mejoras extras significativas en todas las variables (TE = 0,8 - 1,51), excepto para la fuerza de agarre. Esto supuso revertir la fragilidad en el 36% de los casos y conseguir una alta autonomía del 59% de los participantes después del periodo de entrenamiento de cada grupo.

Tanto el grupo CE-LD como el LE-CD experimentaron pérdidas similares en la capacidad funcional (TE = 0,24 - 0,92) tras los periodos de desentrenamiento. La fuerza de agarre manual mostró un detrimento (TE = 0,23) en el grupo LE-CD después del periodo de inactividad, mientras que la fuerza de agarre no experimentó cambios en el

grupo CE-LD. No obstante, los valores tras el desentrenamiento fueron superiores a los previos a la intervención en todas las variables para ambos grupos, siendo especialmente elevados en la puntuación del SPPB la velocidad de marcha y la habilidad de levantarse (TE = 0,41 – 1,12; $p < 0,05$).

Basándose en estos resultados, se concluye que los beneficios asociados al entrenamiento multicomponente supervisado persisten tras el desentrenamiento en adultos mayores institucionalizados con sarcopenia. Una intervención basada en ejercicio multicomponente de al menos 4 semanas durante 3 veces al año, con no más de 14 semanas de inactividad entre periodos, puede ser suficiente y recomendable para proteger a adultos mayores del declive funcional sufrido por hospitalizaciones, enfermedades o caídas.

ARTÍCULO 2

Título: Test de extensión isométrica de rodilla: Una herramienta adecuada, repetible y práctica para la evaluación de la fuerza de miembros inferiores de adultos mayores institucionalizados

El test de extensión isométrica de rodilla (EIR), que informa de la fuerza muscular de los elementos extensores de la rodilla, es una evaluación física comúnmente usada en geriatría. En la mayoría de los casos, la prueba EIR es evaluada a través de dispositivos isocinéticos, sin embargo, estos dispositivos son altamente costosos y difíciles de encontrar en contextos como residencias de atención geriátrica. Como alternativa, diferentes estudios han propuesto la galga extensiométrica como una herramienta para realizar el test EIR. Sin embargo, ningún estudio ha analizado la repetibilidad intra e inter-sesión del EIR usando una galga extensiométrica en adultos mayores institucionalizados. Por otro lado, los extensores de rodilla representan la musculatura principal envuelta en los movimientos del día a día como caminar o levantarse de una silla. Por tanto, el objetivo de este estudio fue analizar el test EIR con galga extensiométrica en términos de i) repetibilidad intra e inter-sesión y ii) la relación con factores de composición corporal y capacidad funcional de adultos mayores institucionalizados.

Trece adultos mayores que viven en una residencia (87,0 ± 10,9 años, 46% mujeres) completaron cuatro sesiones de evaluación. En la primera sesión, los participantes realizaron una revisión médica y una batería de pruebas funcionales que incluye velocidad de marcha en 6 metros, la prueba *Time Up and Go* (TUG) y el *Sit-to-stand* (STS) test. En la segunda sesión, se evaluó la composición corporal de los adultos mayores a través de absorciometría de rayos X de energía dual. Finalmente, en la tercer y última sesión, los participantes realizaron el EIR test. Los resultados de tres repeticiones de la prueba EIR fueron utilizados para el análisis de la repetibilidad intra-sesión

(repetición 1 vs. repetición 2 vs. repetición 3), mientras que la repetibilidad inter-sesión fue analizada comparando el valor medio de tercera y cuarta sesión. Por otro lado, el valor más alto alcanzado en cualquiera de las dos sesiones se usó para examinar la relación con los parámetros funcionales y de composición corporal. Los análisis estadísticos de repetibilidad incluyeron el coeficiente de correlación intraclase (CCI) y el error estándar de la medida (EEM), expresados en términos absolutos ($N \cdot kg^{-1}$) y relativos (coeficiente de variación, CV = 100 × EEM / media). Además, la relación entre la fuerza de EIR, los parámetros funcionales y la composición corporal fue analizada mediante el coeficiente de correlación de Pearson (r).

Los resultados mostraron una repetibilidad intra-sesión alta o muy alta tanto para la pierna dominante como no dominante (CV ≤ 6,0%; ICC ≥ 0,989). Esta repetibilidad aumentó en la segunda sesión, especialmente para la pierna dominante (CV = 3,6%; EEM = 0.09 $N \cdot kg^{-1}$). Del mismo modo, las dos piernas mostraron una alta repetibilidad inter-sesión (EEM ≤ 0,26 $N \cdot kg^{-1}$; ICC ≥ 0,959). La fuerza de EIR en la pierna dominante se relacionó significativamente con las pruebas de velocidad de marcha en 6 metros (r = 0,77) y TUG (r = -0,74), mientras que la fuerza de EIR en la pierna no dominante se relacionó significativamente con la velocidad de marcha en 6 metros (r = 0.58). Además, la relación entre fuerza de EIR y la masa magra apendicular se mostró significativa para ambas piernas (r ≥ 0,58).

El principal hallazgo de este estudio sugiere que el EIR test utilizando una galga extensiométrica es una prueba adecuada y repetible para evaluar la condición física de adultos mayores institucionalizados.

ARTÍCULO 3

Título: Una evaluación práctica y sensible para detectar cambios en la fuerza del tren inferior en geriatría: el test de extensión isométrica de rodilla

La prueba de extensión isométrica de rodilla (EIR) presenta algunas ventajas comparado a métodos dinámicos como la evaluación de la repetición máxima en sentadilla. Entre las ventajas del EIR test, en particular usando una galga extensiométrica, destacan su simplicidad técnica, su bajo riesgo de lesión, su alta repetibilidad y su facilidad de uso en entornos clínicos por la utilización de dispositivos portátiles. Además de ser una herramienta para evaluar el tren inferior, los valores del EIR test están altamente asociados con variables relevantes para la salud en geriatría como pueden ser la capacidad funcional y masa muscular. Sin embargo, hasta la fecha, no hay evidencia sobre la sensibilidad que tiene esta metodología (EIR + galga extensiométrica) para detectar cambios clínicos en la fuerza del tren inferior de adultos mayores institucionalizados después de un programa de entrenamiento y un periodo de cese del ejercicio. En este contexto, el objetivo de este estudio fue analizar la sensibilidad de la prueba EIR con galga extensiométrica en entornos clínicos para detectar los cambios en la fuerza de las extremidades inferiores de adultos mayores institucionalizados tras un programa de ejercicio y un periodo de inactividad.

