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TESIS DOCTORAL

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Efectos de un programa de ejercicios de alta intensidad por intervalos basado en un entrenamiento en suspensión sobre el riesgo de caídas, la condición física y el estado de salud en personas mayores de 60 años.

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DEPARTAMENTO DE CIENCIAS DE LA SALUD
FACULTAD DE CIENCIAS DE LA SALUD
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AUTORIZACIÓN DE LOS DIRECTORES DE LA TESIS PARA SU PRESENTACIÓN

El Dr. Antonio Martínez Amat y el Dr. Fidel Hita Contreras Directores de la Tesis Doctoral titulada *"Efectos de un programa de ejercicios de alta intensidad por intervalos basado en un entrenamiento en suspensión sobre el riesgo de caídas, la condición física y el estado de salud en personas mayores de 60 años",* realizada por Don. **JOSÉ DANIEL JIMÉNEZ GARCÍA** en el Departamento de Ciencias de la Salud **autorizan su presentación a trámite** dado que reúne las condiciones necesarias para su defensa.

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ÍNDICE

CAPÍTULO 1: FUNDAMENTACIÓN TEÓRICA

Las caídas suponen un grave problema de salud pública en personas mayores debido a su alta morbimortalidad, así como los altos costes económicos y médicos asociados. Se trata de un evento multifactorial que afecta más a las mujeres que a los hombres.

El envejecimiento de la población lleva asociados una serie de cambios funcionales en las personas mayores. Estos cambios pueden estar enmascarados bajo un índice de masa corporal estable, en el que la pérdida de masa muscular se compensa con un aumento de masa grasa, resultando en un fenotipo denominado obesidad sarcopénica (OS). Esta entidad está asociada a una disminución de la función física y de la independencia funcional, con un empeoramiento del equilibrio estático y dinámico, un aumento del miedo a caerse, un incremento de la inseguridad y disminución de la confianza sobre la realización de actividades de la vida diaria (AVD), lo que supone un incremento del riesgo de caídas y de sus complicaciones asociadas.

La práctica del ejercicio físico en sus diversas modalidades se asocia a una mejoría en aspectos relacionados con la salud física y psicológica en cualquier tipo de población. En la actualidad una de las principales barreras para la práctica habitual del ejercicio físico es “la falta de tiempo”. En este contexto se desarrolló el entrenamiento por intervalos de alta intensidad (HIIT, del inglés *high-intensity interval training*), caracterizado por sesiones breves e intermitentes de actividad a alta intensidad, alternados con períodos de descanso o de baja intensidad, en nuestro caso, el HIIT ha demostrado estar relacionado con una mejoría en la calidad de vida y múltiples efectos beneficiosos para la salud, como en distintos ensayos clínicos aleatorizados que tras un HIIT se suele observar un aumento de la masa muscular ya sea como tratamiento único o en comparación con un programa de entrenamiento continuo, pero también se ha encontrado efectos a nivel de grasa, con una disminución del IMC, grasa corporal total y circunferencia abdominal. También se ha demostrado que tras un entrenamiento HIIT se producen mejorías en la sensibilidad a la insulina en músculo y grasa, disminución de la adipogénesis y de la concentración de glucosa en sangre y una mejoría en los marcadores pro-inflamatorios y estrés oxidativo.

INTRODUCCIÓN

1. RIESGO DE CAÍDAS

1.1 Estado actual y problemas asociados al riesgo de caídas

En una población que envejece cada vez más, el número de personas mayores de 65 años está aumentando. En 2010, el 26,2% de la población española eran adultos mayores, pero en 2016 se incrementó hasta el 85,8% (1). Las principales razones de este cambio demográfico se deben al aumento de la esperanza de vida y a un descenso de la natalidad (2). Este envejecimiento está generalmente asociado con un deterioro progresivo de la función física y la salud psicológica (3,4), el aumento constante del riesgo de discapacidad, la dependencia (3) y el aumento de problemas de comorbilidad (5). Esta disminución en el estado de salud es el principal responsable de uno de los problemas más comunes y graves de salud pública, como son las caídas.

Las lesiones no intencionales son la quinta causa principal de muerte en adultos mayores (7,8). Alrededor de un tercio de personas mayores sufren al menos una caída cada año y la incidencia aumenta con la edad (6). Aproximadamente un 20% de las caídas accidentales requieren de atención médica y un 5% dan lugar a una fractura u otras lesiones graves (9).

Desde un punto de vista social, la caída genera problemas psicológicos como el miedo a caerse, la depresión y la aprensión a realizar actividad física (7,8,10,11). Además tiene resultados negativos, tales como fracturas, deterioro funcional, pérdida de confianza y reducción de la calidad de vida (14-17), generando unos costes de salud que pueden ser prevenibles (14) con intervenciones adecuadas, pudiendo evitar los impactos negativos de las caídas en personas mayores con riesgo de caídas (6). En los últimos años, numerosos ensayos aleatorios controlados sobre los factores de riesgo de caídas, se han elaborado y evaluado, obteniendo resultados positivos (6, 12, 13). Evidenciando estas ganancias en la salud fisiológica en gran parte determinada por la dosis correcta de ejercicio, mostrando unas pautas (18,20) de ejercicios para la prevención del riesgo de caídas con un mínimo de 12 semanas de entrenamiento y de 1 a 3 sesiones semanales (19).

1.2 Factores de riesgo de caídas

Existen varios factores de riesgo de caídas, que pueden clasificarse como extrínsecos (incluyendo aquellos relacionados con los efectos derivados del uso de medicamentos, obstáculos o circunstancias de riesgo dentro y fuera del hogar, tipo de calzado, etc.) o intrínsecos (las alteraciones del equilibrio estático y dinámico, el miedo a caerse, la velocidad de la marcha, la fuerza muscular, etc.). Estos factores de riesgo intrínsecos pueden ser modificados por el ejercicio referido de manera estructurada, planificada y repetitiva con actividades en un ejercicio organizado basado en distintos tipos de programas (5,26).

Tres de los factores de riesgo intrínsecos más comunes de riesgo para el riesgo de caídas son la debilidad muscular, enmascarada en su caso por un índice de masa corporal estable, pero compensando esa pérdida de masa muscular con el aumento de masa grasa, el déficit del balance de equilibrio, provocando una disminución de la función física y una creciente insegurad en la población mayor y la inestabilidad de la marcha generando problemas en la autonomía y la capacidad funcional (23-25). Además, son varios los estudios que han revelado una relación entre la baja velocidad y su relación con caídas en los ancianos (21,22).

En la actualidad, además de los factores intrínsecos y extrínsecos asociados al riesgo de caídas en la población mayor, estudios recientes muestran la interacción de esta caída a nivel multifactorial derivados de la reducción de la eficacia en las respuestas posturales (27), la disminución de la agudeza sensorial (28), alteraciones en sistema cardiopulmonar (29), desacondicionamiento asociada a la inactividad (30) y altos niveles de depresión. Generando así un aumento de herramientas de evaluación del riesgo de caídas tan abundantes como los factores contribuyentes.

1.3 Herramientas de predicción en el riesgo de caídas

La prevención del riesgo de caídas y las intervenciones adecuadas para evitar las caídas es uno de los temas más relevantes e importantes a estudiar a nivel multifactorial en la población mayor. Pero antes de prevenir las caídas, es importante conocer la población que se encuentra en situación de riesgo de caídas y cuales son las herramientas más eficaces para conocer la situación de la población. Mayor. En la actualidad uno de los factores más importantes para determinar a una persona mayor en situación de riesgo de caídas es el hecho de que haya sufrido ya una caída en el último año, aumentando su riesgo a poder sufrir una caída de nuevo, además de los factores de demencia y la incontinencia urinaria. Las herramientas para detectar si una población se encuentra en situación de riesgo son cada vez más fiables y existen más investigaciones que las corroboran. La prueba funcional Timed Up and Go Test, es una de las más fiables, habiéndose demostrado en un Metaanálisis de 10 estudios, que el sobrepasar en más de 13,5 seg dicha prueba, muestra que esa persona se encuentra en un alto riesgo de padecer caídas. Al igual que en el caso de las pruebas funcionales, los cuestionarios de valoración cada cada vez son más eficaces, como la Escala de Confianza del Equilibrio (ABC) (31), siendo un test fiable y valido para evaluar la confianza del equilibrio en la población mayor. Además LaJoie (2004) (32), demostraron que al obtener un porcentaje de confianza menor a 67% en el test, existía un alto riesgo de caídas. De manera similar el test de escala de eficacia de caídas internacional (FES-I) (33) es una herramienta fiable para evaluar el miedo a caerse, midiendo en este caso las actividades sociales físicas dentro y fuera de la casa en la población. Además este test ha sido validado su versión española en una población similar a la de nuestro estudio, siendo en mujeres postmenopaúsicas (34).