Treinta y cuatro adultos mayores viviendo en residencias (84,4 ± 9,7 años, 44% mujeres) realizaron el entrenamiento multicomponente Vivifrail durante 4 semanas. Además, una submuestra de 15 participantes (86,0 ± 7,6 años, 40% mujeres) fue reevaluada después de un periodo de inactividad de 14 semanas debido al confinamiento por la pandemia COVID-19. Las evaluaciones físicas constaron de 2 sesiones en cada punto temporal (i.e., T0, T1 y T2). En la primera sesión todos los participantes realizaron la prueba EIR (variable principal). Como complemento y tras 48 horas de recuperación,

la segunda sesión evaluó la capacidad funcional de los participantes usando la batería de pruebas *Short Physical Performance Battery* (SPPB) y la prueba *Time Up-and-Go*, así como la fuerza de agarre manual. La sensibilidad del EIR test fue examinada comparando los cambios generados por el periodo de entrenamiento e inactividad con la repetibilidad inter-sesión del protocolo (usando el EEM previamente publicado).

Todos los participantes realizaron las pruebas fuerza de agarre manual y EIR, aunque no todos pudieron completar las evaluaciones STS (62%), TUG (92%) o velocidad de marcha de 4 m (94%) debido a que la realización de estas pruebas suponía un esfuerzo supramáximo para ellos. Los resultados de cada prueba incluyen los cambios de los participantes que pudieron realizarla en pre y post periodo de entrenamiento o inactividad.

La intervención de entrenamiento produjo mejoras significativas ($p < 0,05$ a $p < 0,001$) para todas las evaluaciones de capacidad funcional (ES > 0,48), mientras que los cambios en la fuerza de agarre no alcanzaron significación (ES < 0,21). Se detectaron cambios significativos ($p < 0,01$) en la fuerza EIR tanto para la pierna dominante (ES = 0,28) como para la no dominante (ES = 0,27) tras el programa d entrenamiento multicomponente. En concreto, se observó que los cambios en las medias del grupo para ambas piernas (dominante = +0,27 $N \cdot kg^{-1}$; no dominante = +0,25 $N \cdot kg^{-1}$) eran superiores a la variabilidad de la prueba de EIR. Considerando los cambios individuales, el 53% (para la pierna dominante) y el 77% (para la pierna no dominante) de los participantes mostraron un aumento/disminución de la fuerza EIR por encima del umbral de variabilidad de la prueba.

Tras el periodo de inactividad, se reportaron disminuciones significativas en la puntuación del SPPB y la prueba TUG ($p < 0,05$, ES > 0,26), pero no en la prueba STS, la velocidad de la marcha y la fuerza de agarre manual (ES > 0,02). También se muestran

descensos significativos ($p < 0,01$) en la fuerza EIR tanto para la pierna dominante (ES = 0,31) como para la no dominante (ES = 0,37). Los cambios en las medias del grupo para ambas piernas (dominante = -0,29 $N \cdot kg^{-1}$; no dominante = -0,32 $N \cdot kg^{-1}$) resultaron ser superiores a la variación de la prueba EIR. En cuanto a los cambios individuales, el 40% y el 73% de los participantes lograron cambios superiores al umbral de variabilidad para las piernas dominante y no dominante, respectivamente.

Estos hallazgos demostraron que la prueba IKE es una evaluación sensible y práctica para detectar cambios clínicos en la fuerza de las extremidades inferiores de adultos mayores institucionalizados después de períodos de ejercicio e inactividad. Debido a su fácil utilización y aplicabilidad, parece pertinente implementar la prueba EIR en residencias de mayores y entornos clínicos.

INTRODUCTION AND JUSTIFICATION

1. INTRODUCTION AND JUSTIFICATION

1.1. Health complications associated with aging

The worldwide population is living longer than ever before, and lifespan is expected to continue to increase over the next decades (Beard & Bloom, 2015). The last European Ageing Report (European Commission, 2021) suggests that the life expectancy for males is set to rise by 7.4 years from 78.7 in 2019 to 86.1 in 2070. Similarly, the life expectancy for females is expected to increase by 6.1 years from 84.2 in 2019 to 90.3 in 2070. According to the World Health Organization (WHO), this increased lifespan results in a larger older population (i.e., ≥60 years), reaching >1000 million people in the world (Michel et al., 2021; WHO, 2018). While advances in medicine have helped to prevent and treat health complications, several ageing-related disorders continue to be prevalent among older adults.

The most common aging-related syndromes are sarcopenia and physical frailty. Sarcopenia is characterized by a progressive decline in muscle mass, strength, and functional capacity (Cruz-Jentoft et al., 2019). Multi-factorial mechanisms cause sarcopenia, among others, abnormal endocrine function, mitochondrial dysfunction, inadequate nutrition, motor neuron loss, or physical inactivity can be reported (Cruz-Jentoft et al., 2010). Estimates from the Eurostat online database (28 European countries) suggests an increase of 60–70% of individuals with sarcopenia by 2045, affecting 12.9 to 22.3% of older people (Ethgen et al., 2017). Physical frailty is characterized by physiological dysfunction that increases vulnerability and dependency (Morley et al., 2013). A recent meta-analysis in 62 countries established that 26% of older adults ⩾ 60 years suffer from frailty (Caoimh et al., 2021). reports 26% of community dwelling y institutionalized older adults ≥ 60 years suffer from this vulnerable condition. This

prevalence is even higher in institutionalized older adults (i.e., living in nursing homes), with an alarming rate of 68.8% (Caoimh et al., 2018).