2. EJERCICIO FÍSICO RELACIONADO CON RIESGO DE CAÍDAS

2.1 Estado actual de intervenciones en prevención de caídas

Ejercicios de equilibrio son importantes para mantener y mejorar el equilibrio postural y a su vez para evitar las caídas. El envejecimiento puede afectar al sistema nervioso central y las propiedades del sistema neuromuscular lo que conduce a déficits en el equilibrio y en el rendimiento de la marcha (35). De acuerdo con Shumway-Cook y Woollacott (36) el equilibrio se puede subdividir en estático / de estado estacionario dinámico (es decir, el mantenimiento de una posición estable en sentado, de pie y caminar), proactivo (es decir, la anticipación de una perturbación predicho), y reactivo (es decir, la compensación de una perturbación) (37,38). Recientemente, Muehlbauer et al. (37) fueron capaces de demostrar que no hay ninguna asociación significativa entre las medidas de estado estacionario, proactivo, reactiva y el equilibrio en personas mayores sanas. Por lo tanto, para la prueba y con fines de formación, pruebas de equilibrio y ejercicios deberían centrarse en los tres dominios por separado y, además, incluir tareas de situaciones doble o múltiple (37), dado que se requiere de múltiples tareas para el desempeño de muchas actividades de la vida diaria (AVD, por ejemplo, bajar las escaleras mientras se habla por el teléfono) (38-40). Además, realizar ejercicios específicos de equilibrio pueden ayudar a contrarrestar el déficit de balance y la inestabilidad de la marcha al reducir el riesgo de caídas en personas mayores (41-44). Un ejemplo es el estudio de Ullmann (2010) (45) en el que se desarrollaron 5 semanas de un entrenamiento de equilibrio y movilidad en población mayor y mostraron mejoras en la predicción del riesgo de caídas con el cuestionario ABC. Otros estudios realizados en adultos mayores con diferentes intervenciones como Pilates (46) y Tai-Chi (47), mostraron resultados significativos en el riesgo de caídas controlados a través del cuestionario FES-I.

Además del equilibrio, se requiere la fuerza muscular/potencia para el buen desarrollo de las AVD (37). Las causas generales de la pérdida de masa de músculo esquelético relacionada con la edad (es decir, sarcopenia) son múltiples (por ejemplo, celular, neural, metabólicas, hormonales contribuyentes) (48-50) y se relacionan en personas mayores con bajos niveles de fuerza muscular o bajo rendimiento físico medido por la velocidad de la marcha (≤80 cm/s), fuerza de agarre y la masa muscular (51). Los seres humanos pierden aproximadamente entre un 20% -30% de su músculo esquelético entre la edad adulta y 80 años de edad (52). Esta pérdida de tamaño de la fibra muscular y el número predominantementese produce en fibras musculares tipo II que conducen a una más rápida disminución de la fuerza muscular en comparación con muscular en general la fuerza (53). Esto es perjudicial ya que la potencia muscular es un requisito previo importante para las reacciones posturales rápidas en respuesta a las perturbaciones externas (54). Los adultos mayores a menudo utilizan la estrategia de cadera o de paso cuando se ve amenazado el equilibrio (8,43). Una disminución de la fuerza muscular retrasaría tales reacciones posturales a las perturbaciones externas (55,56), que probablemente conducen a una pérdida de equilibrio (57) y en última instancia lo que resulta en una caída (58). Un ejemplo en la intervención de fuerza y su relación con el riesgo de caídas es el estudio de Onambelé (2010) (58), donde demostró una mejora significativa en la prueba TUG Test, siendo ésta una herramienta fiable en la predicción del riesgo de caídas, tras realizar una comparación de entrenamiento de intensidad alta y baja de fuerza en el tren inferior de personas mayores.

En los últimos años, se han publicado numerosos ensayos controlados aleatorios sobre factores de riesgo de caídas (6,12,13). Varios estudios han revelado una relación entre la baja velocidad y su relación con las caídas en el adulto mayor (59,60). Se ha demostrado

que algunos programas de ejercicios, cuando se estructuran, planifican y repiten adecuadamente, pueden modificar estos factores de riesgo intrínsecos (61).
Sin embargo, la mala adherencia al ejercicio en esta población mayor es reconocido como un factor limitante para el logro del ejercicio adecuado, para que este sea efectivo (28,29,63). Para conseguir esta adherencia se ha demostrado que los participantes se adhieren al ejercicio durante las primeras etapas de sus programas de ejercicios, independientemente de si el método es individual o colectivo (30), pudiendo esta disminuir a medida que pase el tiempo. Por lo tanto, se entiende que la adherencia es un factor importante a trabajar para que el tratamiento logre los resultados marcados.

2.2 HIIT y Entrenamiento en Suspensión (TRX)

El entrenamiento a intervalos de alta intensidad (HIIT) ha atraído la atención en los últimos años como una opción de ejercicio para la población joven y adulta. Este tipo de ejercicio se caracteriza por sesiones breves e intermitentes de actividad de alta intensidad que alternan con períodos de descanso o baja intensidad. Además, el HIIT ha sido descrito como una actividad más satisfactoria que el ejercicio continuo de intensidad moderada (64). La seguridad en un programa HIIT es de suma importancia, especialmente en poblaciones en riesgo, pero varios estudios han demostrado que la capacitación en HIIT es segura y bien tolerada por participantes saludables en diferentes poblaciones (65), así como también por pacientes con algunas afecciones clínicas, como enfermedad cardíaca (66). El número de estudios que investigan este tipo de entrenamiento en la población anciana ha aumentado últimamente (67,68). En este contexto, García Pinillos (2017) (69) estudiaron los efectos del HIIT en el rendimiento físico en adultos mayores sanos, con una intervención HIIT de ejercicios de Fuerza.
Además, recientemente se ha demostrado que el control postural y el riesgo de caídas pueden mejorar después del HIIT en comparación con los efectos de un programa de ejercicio continuo en jóvenes sanos y sin entrenamiento (70), y también en pacientes con algún tipo de patología (4). En los ancianos, algunos ensayos aleatorios han estudiado los efectos sobre los resultados cardiovasculares y antropométricos después de las intervenciones HIIT (72,73). En estos apartados, encontramos los estudios sobre entrenamiento HIIT en población mayor, donde Knowles (68) y Nemoto (61) mostraron resultados significativos en la presión sistólica tras un entrenamiento HIIT en comparativa con un grupo CONTROL. Un estudio de Bruseghini (74), en cambios antropométricos,

mostraron cambios significativos el porcentaje graso, grasa absdominal y relación cintura-cadera tras un entrenamiento HIIT en población mayor. En el contexto actual, uno de los nuevos tipos de ejercicios HIIT es el entrenamiento de suspensión. En esta actividad, la intensidad del ejercicio puede variar según la posición del cuerpo y los efectos de la gravedad, y el peso corporal actúa como resistencia. Debido a sus efectos beneficiosos sobre la activación muscular y el equilibrio (75), el entrenamiento con suspensión puede ser especialmente recomendado para adultos mayores.

3. HERRAMIENTAS DE VALORACIÓN USADAS EN ESTE ESTUDIO: COMPOSICIÓN CORPORAL Y ANTROPOMETRÍA

3.1 Conceptos generales

Para valorar la composición corporal se usó análisis de impedancia bioeléctrica para medir la composición corporal, la masa del músculo esquelético y el porcentaje de grasa corporal se examinaron utilizando el analizador de impedancia bioeléctrica InBody 720 (Biospace Co., Ltd; Seúl, Corea), con una frecuencia operativa de 50 kHz a 800 µA (Figura 1). Para la antropometría, todos los datos antropométricos fueron recopilados por un médico especializado de acuerdo a un protocolo estandarizado (76).