Both sarcopenia and physical frailty adversely affect cardiovascular, musculoskeletal, and nervous systems leading to poor functional capacity and strength weakness (Cadore et al., 2019). Functional capacity refers to the ability to perform daily living actions such as walking, rising from a chair, climbing stairs, or keeping balance (Wang, 2004). Deficits in functional capacity and strength have a critical impact on health, quality of life, and long-term care, particularly as society gets older and frail (Baltasar-Fernandez et al., 2021; Benzinger et al., 2019; Cruz-Jentoft et al., 2019; Inouye et al., 1998). An exacerbated loss of functional capacity may double the risk of institutionalization and triple the risk of mortality in older adults (Losa-Reyna et al., 2022). Likewise, an aggravated reduction muscular strength in older adults increases the risk of mortality by 32% compared to those with the highest levels of strength (Ruiz et al., 2008). Dependence through poor functional capacity and strength is a challenge to health systems due to high economic costs (Cumming et al., 2009; García-Nogueras et al., 2017). In particular, frail older adults from Spain have a higher economic cost associated with the treatment compared to healthy older adults (2.476 vs. 1.217 €/per year) (García-Nogueras et al., 2017).

1.2. Impact of physical exercise on functional capacity and strength in the older population

Increments in exercise and physical activity levels is associated with a longer health span and may halt the progression of aging-related syndromes, including sarcopenia and frailty (Valenzuela et al., 2020). In addition to health benefits, increasing physical activity levels can have substantial economic benefits. According to the latest

WHO estimates, physical activity policies return 70% benefits for every 1 € invested (WHO, 2023). The implementation of tailored exercise is arguably demonstrated as a very effective strategy to improve functional capacity, strength, muscle mass, and health status (Izquierdo et al., 2020). Regular physical exercise produces a wide range of health improvements by reducing muscle atrophy, inflammatory processes, and loss of bone density while maintaining appropriate insulin sensitivity, mitochondrial activity, and physical abilities (Valenzuela et al., 2019). Noteworthily, the specific adaptation will highly depend on the particular exercise modality (e.g., aerobic, resistance or multicomponent training) and intensity (low, middle or high).

Aerobic training (AT, continuous movements of the body's large muscles for a sustained period that increases caloric requirements) principally improves functional capacity, maximal oxygen consumption ($V0_{2max}$), systemic vascular function, body fat, and metabolic profile (Henderson et al., 2017; Huang et al., 2005; Sun et al., 2018; Swoap et al., 1994; Theodorou et al., 2016). The American College of Sports Medicine (ACSM) (Garber et al., 2011) reports that vigorous-intensity AT (i.e., 60-84% of heart rate reserve) generated greater improvements on V02max compared with moderate-intensity (i.e., < 60% heart rate reserve). However, the evidence on what AT intensity produces greater adaptations in functional capacity is scarce.

On the other hand, resistance training (RT, exercise against external loads or body weight) mainly augments muscle mass, strength, and functional capacity (Fragala et al., 2019; Talar et al., 2021). A meta-analysis comparing the effect of different RT programs (high vs moderate vs low intensity) on maximal strength and functional capacity (Steib et al., 2010) reported greater effectivity of high intensity (i.e., 75-85% of one-repetition maximum, 1RM) compared to lower intensities on maximal strength. Nevertheless, the functional capacity adaptations were not dependent on RT intensity (Steib et al., 2010).

Moreover, a recent meta-analysis analyzing the effect of different RT volumes on muscle mass, strength, and functional capacity extends the evidence of the effective number of sets and repetitions (Marques et al., 2022). These findings suggest that 3 sets of 8-12 repetitions are effective for optimizing lower-limb strength, while 1 set of the same repetitions is sufficient for improving upper-limb strength and muscle mass (Marques et al., 2022). Furthermore, intra-set fatigue (i.e., the level of fatigue generated within each training set) is other parameter of RT that can influence adaptations in older adults. On this matter, RT to failure should be avoided due to the excessive fatigue and muscle soreness it produces (Dos Santos et al., 2019). Additionally, RT to failure report equally effectiveness as RT with 50% of the possible maximum repetitions on functional capacity and strength of older adults (Teodoro et al., 2019).

The combination of AT and RT within the same session (i.e., concurrent training, CT) may provide additional physiological benefits (Cadore et al., 2010, Cadore et al., 2013; García-Pinillos et al., 2019). Interestingly, multicomponent training (MT) combining resistance and aerobic efforts in addition to balance training shows the best results in improving functional capacity and strength weakness in older adults (Fragala et al., 2019) even in institutionalized frail nonagenarians (Cadore et al., 2014). This has been amply demonstrated in daily acute interventions of 1 week (Sáez de Asteasu et al., 2019), short-term programs of 4–8 weeks (Buendía-Romero et al., 2020; Courel-Ibáñez et al., 2020), and long-term training over 12 weeks (Tarazona-Santabalbina et al., 2016).

Although unsupervised training programs show benefits on muscle strength and functional capacity in older adults (Chaabene et al., 2021; Prieto-Moreno et al., 2022), exercise programs directed by qualified trainers (i.e., supervised) report higher functional and strength adaptations compared to home-based programs in this population (Lacroix et al., 2017).

1.3. The inevitable consequence of exercise cessation: detraining

Maintaining adequate functional capacity levels in the older population is a challenge due to the inherent age-related deterioration altering the musculoskeletal system and its ability to perform coordinated actions (Grgic, 2022; Mayfield et al., 2022). Although this decline can be reverted by exercise, training interventions in older adults are commonly interrupted or even stopped due to falls, illness or hospitalizations (Gill et al., 2011), leading to a partial or complete loss of the adaptations (i.e., detraining) (Covinsky et al., 2003). Older people with better physical conditions prior to the interruption suffer a minor loss in functional capacity during the inactivity period (Gill et al., 2010).

Prior studies suggest that regular exercise training may have a protective effect on inactivity-related deconditioning (i.e., retention of positive changes generated by physical exercise after training cessation) (Toraman & Ayceman, 2005; Yasuda et al., 2014). In particular, strength and functional adaptations can persist after short (Pereira et al., 2012; Toraman, 2005) and even long-term exercise cessation (Blasco-Lafarga et al., 2020; Yasuda et al., 2014) in community-dwelling older adults. Exercise appears to report a protective effect against physical atrophy during periods of inactivity, which is especially important for the oldest old population (Toraman, 2005) and institutionalized adults (Cadore et al., 2014). Nonetheless, the available information about the protective effects of exercise programs after short and long deconditioning periods in older adults living in nursing homes is scarce.

1.4. Assessments for measuring functional capacity and strength in geriatrics

Concerning functional capacity assessment, several tests are implemented in older adults to evaluate their ability to perform daily actions. Standing from a seat position is a

crucial daily activity and a requisite for the independence of older adults (Alcazar et al., 2021). This parameter, mainly evaluated in 5 repetitions or during 30 seconds, provides information on the risk of hospitalization and mortality in the elderly population (Losa-Reyna et al., 2022). Moreover, recent advances in this assessment lead to obtain muscle power of this test using reduce time, space, and material requirements (Alcazar et al., 2018). Balance refers to the ability to maintain stability and prevent falls (Lesinski et al., 2015). In older adults, balance assessment involves their ability to maintain stability under different conditions such as feet together or tandem position (Zech et al., 2012). Gait speed, also termed walking ability, is a simple and accessible clinical indicator of health in older adults (Studenski et al., 2011). Common walking tests for older adults in clinical practice are the 4-meter gait speed test (Goldberg & Schepens, 2011) or the 6-minute walk test (Enright et al., 2003). The Short Physical Performance Battery Test (Guralnik et al., 1994) considers all of the above capacities (i.e., standing ability, balance, and gait speed) and is the most common functional evaluation in older adults (Izquierdo et al., 2019; Sáez de Asteasu et al., 2020; Zech et al., 2012).

Although several strength tests are available, not all are suitable for older adults. For example, the 1RM and the number of repetitions to failure (nRM) tests have been used to evaluate dynamic strength capacity in older adults (Mazini-Filho et al., 2022; Pereira et al., 2012). The 1RM test refers to an incremental loading evaluation up to the heaviest load that the participant can properly lift without any external help, completing the full range of motion (Knutzen et al., 1999). The nRM test requires the participant to perform as many repetitions as possible with a given load, and then the 1RM is calculated using estimation formulas (Knutzen et al., 1999). Nonetheless, both tests generally produce excessive fatigue and muscle soreness in the older population.

On the other hand, isometric testing is widely recognized as one of the most frequently employed methodologies for evaluating strength capacity in the geriatric population (Mey et al., 2023), mainly because of its technical simplicity, low injury risk, and high reliability (Mathiowetz et al., 1984). In particular, the handgrip evaluation is the most common test used to assess this physical capacity in older adults (Lee & Gong, 2020), due to its low variability test-retest, portability, and ease of use within clinical. However, this test is limited to the upper limb and has been questioned as a comprehensive measure of overall muscle strength. Therefore, lower limb strength tests are suggested as a complementation of the handgrip test in older adults (Rodacki et al., 2020; Yeung et al., 2018). The knee extensors represent the main muscles involved in common daily movements as chair rising or walking (Besier et al., 2009). Therefore, the isometric knee extension (IKE) test is proposed as a complement to handgrip for screening isometric strength in older adults. Isokinetic devices are considered the gold standard system for measuring the IKE test (Stark et al., 2011), nevertheless, these devices could be high-cost and low-practical tools in contexts as nursing homes. Alternatively, the IKE test in a field-based context has been examined using a strain gauge (Ruschel et al., 2015). On this matter, a high intra- and inter-session repeatability has been found in the IKE test conducted by healthy adults, using the aforementioned force sensors (Courel-Ibáñez et al., 2020; Ruschel et al., 2015).

Nonetheless, no study to date has analyzed the repeatability of this methodology (IKE test + strain gauge) in older adults living in nursing homes. This comprehensive analysis would allow to examine the feasibility of this practical test to be incorporated into the battery tests commonly used to measure strength capacity in older adults. Similarly, there is no information on the sensitivity of this practical test to detect clinical changes in IKE strength after training or exercise cessation period.

1.5. Justification

Against this background, there is a gap concerning the protective effects of exercise programs after short and long deconditioning periods in institutionalized older adults. Furthermore, there is a lack of evidence on the repeatability and sensitivity of the IKE test using a portable device in older people living in nursing homes, as well as the association between the IKE test and functional and body composition parameters. Hence, the current PhD Thesis addresses these research gaps conducting a comprehensive analysis.

OBJECTIVES AND HYPOTHESES

2. OBJECTIVES AND HYPOTHESES

The current PhD Thesis has multiple objectives and hypotheses that are presented through three studies:

OBJECTIVES STUDY I

i. To analyze the effects of short (4 weeks) and long (24 weeks) tailored multicomponent training (Vivifrail) on functional capacity and handgrip strength of institutionalized older adults with sarcopenia.

ii. To determine whether the effects of long (24 week) and short (4 weeks) training programs on functional capacity and handgrip persist after short (6 week) and long (14 week) inactivity periods in older adults with sarcopenia living in nursing homes.

HYPOTHESES STUDY I

i. The Vivifrail exercise intervention, both short and long-term, will be highly effective in improving the functional capacity and handgrip strength of institutionalized older adults with sarcopenia.

ii. The benefits generated by the multicomponent training (Vivifrail) on functional capacity and handgrip strength will persist after short and long inactivity periods in older adults with sarcopenia living in nursing homes.

OBJECTIVES STUDY II

i. To analyze the field-based IKE test in terms of intra- and inter-session repeatability in older adults with sarcopenia living in nursing homes.

ii. To examine the relationship of the IKE test with functional and body composition factors of sarcopenia in institutionalized older adults.

HYPOTHESES STUDY II

i. The field-based IKE test will be a repeatable physical assessment in institutionalized older adults with sarcopenia.

ii. The IKE test will be highly associated with functional capacity and muscle mass of older adults with sarcopenia living in nursing homes.

OBJECTIVES STUDY III

i. To examine the sensitivity of the IKE test within clinical settings to detect changes in the lower-limb strength of institutionalized older adults after exercise training and inactivity periods.

HYPOTHESES STUDY III

i. The IKE test will be a sensitive assessment to detect changes in the lower-limb strength of institutionalized older adults after exercise training and inactivity periods.