Figura 1: analizador de impedancia bioeléctrica InBody 720 (Biospace Co., Ltd; Seúl, Corea)

3.2 Protocolo de uso y consideraciones generales

La altura se redondeó a los 0,01 cm más cercanos con un estadímetro. Los participantes usaron ropa liviana y estaban descalzos cuando se les midió. Se tomaron circunferencias de cintura-cadera y se redondearon a los 0,1 cm más cercanos utilizando una cinta métrica no estirable. El índice de masa corporal (IMC) se calculó como la masa corporal en kilogramos dividida la altura al cuadrado en metros.

Para la prueba de bioimpedancia eléctrica, los participantes se mantuvieron erguidos con los brazos separados del tronco y las piernas ligeramente abiertas. Previamente se había controlado los factores para que la prueba fuese lo más correcta posible, sin poder realizar esta prueba personas con marcapasos o prótesis de cualquier tipo. Esta prueba se realizó en ayunas, sin haber bebido o comido en las cuadro horas anteriores a la prueba y con la vejiga vacía y sin haber realizado ejercicio físico antes de la prueba.

4. HERRAMIENTAS DE VALORACIÓN USADAS EN ESTE ESTUDIO: FUERZA MUSCULAR DE AGARRE

4.1 Conceptos generales

La fuerza de agarre de la empuñadura se define como la suma de la fuerza de los musculos flexores contra la palma de la mano, actuando los musculos extensores de manera secundaria, ayudando así a la contribución de los músculos intrínsecos a generar un papel menor en la generación de fuerza de agarre (77). Aunque la fuerza de agarre se evalue como la fuerza de la mano, ésta también refleja una visión de la fuerza general (78).

4.2 Protocolo de uso y consideraciones generales

La fuerza muscular, medida por un dinamómetro analógico de empuñadura (TKK 5001, Grip-A, Takei, Tokio, Japón) con un lapso de agarre de 4,5 cm, se empleó para la fuerza muscular. Se pidió a los participantes que aplicaran su fuerza de agarre máxima tres veces con la mano izquierda y la derecha, con intervalos de descanso de 30 segundos entre las mediciones. El esfuerzo medido máximo fue considerado como su fuerza de agarre (79).

5. HERRAMIENTAS DE VALORACIÓN USADAS EN ESTE ESTUDIO: ANÁLISIS DE LA MARCHA, VELOCIDAD DE LA MARCHA Y EQUILIBRIO DINÁMICO

5.1 Conceptos generales

El sistema de análisis de la marcha OptoGait (Microgate Italy, Bolzano-Bozen, Italia) (Figura 2), es un dispositivo que consiste en un sistema de detección opto-eléctrico, se empleó para el análisis de la marcha. La barra del transmisor tiene 96 diodos emisores de luz (LED) que se comunican en el espectro infrarrojo. La barra del receptor, que se encuentra frente a ella, tiene el mismo número de LED. Las barras del transmisor y del receptor del OptoGait se instalaron en ambos lados de una cinta de correr. Utilizando una tasa de captura de datos de 1,000 transmisiones / recepciones por segundo, se pueden medir con precisión actividades como correr, saltar o el tiempo que se pasa en tierra o en el aire. A partir de estos datos básicos, el software analiza los datos medidos en tiempo real en una serie de movimientos. Los datos recopilados por OptoGait utilizan las diferencias en las variables de la marcha entre las piernas izquierda y derecha: cuanto menor sea la diferencia, mayor será la estabilidad y la capacidad de equilibrio.

Para controlar la velocidad de la marcha y el equilibrio dinámico, el Timed Up-and-Go test (TUG) es un método simple, válido y fiable para evaluar la movilidad funcional, velocidad de la marcha y el equilibrio (81), que ya se ha utilizado en mujeres ancianas (82). Esta misma prueba se utilizó para valorar la velocidad de la marcha y el equilibrio dinámico en el estudio actual. Se ha informado que esta es una herramienta útil para identificar a los adultos que viven en la comunidad que están en riesgo de caídas (80).

Figura 2: Una participante realizando la prueba de análisis de la marcha OptoGait (Microgate Italy, Bolzano-Bozen, Italia)

5.2 Protocolo de uso y consideraciones generales

Para el análisis de la marcha, las barras OptoGait se colocaron en ambos lados de una cinta de correr. El ancho del paso es la distancia entre dos pasos sucesivos (entre dos X). Para evaluar el análisis de la marcha, se usó la prueba "Caminar a 3 mph o 5 km / h", que consiste en caminar durante 30 segundos en la banda para caminar, mientras que los parámetros de marcha fueron recolectados por el sistema de fotocélulas a una velocidad constante de 3.5 km / h tanto en la banda para caminar como en el sistema informático. Se realizaron dos familiarizaciones y cinco ensayos experimentales con un intervalo de descanso de 1 minuto entre los ensayos. Los parámetros de la marcha fueron: Longitud del paso (cm): distancia entre el primer contacto de un pie y el primer contacto del opuesto. Doble apoyo (s): período de tiempo cuando ambos pies tocan el suelo. Tiempo de paso (s): tiempo entre el primer contacto de un pie y el primer contacto del pie opuesto. Longitud de zancada (cm): distancia entre la punta de dos huellas posteriores del mismo pie o la distancia entre los talones de dos huellas posteriores del mismo pie. Velocidad de marcha (m / s) y distancia (cm) recorrida durante la prueba.

Para controlar la velocidad de la marcha y el equilibrio dinámico se realizó el Timed Up and Go Test, que se basa en actividades cotidianas y requiere pararse de una silla sentado, caminar tres metros, girar y sentarse nuevamente (38). Se registra el tiempo requerido por el sujeto para completar esta tarea. Con el tiempo mostrado en realizar la tarea, es la variable con la que controlamos el equilibrio dinámico en este estudio. Además, el tiempo anotado en la prueba TUG se convirtió en una estimación de la velocidad de la marcha usando la fórmula [6 / (tiempo TUG) * 1.62] (79).

6. HERRAMIENTAS DE VALORACIÓN USADAS EN ESTE ESTUDIO: CALIDAD DE VIDA SUBJETIVA (SF-36), ESCALA DE CONFIANZA DEL EQUILIBRIO (ABC) Y MIEDO A CAERSE (FES-I)

6.1 Conceptos generales

Estas herramientas se han unificado en la explicación debido a que son los 3 cuestionarios cualitativos que se han usado para controlar la calidad de vida subjetiva, la escala de confianza del equilibrio y el miedo a caerse en personas mayores de 60 años.

6.2 Protocolos de uso y consideraciones generales

6.2.1. Calidad de Vida Subjetiva

La encuesta de salud genérica de formato corto de 36 ítems (SF-36) es un instrumento válido y fiable que se usa ampliamente para medir la calidad de vida genérica relacionada con la salud (85). Consiste en nueve escalas o dominios: función física (diez ítems), dolor físico (cuatro ítems), cambio de salud (dos ítems), salud general (cinco ítems), vitalidad (cuatro ítems), funcion social (dos ítems), desempeño emocional (tres ítems), y salud mental (cinco ítems). El SF-36 también proporciona dos medidas de resumen: un resumen de componentes físicos (PCS) y un resumen de componentes mentales (MCS). La puntuación total varía de 0 a 100, donde 0 representa la peor calidad de vida y 100 representa la mejor calidad de vida. La versión en español del SF-36 fue traducida y validada en la población española por Alonso et al. (83) y su confiabilidad se ha demostrado en varios rangos de edad, incluido el del presente estudio (84)

6.2.2 Escala de confianza del equilibrio

La Escala de Confianza del Equilibrio para Actividades Específicas (ABC) se utilizó para evaluar la confianza del equilibrio (32). Esta es una medida válida y fiable para evaluar la confianza de equilibrio en adultos mayores que viven en comunidades (86). El ABC consta de 16 preguntas que preguntan acerca de la confianza de un individuo (con un puntaje de 0% [sin confianza] a 100% [confianza completa]) al realizar 16 tareas de AVD (86). El puntaje general se presenta como un porcentaje promedio y describe si una persona cree que puede realizar tareas de AVD sin perder el equilibrio y volverse inestable (10). Una puntuación general más alta representa una mayor confianza en el equilibrio. La versión en español del cuestionario FES-I, ha sido validada recientemente y además se empleó en este estudio (87).

6.2.3 Miedo a caerse

El miedo a caer se evaluó utilizando la Escala Internacional de Eficacia de Caídas (FES-I) (34). El FES-I es un cuestionario corto (16 ítems) y fácil de administrar que mide el nivel de preocupación sobre las caídas durante las actividades sociales y físicas dentro y fuera del hogar, independientemente de si la persona realiza la actividad o no. La versión en español de la FES-I ha sido validada en la población postmenopáusica (35). Una puntuación más alta en la FES-I se correlaciona con un mayor miedo a caerse.

CAPITULO 2: PROBLEMA DE INVESTIGACIÓN

En la actualidad y sobre todo en el ámbito de la salud en personas mayores, las caídas son una de las principales causas de cese de la actividad física junto con un aumento del miedo a caerse y una disminución de la calidad de vida en esta población. La prevención de caídas supone un importante foco de atención de todos los profesionales de distintos campos. Esta población genera una disminución constante de la condición física debido sobre todo a un déficit muscular y la pérdida de confianza en sus AVD. Los persistentes cambios en los conceptos de salud en población mayor, provoca que la esta población cada vez quiera envejecer con unos hábitos de vida más saludables, provocando una calidad de vida mejor que en antaño. Por ello los nuevos conceptos de salud, provocan que esta población cada vez quiera mejorar su calidad de vida y que el aumento de la longevidad haya aumentado y con ello el estado de salud en estas edades, generando cada vez un mayor bienestar y una mejora de la salud en la denominada tercera edad.

Las caídas provocan en la actualidad unos costes económicos para la sanidad, además de los problemas que presentan en la población mayor como fracturas, problemas psicológicos y el miedo a realizar actividad física debido a que puedan generar una caída nuevamente. Sin embargo, con intervenciones adecuadas en esta población se ha demostrado que de manera preventiva se puede disminuir el número de caídas y el riesgo de caerse nuevamente. Estas intervenciones basadas en ejercicios de equilibrio, fuerza, inestabilidad, resistencia y ejercicios combinados mejoran estos problemas en la población mayor, además de obtener mejoras en la calidad de vida y la condición física, mejorando así las AVD en las personas mayores.

En el caso de las intervenciones más adecuadas para la población mayor y ya investigadas en población joven, encontramos los ejercicios HIIT, siendo estos un tipo de entrenamiento con una duración menor a los entrenamientos habituales y mostrando resultados similares a los entrenamientos continuos y una mayor satisfacción. En el caso de la población mayor, la seguridad de un programa de entrenamiento HIIT es un tema de gran importancia, especialmente en población de resto, pero ya son varios los estudios que han demostrado que los entrenamientos HIIT son seguros y bien tolerados por la población mayor. Además en el ámbito de la seguridad, uno de los nuevos tipos de ejercicios HIIT es el entrenamiento de suspensión. En esta actividad, la intensidad del ejercicio puede variar según la posición del cuerpo y los efectos de la gravedad, y el peso corporal actúa como resistencia, provocando una seguridad mayor a la hora de realizar los entrenamientos en la población mayor.

Basándonos en estas observaciones nos parece oportuno estudiar la prevención de las caídas, la mejora de la condición física y el aumento del estado de salud en personas mayores de 60 años tras un entrenamiento HIIT. Por otro lado, consideramos adecuado el análisis también de los datos con una intervención continua (MIIT) y comprobar las posibilidades de mejora que presenta este tipo de entrenamiento.

CAPÍTULO 3: HIPÓTESIS Y OBJETIVOS

Hipótesis

Un programa de entrenamiento en suspensión por intervalos de alta intensidad (HIIT) de 12 semanas de duración, en comparación con un programa de entrenamiento por intervalos a intensidad moderada (MIIT), disminuye el riesgo de caídas y mejora el estado de salud, la condición física y la calidad de vida en mayor medida que un grupo que no realice ningún tipo de ejercicio en personas mayores de 60 años.

Objetivos

Objetivo principal: El objetivo principal del presente estudio aleatorizado controlado con ciego simple es analizar los efectos de un programa de entrenamiento en suspensión por intervalos de alta intensidad (HIIT) sobre el riesgo de caídas, la condición física y la salud física y mental en personas mayores de 60 años.

Objetivos secundarios: Analizar, en personas mayores de 60 años, los efectos y las posibles diferencias entre los tres grupos (HIIT, MIIT y CONTROL) tras el período de intervención respecto a las siguientes variables:

- Estudio de la marcha, equilibrio dinámico, fuerza muscular y miedo a caerse.
- Composición corporal (masa muscular y grasa, índice de masa corporal e índice cintura cadera)
- Calidad de vida y valoración funcional.
- Fuerza de agarre y miedo a caerse.

CAPÍTULO 4: MARCO TEÓRICO

Las caídas en es uno de los principales problemas en la población mayor, generando dichas caídas fracturas de caderas y lesiones no intenciones, que generan unos costes para la sanidad pública y que pueden ser contrarrestados con la práctica de ejercicio físico correcto.

Las intervenciones correctas, el tiempo de duración, las horas semanales, el tipo de ejercicio adecuado, la adherencia a esta población genera un reto a todos los profesionales que atienden a la población mayor desde un punto de vista multifactorial.

Para poder mejorar el estado de salud, la condición física y el riesgo de caídas, es necesario analizar los cambios que provoca un entrenamiento específico en los sujetos mayores de 60 años con una intervención adecuada. Ya existían varios estudios de fuerza, equilibrio que demostraron mejoras en el riesgo de caídas en la población mayor. Por otro lado, el entrenamiento en suspensión es un campo más desconocido, aunque si el entrenamiento de alta intensidad por intervalos ha sido ampliamente usado en población mayor.

Para el desarrollo de esta tesis doctoral se han realizado 2 estudios, presentados a revistas de impacto, en el cual se intenta solventar los planteamientos objeto de esta tesis. Los estudios son analizados previamente y presentados en el formato original a las revistas que fueron enviadas

LISTA DE ESTUDIOS

La siguiente memoria de tesis está compuesta por los siguientes estudios:

ESTUDIO I

JOSÉ DANIEL JIMÉNEZ-GARCÍA, FIDEL HITA-CONTRERAS, MANUEL DE LA TORRE-CRUZ, RAQUEL FABREGAS-CUADROS, AGUSTÍN AIBAR-ALMAZAN, DAVID CRUZ-DIAZ, ANTONIO MARTÍNEZ-AMAT.

HIGH-INTENSITY INTERVAL TRAINING USING SUSPENSION TRAINING LOWER BODY EXERCISES IMPROVES THE RISK OF FALLS IN HEALTHY OLDER ADULTS

The Journal of Aging and Physical Activity: ACEPTADO

ESTUDIO II

JOSÉ DANIEL JIMÉNEZ-GARCÍA, ANTONIO MARTÍNEZ-AMAT, MANUEL DE LA TORRE-CRUZ, RAQUEL FABREGAS-CUADROS, DAVID CRUZ-DIAZ, AGUSTÍN AIBAR-ALMAZAN, ACHALANDABASO-OCHOA, ALEXANDER, FIDEL HITA-CONTRERAS.

SUSPENSION TRAINING HIIT IMPROVES GAIT SPEED, STRENGTH AND QUALITY OF LIFE IN OLDER ADULTS

International Journal of Sport Medicine: ACEPTADO

CAPÍTULO 5: MATERIAL Y MÉTODOS

Todos los estudios que componen la presente tesis fueron aprobados por el Comité de Ética de la Universidad de Jaén con Referencia: DIC.17/5.TES.

El diseño de la presente tesis se describe a continuación. Las valoraciones realizadas en cada uno de los estudios, así como la metodología estadística se encuentran descritos en los artículos tal cual han sido realizados.

Sujetos:
A todos los sujetos se les explicó por escrito y verbalmente en qué consistía el experimento y firmaron un consentimiento informado, accediendo a participar en él de manera libre y voluntaria.

Ochenta y dos sujetos cumplieron con los criterios de inclusión y exclusión y fueron randomizados en 3 grupos (Grupo HIIT n=28, Grupo MIIT n=27 y Grupo CONTROL n= 27).