STUDY 1

3. STUDY 1

TITLE: Impact of Tailored Multicomponent Exercise for Preventing Weakness and Falls on Nursing Home Residents' Functional Capacity

Journal of the American Medical Directors Association

ABSTRACT

Objectives: To determine whether the benefits of long (24 weeks) and short (4 weeks) training programs persisted after short (6 weeks) and long (14 weeks) periods of inactivity in older adult nursing home residents with sarcopenia. **Design:** Multicenter randomized trial. **Intervention:** The Vivifrail tailored, multicomponent exercise program (http://vivifrail.com) was conducted to individually prescribe exercise for frail older adults, depending on their functional capacity. The training included 4 levels combining strength and power, balance, flexibility, and cardiovascular endurance exercises. **Setting and Participants:** Twenty-four institutionalized older adults (87.1 ± 7.1 years, 58.3% women) diagnosed with sarcopenia were allocated into 2 groups: the Long Training-Short Detraining (LT-SD) group completed 24 weeks of supervised Vivifrail training followed by 6 weeks of detraining; the Short Training-Long Detraining (ST-LD) group completed 4 weeks of training and 14 weeks of detraining. **Measures:** Changes in functional capacity and strength were evaluated at baseline and after short and long training and detraining periods. **Results:** Benefits after short and long exercise interventions persisted when compared with baseline. Vivifrail training was highly effective in the short term (4 weeks) in increasing functional and strength performance (effect size = 0.32-1.44, $P < .044$) with the exception of handgrip strength. Continued training for 24 weeks produced 10% to 20% additional improvements ($P < .036$). Frailty status was reversed in 36% of participants, with 59% achieving high self-autonomy. Detraining resulted in a 10% to

25% loss of strength and functional capacity even after 24 weeks of training (effects size = 0.24-0.92, P < .039). **Conclusions:** Intermittent strategies, such as 4 weeks of supervised exercise 3 times yearly with no more than 14 weeks of inactivity between exercise periods, appear as an efficient solution to the global challenge of maintaining functional capacity and can even reverse frailty in vulnerable institutionalized older adults.

Keywords: confinement; long-term care; physical inactivity; health; hospital; COVID-19

Link: https://www.sciencedirect.com/science/article/abs/pii/S1525861021005211

STUDY 2

4. STUDY 2

TITLE: Isometric knee extension test: A practical, repeatable, and suitable tool for lower-limb screening among institutionalized older adults

Experimental Gerontology

ABSTRACT

We aimed to analyze the isometric knee extension test (IKE) test in terms of i) intra- and inter-session repeatability, and ii) relationship with functional and body composition factors of sarcopenia among institutionalized older adults. Thirteen institutionalized older adults (age = 87 ± 10 years, body mass [BM] = 73.1 ± 10.9 kg, body mass index [BMI] = 28.5 ± 3.8 kg·m^2) were recruited from a nursing home. The variability of maximal isometric force registered in three IKE trials performed on the same day was used to examine intra-session repeatability, whereas inter-session repeatability was analyzed by comparing maximal isometric force from two different days. Furthermore, functional (Handgrip, 6-m Gait Speed, Time Up and Go [TUG], and Sit-to-stand tests) and body composition (appendicular lean mass adjusted by BMI, ALM/BMI) evaluations were conducted. Statistics included the intraclass correlation coefficient (ICC) and the standard error of measurement (SEM), expressed in both absolute (N·kg^{-1}) and relative terms (coefficient of variation, CV = 100 × SEM / mean). High to very high intra-session repeatability was found for both the dominant and non-dominant legs (CV ≤ 6.0%, ICC ≥ 0.989). Similarly, both legs showed high inter-session repeatability (SEM ≤ 0.26 N·kg^{-1}, ICC ≥ 0.959). On the other hand, significant relationships were found between Dominant and Non-dominant IKE tests and 6-m Gait Speed (r = 0.77; r = 0.58), ALM/BMI (r = 0.62; r = 0.58), and Non-dominant Handgrip/BM (r = 0.60; r = 0.68). In addition, a significant association was found between

Dominant IKE/BM and TUG (r = -0.74), as well as between Non-dominant IKE/BM and Dominant Handgrip/BM (r = 0.67). These findings suggest that the IKE test is a repeatable and suitable strategy for lower-limb screening in institutionalized older adults.

Keywords: geriatric; aging; functional capacity; long-term care; frailty

Link: **https://www.sciencedirect.com/science/article/pii/S0531556521003570**

STUDY 3

5. STUDY 3

TITLE: A Sensitive and Practical Evaluation to Detect Lower-Limb Strength Changes in Geriatrics: The Isometric Knee Extension Test

Applied Sciences

ABSTRACT

This study aimed to examine the sensitivity of the isometric knee extension (IKE) test to detect changes in the lower-limb strength of institutionalized older adults after exercise and inactivity periods. Thirty-four and fifteen institutionalized older adults completed the training and inactive periods, respectively. At each time point, the participants completed two testing sessions. In the first session, they performed the IKE test. As a complement to this evaluation, the second testing session was used to assess their functional capacity and handgrip strength. The sensitivity of the IKE test was examined by comparing the changes generated in this test against the repeatability of the protocol. A 4-week multicomponent Vivifrail program was implemented. After that, a subsample of the participants was re-evaluated after a 14-week inactivity period. Significant changes ($p < 0.01$; ES ≥ 0.27) in the IKE strength for both the dominant (+0.27 N/kg) and non-dominant legs (+0.25 N/kg) were produced after the training intervention. Likewise, significant decrements ($p < 0.01$; ES ≥ 0.31) were detected after the inactive period for the dominant (−0.29 N/kg) and non-dominant legs (−0.32 N/kg). All mean changes were found to be superior to the variability threshold of the IKE test for both legs, with superior sensitivity for the non-dominant leg (≥73%). Thus, the IKE test is a sensitive and practical tool for detecting changes in the lower-limb strength of institutionalized older adults after exercise and inactivity periods. Because of its applicability, it seems pertinent to implement the IKE test in a geriatric context.

Keywords: physical evaluation, multicomponent exercise, detraining, COVID-19 confinement, aging

Link: https://www.mdpi.com/2076-3417/13/5/2946

CONCLUSIONS

6. CONCLUSIONS

The current PhD Thesis reports multiple conclusions according to the above-mentioned objectives:

CONCLUSIONS STUDY I

i. The Vivifrail exercise intervention, both short and long-term, was highly effective in improving the functional capacity of institutionalized older adults with sarcopenia.

This conclusion supports hypothesis 1 of Study 1.

ii. The benefits generated by the multicomponent training (Vivifrail) on functional capacity and handgrip strength were maintained after short and long inactivity periods in older adults with sarcopenia living in nursing homes.

This conclusion supports hypothesis 2 of Study 1.

CONCLUSIONS STUDY II

i. The IKE test is a repeatable physical assessment in institutionalized older adults with sarcopenia.

This conclusion supports hypothesis 1 of Study 2.

ii. The IKE test is highly associated with functional capacity (e.g., agility, gait speed, and standing ability) and muscle mass of older adults with sarcopenia living in nursing homes.

This conclusion supports hypothesis 2 of Study 2.

CONCLUSIONS STUDY III

iii. The IKE test is a sensitive and practical assessment to detect changes in the lower-limb strength of institutionalized older adults after exercise training and inactivity period.

This conclusion supports hypothesis 1 of Study 3.

PRACTICAL APPLICATIONS

7. PRACTICAL APPLICATIONS

The current PhD Thesis reports numerous practical applications about i) exercise strategies for reversing functional impairments in older adults and ii) suitable physical assessments for older adults with frailty.

Concerning the practical applications for preventing and even reversing frailty in institutionalized older adults**,** the supervised Vivifrail training program is a highly effective and safe exercise-based prescription for preventing weakness in institutionalized older adults. This finding has been confirmed even in different nursing homes after short-term programs, although longer periods report 10-20% additional improvements on functional capacity. These benefits can be achieved at a reduced economic cost related to the supervised Vivifrail exercise program, which includes the cost of equipment (500€ for dumbbells, ankle weights, and handgrip balls) and the salary of a qualified strength and conditioning trainer (Degree in Sports Science) (500-600€/monthly). Furthermore, this PhD Thesis provides an efficient strategy through an intermittent exercise intervention such as 4 weeks of supervised exercise 3 times yearly with no more than 14 weeks of inactivity between exercise periods. This approach can be appropriate and sufficient to protect older adults from functional decline due to hospitalizations, illnesses, or falls.

Concerning physical evaluation in older adults, this PhD Thesis develops the use of an affordable, repeatable, sensitive, and suitable assessment in geriatrics: the field-based IKE test using a strain gauge. Firstly, this evaluation is affordable because the strain gauge used is inexpensive (250€) compared to other devices for measuring lower-limb strength such as isokinetic devices (≥40.000€). Furthermore, the IKE test is a repeatable assessment due to its reduced intra and inter-session variability. Additionally, this evaluation is sensitive to detect strength changes produced by training and inactivity

periods because these changes exceed the variability of the test (i.e., SEM). Finally, the IKE test is a suitable assessment for frailty older adults living in nursing homes due to its technical simplicity and capability to be performed even by older adults who are unable to walk or rise from a chair.

FUTURE PERSPECTIVES

8. FUTURE PERSPECTIVES

The following topics should be examined in future studies to complement the findings of the current PhD thesis:

i. To analyze functional adaptations after middle-term (8-12 weeks) training and multicomponent exercise cessation in institutionalized older adults with sarcopenia.

ii. To examine metabolic, neural, and morphologic adaptations (e.g., hemodynamic profiles, motor unit recruitment, and changes in muscle cross-sectional area or appendicular lean mass) that can explain functional capacity preservation after inactivity periods in older adults with sarcopenia living in nursing homes.

iii. To review the available evidence on the protective effect of different exercise modalities and intensities to preserve functional capacity after inactivity periods in older adults.

iv. To review the available evidence on the protective effect of different exercise modalities and intensities to preserve strength after inactivity periods in older adults.

v. To extend the repeatability analyses of the IKE test using a strain gauge in healthy community-dwelling older adults or older adults with other diseases such as cognitive disorders.

vi. To analyze the sensitivity of the IKE test using a strain gauge to detect changes in lower-limb strength of healthy community-dwelling older adults or older adults with other impairments after exercise training and inactivity period.

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APPENDIXES

10. APPENDIXES

10.1. APPENDIX 1. Scientific contributions in conferences

On behalf of the Local Organising Committee, we hereby certify that the contribution entitled:

"***Effect of short- and long-term detraining on functional capacity and strength in institutionalized older adults***"

whose authors are:

Ángel Buendía-Romero, Alejandro Martínez-Cava, Silverio García-Conesa, Jesús G. Pallarés, Javier Courel-Ibañez

Has been presented as an oral communication at the1st International Virtual Congress "Exercise, Aging and Health". The INTERMAE Project, held online from May 13th to 14th 2021.

David Jiménez-Pavón
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Confirmation of Presentation

This is to certify that the following title has been presented at the 26th Annual Congress of the European College of Sport Science between 8 - 10 September 2021.

Ángel Buendía-Romero

Faculty of Sport Sciences, University of Murcia, Spain
Calle Argentina s/n
30720 San Javier, Spain

Abstr.-ID: 386, Presentation format: Oral , Session name: OP-MH08 - Aging and Elderly
Title: Is the isometric knee extension test a repeatable and suitable tool for lower-limb screening among institutionalized older adults?
Authors: Buendía Romero, Á., Hernández Belmonte, A., García Conesa, S., Martínez Cava, A., Franco López, F., Conesa Ros, E., Pallarés, J.G., Courel Ibáñez, J.
Institution: Faculty of Sport Sciences, University of Murcia, Spain
Presentation date: 11.09.2021, 00:00, Lecture room: -Track 3, No: 5

European College of Sport Science

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Red de Entrenamiento de Fuerza

UNIVERSIDAD DE GRANADA

FACULTAD DE CIENCIAS DEL DEPORTE

I CONGRESO INTERNACIONAL SOBRE OPTIMIZACIÓN DEL ENTRENAMIENTO DE FUERZA Y RENDIMIENTO NEUROMUSCULAR

Se certifica que

Buendía-Romero, Á, Romero-Borrego, E., Hernández-Belmonte, A., Martínez-Cava, A., Franco-López, F., Pallarés, J.G han presentado el **póster** titulado "**Is the isometric knee extension test a sensible tool for assessing physical condition changes among institutionalised older adults?**" en el "I Congreso Internacional sobre Optimización del Entrenamiento de Fuerza y Rendimiento Neuromuscular" celebrado en la Facultad de Ciencias del Deporte de la Universidad de Granada los días 7 y 8 de Octubre de 2022.