Intervención:
La herramienta de entrenamiento en suspensión consta de dos correas y dos asas, que requieren un agarre continuo. El régimen de ejercicio presentado aquí se desarrolló utilizando el TRX (TRX; Fitness Anywhere LLC, San Francisco, California, EE. UU.). Los participantes asignados al MIIT GROUP y al HIIT GROUP recibieron dos sesiones por semana de TRX durante doce semanas. Cada sesión se dividió en tres períodos: calentamiento (10 minutos), actividad principal de sentadilla con el sistema en suspensión dividido en cuatro intervalos de cuatro minutos a una intensidad del 90-95% de la frecuencia cardíaca máxima seguida de intervalos de descanso activo de tres minutos al 50-70% (25 minutos) y un período de enfriamiento (10 minutos). La HR máxima se obtuvo siguiendo las instrucciones de Elligsen et al., (2017) [9]. El grupo MIIT y el grupo HIIT siguieron el mismo protocolo, pero utilizando intensidades más bajas en el grupo MIIT: la actividad principal de sentadilla con TRX utilizando el 70% de la FC máxima, y los intervalos de descanso activos utilizando el 50-55% de la FC máxima. Un monitor de HR (V800, Polar Electro, Kempele, Finlandia) controla individualmente la intensidad del entrenamiento. Para garantizar que la HR de los participantes se mantuviera en el rango determinado según la edad de cada uno y el grupo asignado, la intensidad se adaptó

individualmente a la HR en esfuerzos moderados o vigorosos. Las sesiones de entrenamiento fueron controladas por un licenciado en ciencias de la actividad física y el deporte. Cada participante recibió una cinta de video con las ejecuciones correctas de los ejercicios, lo que garantiza la coherencia de la capacitación y es útil como recurso. Las sesiones de HIIT se llevaron a cabo el martes y el jueves, y las sesiones de MIIT se llevaron a cabo el lunes y el miércoles, siempre al mismo tiempo (10: 00-11: 00 a.m.), lo que significa un descanso de 24 horas entre sesiones. Los participantes se excluyeron si se perdieron más de cinco sesiones durante la intervención de doce semanas. Si surgieron lesiones u otros efectos en los participantes durante la intervención, se recolectaron.

Estudio 1: HIGH-INTENSITY INTERVAL TRAINING USING SUSPENSION TRAINING LOWER BODY EXERCISES IMPROVES THE RISK OF FALLS IN HEALTHY OLDER ADULTS

The objective of this study was to compare the effects of high-intensity interval training (HIIT) and moderate-intensity interval training (MIIT) programs, both with a suspension training system, on several fall risk factors in healthy older adults.

Estudio 2: SUSPENSION TRAINING HIIT IMPROVES GAIT SPEED, STRENGTH AND QUALITY OF LIFE IN OLDER ADULTS

This study aimed to evaluate the effects of a twelve-week high-intensity interval exercise (HIIT) training program involving suspension exercises (TRX) on the muscle strength, body composition, gait speed, and quality of life of older adults.

Estudio 1	**HIGH-INTENSITY INTERVAL TRAINING USING SUSPENSION TRAINING LOWER BODY EXERCISES IMPROVES THE RISK OF FALLS IN HEALTHY OLDER ADULTS**
Diseño	RCT
Sujetos	73 sujetos superan los criterios inclusión y exclusión y finalizan el proceso de intervención y medición. -Grupo Control (n=23) -Grupo MIIT (n=24) -Grupo HIIT (n=26)
Intervención	-Grupo Control: Mantuvo sus hábitos normales de actividad física durante 12 semanas. -Grupo HIIT: Entrenamiento en suspensión (TRX) de sentadillas (4 intervalos de 4 minutos a intensidad 90-95% FCMax con recuperación activa de 3 minutos entre series al 50-70% FCMax). -Grupo MIIT: Entrenamiento en suspensión (TRX) de sentadillas (4 intervalos de 4 minutos a intensidad 70% FCMax con recuperación activa de 3 minutos entre series al 50-55% FCMax).
Variables	-Equilibrio dinámico -Análisis de la marcha -Confianza de equilibrio y Miedo a caerse
Método	- Se realizaron las mediciones de las variables en la Semana 0 de la intervención, con los 3 grupos. Al finalizar la intervención los grupos HIIT y MIIT, justo dos semanas después se volvieron a realizar las mediciones de todas las variables en los 3 grupos que participaron en el estudio.

Estudio 2	**SUSPENSION TRAINING HIIT IMPROVES GAIT SPEED, STRENGTH AND QUALITY OF LIFE IN OLDER ADULTS**
Diseño	RCT
Sujetos	73 sujetos superan los criterios inclusión y exclusión y finalizan el proceso de intervención y medición. -Grupo Control (n=23) -Grupo MIIT (n=24) -Grupo HIIT (n=26)
Intervención	-Grupo Control: Mantuvo sus hábitos normales de actividad física durante 12 semanas. -Grupo HIIT: Entrenamiento en suspensión (TRX) de sentadillas (4 intervalos de 4 minutos a intensidad 90-95% FCMax con recuperación activa de 3 minutos entre series al 50-70% FCMax). -Grupo MIIT: Entrenamiento en suspensión (TRX) de sentadillas (4 intervalos de 4 minutos a intensidad 70% FCMax con recuperación activa de 3 minutos entre series al 50-55% FCMax).
Variables	-Antropometría y Composición Corporal -Velocidad de la marcha -Fuerza de agarre -Calidad de vida
Método	- Se realizaron las mediciones de las variables en la Semana 0 de la intervención, con los 3 grupos. Al finalizar la intervención los grupos HIIT y MIIT, justo dos semanas después se volvieron a realizar las mediciones de todas las variables en los 3 grupos que participaron en el estudio.

CAPITULO 6: RESULTADOS Y DISCUSIÓN

Material y Métodos específicos, así como los resultados y la discusión de la presente tesis se exponen en los estudios tal cual han enviados y aceptados en forrmato artículo a las diferentes publicaciones.

Estudio 1

HIGH-INTENSITY INTERVAL TRAINING USING SUSPENSION TRAINING LOWER BODY EXERCISES IMPROVES THE RISK OF FALLS IN HEALTHY OLDER ADULTS

Note: This article will be published in a forthcoming issue of the *Journal of Aging and Physical Activity*. This article appears here in its accepted, peer-reviewed form; it has not been copy edited, proofed, or formatted by the publisher.

Section: Original Research

Article Title: High-Intensity Interval Training Using TRX Lower-Body Exercises Improve the Risk of Falls in Healthy Older People

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Running Head: High-Intensity Interval Training in older people

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High-intensity interval training using TRX lower-body exercises improve the risk of falls in healthy older people

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Running title: High-Intensity Interval Training in older people.

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Abstract

The objective of this study was to compare the effects of high-intensity interval training (HIIT) and moderate intensity interval training (MIIT) programs, both with a suspension training system, on several fall risk factors in healthy older adults. A total of 82 participants (68.49 ± 5.18 years) were randomized to HIIT (n=28), MIIT (n = 27), or control (n = 27) groups. Balance confidence (Activities-specific Balance Confidence Scale), fear of falling (Falls Efficacy Scale International), dynamic balance (Timed Up and Go Test) and gait analysis (OptoGait optical detection system) were assessed. Statistical analysis showed improvements after the intervention in HIIT group compared with MIIT and control group regarding the fear of falling ($p < .05$ and $< .01$ respectively), gait (both $p < .05$), and dynamic balance ($p < .05$ and $< .01$ respectively), while both HIIT and MIIT improved balance confidence compared to group control ($p < .01$ and $p < .05$ respectively). We can conclude that HIIT has significant beneficial effects of fall risk in older adults.

Key words: HIIT; TRX; Risk of falls; Older adults.

Introduction

Worldwide, the number of people over 60 is growing faster than any other age groups (WHO, 2007). Aging is generally associated with, neuromuscular impairment and gait and balance disorders, loss of mobility and an increased rate of falls and fractures (Muhlbeg & Sieber, 2004).

Unintentional injuries are the fifth leading cause of death in older adults (American Geriatrics Society and British Geriatrics Society, 2011). Approximately 20% of accidental falls require medical attention and 5% lead to a fracture or other serious injuries (Kannus et al., 2005). From a social point of view, falling generates psychological problems such as fear of falling, depression, and apprehension about physical activity (American Geriatrics Society & British Geriatrics Society, 2011; World Health Organization, 2007). Some of its negative results include functional deterioration and loss of confidence (American Geriatrics Society and British Geriatrics Society, 2011). All this generates health costs that can be preventable (Kumar et al., 2014) with appropriate interventions and can help attenuate the negative impacts of falls in older adult people at risk (Gillespie et al., 2012).

There are several risk factors for falls, which can be classified as either extrinsic or intrinsic. Three of the most common intrinsic risk factors for falls are muscle weakness, balance deficit, and gait instability (American Geriatrics Society and British Geriatrics Society, 2011; Granachet et al., 2011). In recent years, numerous randomized controlled trials on risk factors for falls have been published (Blank et al., Gillespie et al., 2012; Tinetti, & Kumar, 2010). Several studies have revealed a relationship between low speed and its relationship with falls in the older adult (Chang, Chen, & Chou; 2016, Viccaro, Perera, & Studenski; 2011). It has been show that some exercise programs, when properly structured, planned, and repeated, can modify these intrinsic risk factors (Nemoto et al., 2007).

One of the main barriers to the habitual practice of physical exercise in adults is "the lack of time" (Stutts, 2002). With this in mind, high-intensity interval training (HIIT) was developed with low-volume exercises. Furthermore, HIIT has been described to be perceived as a more satisfactory activity than continuous exercise of moderate intensity (Bartlett et al., 2011). Safety in a HIIT program is of paramount importance, especially in at-risk populations, but several studies have shown that HIIT training is safe and well tolerated by healthy participants in different populations (Kessler, Sisson, & Short, 2012) as well as by patients with some clinical conditions such as heart disease (Rognmo et al., 2012). García-Pinillos et al. (2017) studied the effects of HIIT on physical performance in healthy older adults, but to the best of our knowledge there are no studies focused on fall risk factors such as the fear of falling, dynamic balance or gait speed in this population.

We hypothesized that a twelve-week high-intensity interval training program (HIIT) with a suspension training system (TRX) would provide several benefits over a moderate intensity interval training (MIIT) and over the results of a group that does not perform any type of exercise. Among such benefits we included a decrease in the risk of falls and improvements in fear of falling, dynamic balance, and gait speed for people 60 and older. The main objective of this randomized controlled trial was to analyze the effects of a HIIT vs. MIIT, both using TRX, on fall risk factors such as balance confidence, fear of falling, dynamic balance and gait in healthy older people.

Material and Method

Experimental approach to the problem

The present study analyzed the effects of a TRX-based HIIT and MIIT programs on balance confidence, fear of falling, dynamic balance and gait in healthy older people. In order to achieve these objectives 73 older adults (68.49 ± 5.18 years, 76.7% women) were assessed.

Study design and participants

This is a randomized controlled clinical trial (RCT) which is part of a research project that analyzed the effects of two different TRX training programs (HIIT and MIIT) on different physical and psychological health indicators in community-dwelling older adults ,registered at clinicaltrials.gov a NCT03404830 (https://clinicaltrials.gov/ct2/show/NCT03404830), so there may be some overlap with respect to participants and general methodology.

The recruitment of participants was carried out through the sports service of the Town Hall of "xxxxxx (xxxxxx, xxxxx)" and using its municipal records, local media and social networks. From a total of 90 persons who were initially contacted and screened, 82 met the eligibility criteria and accepted to be enrolled. Participants included in the study were randomly assigned to a high-intensity interval training group (HIIT group), to a moderate intensity interval training (MIIT group), or to a control group in a 1:1:1 ratio using a computer-generated table of numbers. Assignments were kept at a locked location in a sealed, opaque envelope, to be later opened by an independent part not involved in subject selection, evaluation of results, or treatment. A total of 28 people were assigned to the HIIT group, 27 to the MIIT group, and 27 to the control group. These numbers were later reduced to 26 for the HIIT group, 24 for the MIIT group, and 23 for the control group for various reasons, showed in figure 1. In order to participate in the study, participants were required to be over 60 years old and able to understand the instructions, programs, and protocols of this project. An informed written consent was obtained from each participant before enrollment. Exclusion criteria were any condition (i.e. cardiovascular or neuromuscular disease) that contraindicated the exercise program performance, diseases that could alter balance and functional activity (such as auditory or vestibular alterations), central or peripheral neurological disorders, serious psychiatric or somatic diseases or were already included in other training program. Before the beginning of the study, all participants signed an informed consent form after a detailed description of the procedures. This study was approved by the local Human Ethics Committee and was conducted in accordance with the Declaration of Helsinki, good clinical practices, and applicable laws and regulations.

Study variables

All variables were measured before training (week 0) and just after the training period (week 12). Demographic and clinical data such as age, weight, height, physical activity time (hours per week) and the number of falls in the previous year were collected. Participants were classified as physically active if they regularly. Anthropometric data were collected by a well-trained physician. A 100g–130 kg precision digital weight scale (Tefal) and a T201-T4 Asimed adult height scale were employed for weight and height assessment. Body mass index (BMI) was calculated by dividing the participant's weight (kg) by her height squared (m^2).

Balance confidence and fear of falling

The Activities-specific Balance Confidence Scale (ABC) was used to assess balance confidence (Powel & Myers, 1995). This is a valid and reliable measure to assess balance confidence in community-dwelling older adults (Moore et al., 2011). The ABC consists of 16 questions that inquire about an individual's confidence (scored from 0% [no confidence] to 100% [complete confidence]) while performing 16 ADL tasks (Moore et al., 2011). The overall score is presented as a mean percentage and describes whether an individual believes he or she is able to perform ADL tasks without losing balance and becoming unsteady (Jørstad et al., 2005). Higher overall score represents greater balance confidence. The Spanish version of the FES-I, which has been recently validated, was employed in this study (Montilla-Ibáñez et al., 2017).

Fear of falling was assessed using the Falls Efficacy Scale International (FES-I) (Yardley et al., 2005). The FES-I is a short (16 items) and easy-to-administer questionnaire that measures the level of concern about falling during social and physical activities inside and outside the home, regardless of whether or not the person actually performs the activity. The Spanish version of the FES-I has been validated in the postmenopausal population (Lomas-Vega et al., 2012). A higher score in the FES-I correlates with a greater FoF.

Dynamic balance

The Timed Up and Go Test (TUG) is a simple, valid, and reliable method to assess functional mobility and dynamic balance, and it has already been used in older adult women (Pisciottano et al., 2014). It is based on every day activities and requires standing from a chair, walking three meters, turning around, and sitting down again (Podsiadlo & Richardson, 1991). The time required by the subject to complete this task is recorded. This has been reported to be a useful tool for identifying community-dwelling adults who are at risk for falls (Okumiya et al., 1998).

Gait analysis

The OptoGait gait analysis system (Microgate Italy, Bolzano-Bozen, Italy), a device consisting of an opto-electrical detection system, was employed for gait analysis. The transmitter bar has 96 light-emitting diodes (LEDs) that communicate in the infrared spectrum. The receiver bar, which is positioned opposite it, has the same number of LEDs. The transmitter and receiver bars of the OptoGait were installed on both sides of a treadmill. Using a data capture rate of 1,000 transmissions/receptions per second, activities such as running, jumping, or the time spent on the ground or in the air can be accurately measured. From these basic data, the software analyzes the data measured in real time in a series of movements. The data collected by the OptoGait uses the differences in gait variables between the left and right legs: the smaller the difference, the greater the stability and balancing ability.

The OptoGait bars were assembled on both sides of a treadmill. The width of the step is the distance between two successive steps (between two X's). To assess the gait analysis, the "Treadmill Walking 3 mph or 5 km/h" test was used, which involves walking for 30 seconds on the walking belt, while gait parameters were collected by the photocell system at a constant speed of 3.5 km/h both in the walking belt and in the computer system. Two familiarization and five experimental trials with a rest interval of 1minute between trials were performed. Gait parameters were: Step length (cm): distance between the first contact of one foot and the first contact of the opposite. Double support (s): period of time when both feet touch the ground. Step time (s): time between the first contact of one foot and the first contact of the opposite foot. Stride length (cm): distance between the tip of two subsequent footprints of the same foot or the distance between the heels of two subsequent footprints of the same foot. Gait speed (m/s) and distance (cm) covered during the test.

Training programs

Participants assigned to the MIIT and HIIT groups performed lower-body exercises with a TRX, for four weeks (twice a week) before the beginning of the intervention, to become familiar with this type of training. Participants in the control group attended two 90-minute health education classes focused on health promotion during the study period. The instructors provided participants with information regarding exercise and healthy diets, although no specific information or recommendations regarding cognitive health were given. The research staff made additional contact with participants during the study period via telephone to promote adherence to the education programme and retention of information.