El trabajo ha sido galardonado por el comité científico con el:

Tercer premio al mejor póster

Granada, 12 de octubre de 2022

GARCIA RAMOS AMADOR - 25729208M

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D. Amador García Ramos
Presidente del congreso

Se certifica la presentación del trabajo titulado

Does β-hydroxy-β-methylbutyrate (HMB) supplementation produce extra improvements to multicomponent training on functional capacity among older adults?

Cuya autoría pertenece a **Buendía-Romero, A., Hernández-Belmonte, A., Romero-Borrego, E., Martínez-Cava, A., Franco-López, F., Pallarés, JG.**, bajo el formato de **COMUNICACIÓN ORAL** en el **"III Congreso Internacional de Investigación Aplicada en Ciencias de la Actividad Física y el Deporte"**. Congreso que ha sido organizado por la Facultad de Ciencias del Deporte de la Universidad de Murcia, en la localidad de San Javier (Murcia), durante los días 21 y 22 de octubre de 2022.

Y, para que así conste, a petición del/los interesado/s, se certifica su contribución a los efectos oportunos en San Javier (Murcia) a 22 de octubre de 2022.

UNIVERSIDAD DE MURCIA

Fdo. J. Arturo Abraldes Valeiras
Director del III Congreso Internacional de Investigación Aplicada en Ciencias de la Actividad Física y el Deporte

Facultad de Ciencias del Deporte
Universidad de Murcia · Campus de San Javier

Firmado con Certificado Electrónico. La información sobre el firmante, la fecha de firma y el código de verificación del documento se encuentra disponible en los márgenes del certificado

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Código seguro de verificación: RUxRMpsf-aC8BiyOv-m4982PA2-Yom/HgVJ

The presentation of the manuscript titled

Exercise training produces standing ability benefits even after an inactivity period in older adults: a systematic review and meta-analysis

Authored by **Buendía-Romero, A., Hernández-Belmonte, A., Pallarés, JG., Courel-Ibáñez, J., Vetrovsky, T.** in the **ORAL COMMUNICATION** format at the **"III International Congress of Applied Research in Physical Activity and Sport Sciences"**. This congress has been organized by the Faculty of Sports Sciences of the University of Murcia, in San Javier (Murcia), on October 21 and 22, 2022.

In witness whereof, at the request of the interested party/s, their contribution is certified to the appropriate effects in San Javier (Murcia) on October 22, 2022

UNIVERSIDAD DE MURCIA

Fdo. J. Arturo Abraldes Valeiras
Chairman of III International Congress of Applied Research in Physical Activity and Sport Sciences

Facultad de Ciencias del Deporte
Universidad de Murcia · Campus de San Javier

Firmado con Certificado Electrónico. La información sobre el firmante, la fecha de firma y el código de verificación del documento se encuentra disponible en los márgenes del certificado

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Código seguro de verificación: RUxPWoWf-legVX3Y8-rr3H2Fa2-cu8WwGod

10.2. APPENDIX 2. Certificate of research stays

UNIVERSIDAD DE
MURCIA

CERTIFICADO DE ESTANCIA DE INVESTIGACIÓN FUERA DE ESPAÑA PARA OPTAR A MENCIÓN DE «DOCTORADO INTERNACIONAL»

INTERNATIONAL Ph.D. VISITING RESEARCH CERTIFICATE

1. DATOS DEL DOCTORANDO QUE HA REALIZADO LA ESTANCIA / Ph.D. STUDENT´S PERSONAL DATA

Nombre y apellidos del doctorando/a / Ph.D. student name and surname: Ángel Buendía Romero
Centro de origen / Institution of origin: Escuela Internacional de Doctorado de la Universidad de Murcia
Programa de Doctorado / Doctoral Programme: Ciencias de la Actividad Física y del Deporte
Título de la tesis / Thesis title: Efecto del entrenamiento y su cese sobre la capacidad funcional y fuerza en adultos mayores

2. DATOS DEL CENTRO EN EL QUE SE HA REALIZADO LA ESTANCIA / HOST INSTITUTION

Nombre del Centro de Educación Superior o Instituto de Investigación / Name of the host institution: Charles University
Departamento/Centro / Department/Centre: Department of Physiology and Biochemistry, Faculty of Physical Education and Sport
Dirección del Centro / Address: José Martího 31, 16252, Praha 6
Localidad y país / City and country:Praga, República Checa

3. DATOS DEL TUTOR/INVESTIGADOR RESPONSABLE DE LA ESTANCIA / RESEARCH SUPERVISOR AT HOST INSTITUTION

Nombre y apellidos del tutor/investigador / Research supervisor name and surname: Michal Steffl
DNI/Pasaporte nº. / **I.D.** / Passport nº: 212072831
E-mail: Steffl@ftvs.cuni.cz
Departamento/Centro al que pertenece / Department/Centre: Department of Physiology and Biochemistry, Charles University

En/In Praga a Junio/June 2023

Firmado y sellado / Signed and stamped*. Dr Dº.: Michal Steffl

UNIVERZITA KARLOVA
Fakulta tělesné výchovy a sportu
José Martího 31, 162 52, Praha 6

(*) Debe firmar y sellar todas las hojas del informe / You must sign and seal all the pages of the report

– 13 –

COMISIÓN GENERAL DE DOCTORADO DE LA UNIVERSIDAD DE MURCIA (España)

Página **1** de **2**

4. **CERTIFICADO DE LA ESTANCIA / VISITING RESEARCH CERTIFICATE** (1):

(1)A cumplimentar por el tutor investigador responsable de la estancia / To complete by the research supervisor.