Subjects allocated to both HIIT and MIIT groups received two sessions per week of TRX for twelve weeks. In the HIIT group, each session was divided into three periods: warm-up (10 minutes), main squat activity with the system in suspension divided into four four-minute intervals at an intensity of 90-95% of the maximum heart rate (HR), followed by active rest intervals of three minutes at 50-70% of the maximum HR (25 minutes), and a cool-down period (10 minutes). Maximum HR was calculated according to Elligsen et al., (2017). In the MIIT group, the same protocol as the HIIT group was followed, but with lower intensities: 70% of the maximum HR for the main squat activity with TRX, and 50-55% of the maximum HR for the active rest intervals. The training intensity was individually controlled by an HR monitor (V800, Polar Electro, Kempele, Finland). The intensity was individually tailored to HR at moderate or vigorous efforts, ensuring that their HR was kept in the range determined according to each participant's age and their assigned group. The training sessions were directed by a well-trained sports instructor. As a participant resource, and to ensure the consistency of the training, a videotape with the correct executions of the exercises was provided, and instructors were supervised by physical therapists who supported each class. The sessions were held at the same time (10:00-11:00 a.m.) and with a 24h-rest between sessions, on Tuesday and Thursday (HIIT) and Monday and Wednesday (MIIT). Participants were excluded if more than five sessions were lost during the twelve-week intervention. During the intervention, injuries or other effects reported by the participants were collected.

Statistical analyses

Data were analyzed using SPSS v.21.0 for Windows (SPSS Inc., Chicago, USA) and the level of statistical significance stood at $p < .05$. Descriptive statistics are shown as means and standard deviations. The chi-squared test was used to compare sociodemographic variables between groups. The analysis of variance of a single factor was used to verify the non-existence of statistically significant differences in the pre-intervention measures. Likewise, a 3x2 mixed covariance analysis was used, considering as intergroup variable the type of intervention received (group to which the participant was assigned) and as the intrasubject variable the measurement time (pre- and post-intervention) for each of the dependent variables (ABC, FES-I, TUG, and gait speed). The covariate considered was the BMI of the participants. The analysis of possible interactions was carried out by analysis of variance and *t* tests for repeated measures. Finally, the magnitudes (effect size) of the differences between values were interpreted using Cohen's *d* statistic (Cohen, 1988). An effect size <0.2 reflects a negligible difference, ≥ 0.2 but ≤ 0.5 a small difference, ≥ 0.5 but ≤ 0.8 a moderate difference, and ≥ 0.8 a large difference.

Results

Participants showed high adherence to the exercise training programs, completing at least 83 % of the sessions. No injuries or adverse effects were observed during the intervention.

Baseline measures

There were no differences between groups in the distribution of men and women, χ2 (2) = 5.70, p = .06, as well as in the participants' reports of having suffered a fall in the last twelve months, χ2 (2) = 4.59, p > .05, depending on the condition to which the participant was assigned. In the examination of anthropometric measurements, statistically significant differences were observed in the variable body mass index, F (2, 70) = 4.58, p = .01. This last factor was used as a covariate in subsequent analyses. No statistically significant differences were observed in any of the dependent variables examined in the baseline or pre-intervention measurements, depending on the group to which the participant was assigned. More information about participants is shown in Table 1.

Changes from baseline

Balance confidence and fear of falling

A 3x2 ANOVA was performed using as a dependent variable the score obtained in the post-treatment ABC test. This revealed a main effect of the intervention group variable, F (2,

69) = 7.13, $p = .002$, $\eta 2 = .17$, as well as a statistically significant interaction of group x measurement time, F (2, 69) = 4.45, $p = .04$, $\eta 2 = .10$. The measurement time variable, F (1, 69) = .22, $p > .05$, was not statistically significant. The detailed analysis of the interaction showed the existence of statistically significant differences between both measurement times

for the control group, t (22) = 3.18, $p = .004$, $d = .63$. Likewise, statistically significant differences were found in the post-treatment measures between the control group and the MIIT groups, t (45) = 2.16, $p = .04$, $d = .63$ and HIIT, t (47) = 3.98, $p < .001$, $d = 1.12$, respectively.

When the dependent variable was the post-intervention score obtained in the FES test, the ANOVA showed the existence of a main effect of the intervention group variable, F (2, 69) = 6.68, $p = .002$, $\eta 2 = .16$, as well as a statistically significant interaction of group x measurement time, F (2, 69) = 8.62, $p < .01$, $\eta 2 = .20$, statistically significant. The measurement time variable, F (1, 69) = .19, $p > .05$, was not statistically significant. The analysis of the interaction revealed the existence of statistically significant differences between both measurement times in the HIIT group, t (25) = 3.95, $p = .001$, $d = 1.06$. Likewise, statistically significant differences were found in the post-treatment measures between the HIIT group and the two remaining groups, t (48) = -3.30, $p = .002$, $d = .92$, for MIIT and t (47) = -4.58, $p <.001$, $d = 1.27$, in relation to the control group. Figure 2 shows more information about fear or falling.

Dynamic balance

Figure 3 shows significant changes in the Timed Up and Go Test (Tug Test). The analysis conducted for the variable time spent in the Timed Up-and-Go test showed the existence of a main effect of the intervention group variable, F (2, 69) = 4.32, $p = .017$, $\eta 2 = .11$, as well as a statistically significant interaction of group x measurement time, F (2, 69) = 3.75, $p = .028$, $\eta 2 = .10$. The measurement time variable, F (1, 69) = 3.90, $p = .052$, was not statistically significant. The detailed analysis of the interaction revealed the existence of statistically significant differences between both measurement times in the HIIT group, t (25) = 5.12, p = .001, d = 1.67. Likewise, statistically significant differences were found in the post-treatment measures between the HIIT group and the two remaining groups, t (48) = -4.99, p = .002, d = 1.41 for MIIT and, t (47) = -4.57, p < .001, d = 1.37, in relation to the control group.

Gait analysis

The results obtained in the OptoGait test are reported in Table 2. Several 3x2 covariance analyses were performed using as dependent variables the scores obtained for the parameters of the OptoGait test. The results, once the effects of the covariable body mass index were considered, revealed the existence of a statistically significant interaction of group x time for the dependent variable double support, F (2, 69) = 3.44, p = .038, $\eta 2$ = .09. The detailed analysis of the same showed statistically significant differences between the values reached in each and every group in the post-intervention measure, t (48) = 2.18, p = .034 (HIIT vs. MIIT), t (47) = -2.02, p = .049, d = 0.70, (HIIT vs. control) , d = -0.52, and, finally, t (45) = -3.75, p = .001 (MIIT vs. control), d = -1.09.

In turn, we obtained a statistically significant interaction of group x time for the dependent variable distance, F (2, 69) = 3.75, p = .028, $\eta 2$ = .10. The detailed analysis showed statistically significant differences between the pre- and post-intervention measures in the MIIT, t (23) = -2.35, p = .028 d = -0.56 and control groups, t (22) = -2.20, p = .039, d = -0.63. No main effect or statistically significant interaction was observed for the rest of the dependent variables.

Finally, the group variables did not reach a statistically significant main effect, F (2, 69) = 2.69, p> .05, nor did measurement time, F (1, 69) = .48, p > .05, when the dependent variable considered was the speed of displacement. The group x time interaction did not turn out to be statistically significant either, F (2, 69) = 1.69, p > .05.

Discussion

The aim of the present study was to analyze the effects of a HIIT vs. MIIT, both using TRX, on some important fall risk factors. Our analysis showed that balance confidence significant improved in both HIIT and MIIT programs, whereas compared with the other two groups, HIIT had better results in the fear of falling, gait analysis and dynamic balance.

To the date, very few studies with suspension training have been performed in older adults, aiming at body composition or muscle strength (Gaedtke & Morat, 2015; Campa, Silva & Toselli, 2018). Nevertheless, there is extensive clinical trial literature concerning fall risk prediction regarding several types on intervention. An example is the study by Ullman et al. (2010), in which they developed a five-week intervention of balance and mobility in older adults which showed significant improvements in predicting the risk of falls with the ABC questionnaire (Ullman et al., 2010). Similarly, compared with control group, in the present study significant improvements were observed in balance confidence assessed by the ABC total score in MIIT ($d = 0.63$) and especially in HIIT ($d = 1.12$) groups. Other studies conducted in older adults with different interventions such as Pilates (Cruz-Diaz et al., 2015) and tai chi (Mortavazi et al., 2018), showed significant improvements in the risk of falls as measured through the FES-I questionnaire, with data similar to the ours, where HIIT participants had significant improvements in the fear of falling compared to MIIT ($d = 0.92$) and control ($d = 1.27$) groups.