El abajo firmante certifica que el doctorando/a arriba mencionado/a ha realizado una estancia en este Centro bajo mi supervisión en las siguientes fechas: desde el 15 de 09 de 2021 hasta el 16 de 12 de 2021, realizando:

Analizar fatiga neuromuscular usando tensiomiografía

Evaluar la fatiga tras diferentes protocolos de saltos con contramovimiento usando dos transductores lineales de posición simultáneamente

Valorar fuerza de flexo-extensión de rodilla usando dinamómetros isocinéticos

Analizar arquitectura muscular del vasto lateral del cuádriceps usando ultrasonidos

Evaluar el riesgo de seso y calidad metodológica de artículos seleccionados para una revisión sistemática

Preparar hojas de excel personalizadas para la extracción de datos necesaria en un metaanálisis

Aprender análisis de datos básico usando el programa Rstudio

The person who signs this document certify that the Ph.D. student above-mentioned has visited this institution under my supervision in the following dates: from 15/09/2021 to 16/12/2021. The Ph.D student is able to:

Analyze neuromuscular fatigue using tensiomyography

Evaluate fatigue following different countermovement jump protocols using two linear position transducers simultaneously

Assess knee flexion-extension strength using isokinetic dynamometers

Analyze the muscular architecture of the vastus lateralis of the quadriceps using ultrasound

Evaluate the risk of bias and methodological quality of selected articles for a systematic review

Prepare customized Excel sheets for the necessary data extraction in a meta-analysis

Learn basic data analysis using the RStudio program

En/In Praga a Junio/June 2023

Firmado y sellado / Signed and stamped*. Dr Dº: Michal Steffl

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Fakulta tělesné výchovy a sportu
José Martího 31, 162 52, Praha 6
– 13 –

COMISIÓN GENERAL DE DOCTORADO DE LA UNIVERSIDAD DE MURCIA (España)

UNIVERSIDAD DE GRANADA

CERTIFICADO DE ESTANCIA PREDOCTORAL

Por medio de la presente, certifico que Ángel Buendía Romero ha completado satisfactoriamente una estancia predoctoral de 3 meses (del 09-01-2023 al 10-04-2023) en el Departamento de Educación Física y Deportiva de la Universidad de Granada.

Durante su estancia, Ángel Buendía Romero ha trabajado bajo la supervisión del Dr. Javier Courel Ibáñez, quien ha supervisado y dirigido sus actividades de investigación en el campo de las Ciencias del Deporte. Ángel Buendía Romero ha participado activamente en nuestro grupo de investigación en diversas tareas, tales como la recolección y análisis de datos, la revisión de literatura especializada y la escritura de artículos científicos.

En este periodo, Ángel Buendía Romero demostró un alto nivel de dedicación y compromiso con su investigación. Su trabajo ha sido integral para el progreso de los proyectos en los que ha participado y su contribución ha sido valorada altamente por el grupo de investigación.

En virtud de lo anterior, puedo confirmar que Ángel Buendía Romero ha completado satisfactoriamente una estancia predoctoral de 3 meses en nuestra institución, habiendo cumplido con los objetivos y metas establecidos.

Firmado:
Prof. Javier Courel Ibáñez
Departamento de Educación Física y Deportiva
Universidad de Granada

[Firmado digitalmente]

COUREL IBAÑEZ JAVIER - 76422730D

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10.3. APPENDIX 3. Scientific studies derived from this PhD Thesis

Article 1 Courel-Ibáñez, J., Buendía-Romero, Á*., Pallarés, J. G., García-Conesa, S., Martínez-Cava, A., & Izquierdo, M. (2022). Impact of Tailored Multicomponent Exercise for Preventing Weakness and Falls on Nursing Home Residents' Functional Capacity. *Journal of the American Medical Directors Association, 23*(1), 98-104.

Article 2 Buendía-Romero, Á., Hernández-Belmonte, A., Martínez-Cava, A., García-Conesa, S., Franco-López, F., Conesa-Ros, E., & Courel-Ibáñez, J. (2021). Isometric knee extension test: A practical, repeatable, and suitable tool for lower-limb screening among institutionalized older adults. Experimental Gerontology, 155, 111575.

Article 3 Buendía-Romero, Á., Hernández-Belmonte, A., Franco-López, F., Romero-Borrego, E., Cava, A.M., Pallarés J.G., & Courel-Ibáñez J. (2023) A sensitive and practical evaluation to detect lower-limb strength changes in geriatrics: the isometric knee extension test. *Applied Sciences, 13*(5), 2946.

Article 4 Buendía-Romero, Á., Vetrovsky, T., Estévez-López, F., & Courel-Ibáñez, J. (2021). Effect of physical exercise cessation on strength, functional, metabolic and structural outcomes in older adults: a protocol for systematic review and meta-analysis. *BMJ open*, *11*(12), e052913.

Article 5 Buendía-Romero, Á., Vetrovsky, T., Hernández-Belmonte, A., Izquierdo, M. & Courel-Ibáñez, J. Preserving Functional Capacity in Older Adults: A Systematic Review and Meta-Analysis on the Protective Effects of Exercise Modalities and Intensities during Inactivity Periods.

10.4. APPENDIX 4. Ethics Commission

UNIVERSIDAD DE MURCIA | Vicerrectorado de Investigación e Internacionalización | CEI Comisión de Ética de Investigación | CAMPUS MARE NOSTRUM

INFORME DE LA COMISIÓN DE ÉTICA DE INVESTIGACIÓN DE LA UNIVERSIDAD DE MURCIA

Jaime Peris Riera, Catedrático de Universidad y Secretario de la Comisión de Ética de Investigación de la Universidad de Murcia,

CERTIFICA:

Que D. Jesús García Pallarés ha presentado la memoria de trabajo del Proyecto de Investigación titulado *"ReLiFE: Reverse Limited mobility in Frail people over 80 years through Exercise and nutritional supplementation with HMB",* a la Convocatoria 2019 de Ayudas a Proyectos de I+D+i del Ministerio de Ciencia, Innovación y Universidades.

Que la Comisión de Ética de Investigación de la Universidad de Murcia analizó toda la documentación presentada, y de conformidad con lo acordado el día once de marzo de dos mil veinte[1], por unanimidad, se emite INFORME FAVORABLE, desde el punto de vista ético de la investigación.

Y para que conste y tenga los efectos que correspondan firmo esta certificación con el visto bueno de la Presidenta de la Comisión.

Vº Bº
LA PRESIDENTA DE LA COMISIÓN
DE ÉTICA DE INVESTIGACIÓN DE LA
UNIVERSIDAD DE MURCIA

Fdo.: María Senena Corbalán García

ID: 2574/2019

[1]A los efectos de lo establecido en el art. 19.5 de la Ley 40/2015 de 1 de octubre de Régimen Jurídico del Sector Público (B.O.E. 02-10), se advierte que el acta de la sesión citada está pendiente de aprobación