Concerning dynamic balance, it has been argued that numerous training sessions in a larger population reduce the execution time in the TUG test, with this being one of the greatest functional predictors for risk of falling (Kojima et al., 2015). Studies from Onambélé-Pearson et al. (2010) that most resembles our research is the one carried out by who compared high and low intensity continuous lower-body strength-training program, obtaining similar improvements in the execution of the TUG test. We could find large improvements ($d = 1.67$)

in dynamic balance after HIIT, similar to previous studied that have employed high intensity training (Globas et al., 2012) or HIIT (Garcia-Pinillos et al., 2017) in chronic stroke survivors and healthy older people respectively.

Cruz-Jentoft et al. (2010), also observed that the adult population suffered a decrease in muscle mass, which is associated with low levels of muscle strength and poor physical performance, measured using gait speed (< 80 cm/s) and the TUG test. In our study, gait analysis was performed through a photoelectric cells system and participants who performed HIIT showed improvements regarding distance and total double support but not in gait speed. At this respect, Globas et al. (2012) found improvements in gait velocity after high intensity aerobic exercise in chronic stroke survivors with residual hemiparetic gait, and Kim et al (Kim et al., 2017) is similar population yielded similar results to those of our study regarding the double support variable, which was significantly reduced in the post-training data of both studies.

Since the first studies were published, HIIT has been repeatedly shown as a strong predictor of functional performance (Knowles et al., 2015; Nemoto et al., 2007) in the older adult population. As a result, the most commonly used treatments for the older adult in the last three years have focused on training with cycloergometers, with differences concerning only the details of the work protocols (Bell et al., 2015; Bruseghini et al., 2015; Jabbour et al., 2017; Knowles et al., 2015; Maillard et al., 2016; Mandrup et al., 2017; Mejías-Peña et al., 2016). In contrast, our study contributes an innovative approach, with a pioneering use of HIIT training based on the load proposed by Ellingsen et al. (2017), which suggested four blocks of four minutes (90-95% max. HR), but with TRX for older adults such as the one described by Gaedtke & Morat (2015).

Improvements in fear of falling, dynamic balance, and gait provide a precise picture of the changes induced by the type of training conducted in this research. Our findings also support the different effects between HIIT and MIIT training types. We could observe that after the intervention period, HIIT participants showed a significant improvement compared with MIIT in the fear of falling (d = 0.92), as well as in the TUG test time (d = 1.41), with the mean post-intervention HIIT in our research being 6.82 s ± 0.87, unlike the results described by Onambelé, Breen & Stewart, (2010) which showed a post-intervention mean of 10.82 s ± 0.82.

In conclusion, the results of the present study showed that both interval training programs (HIIT and MIIT) have beneficial effects on several fall risk factors. More precisely, and compared with control group, both HIIT AND MIIT programs improved balance confidence, while HIIT participants obtained significantly better results that those of the other groups regarding the fear of falling, gait analysis and dynamic balance.

Conflict of Interest

The authors declare no conflicts of interest.

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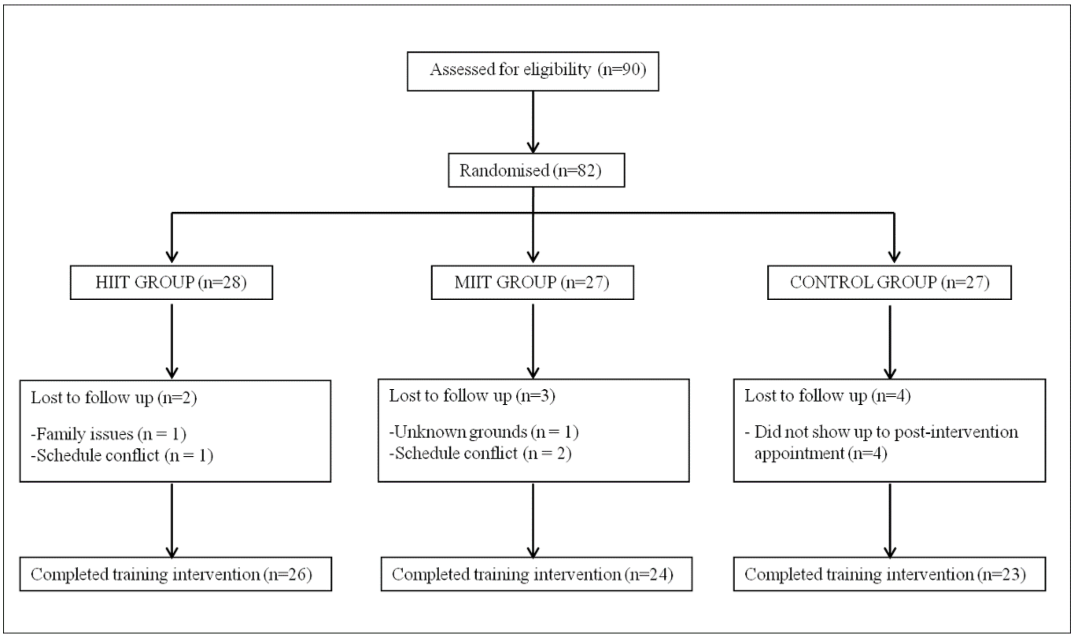

Figure 1: Flow chart of the study participants.

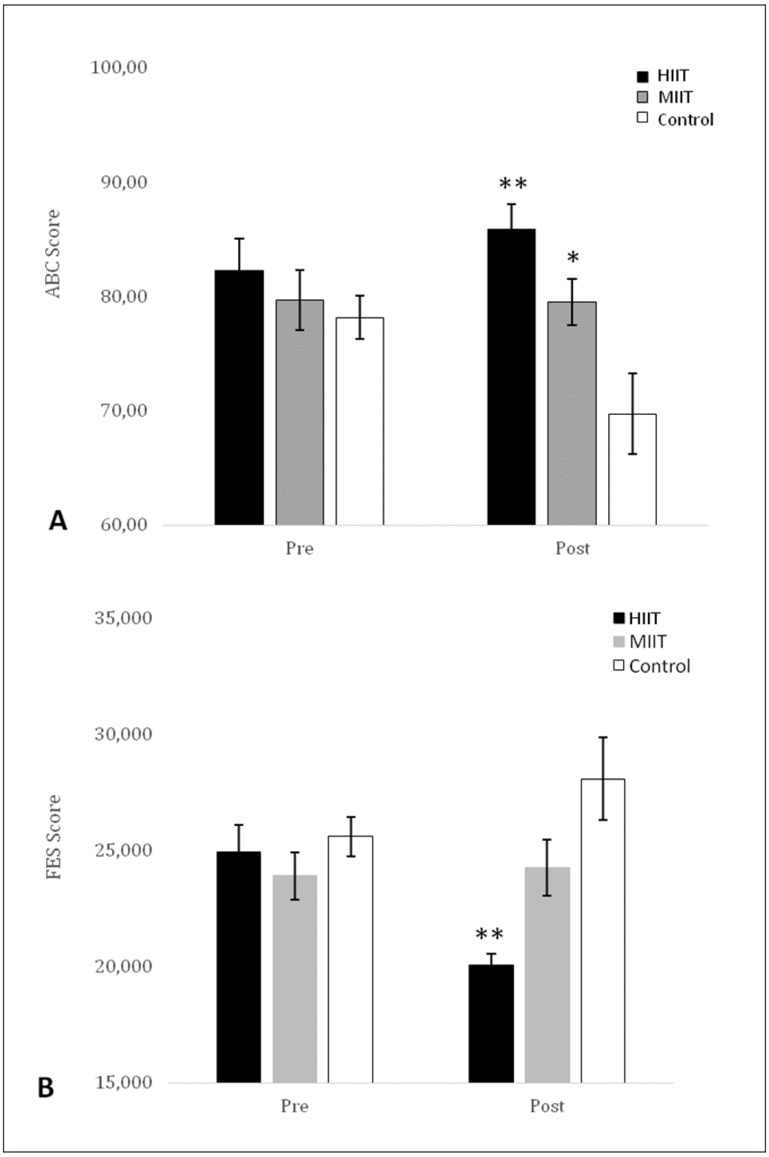

Figure 2: Pre- and post-intervention changes in balance confidence and the fear of falling. ABC = Activities-Specific Balance Sale; FES-I = Falls Efficacy Scale International; HIIT = High Intensity Interval Training; MIIT = Moderate Intensity Interval Training. (A): *p =0.04. ** p = <0.001. (B): **p = 0.001.

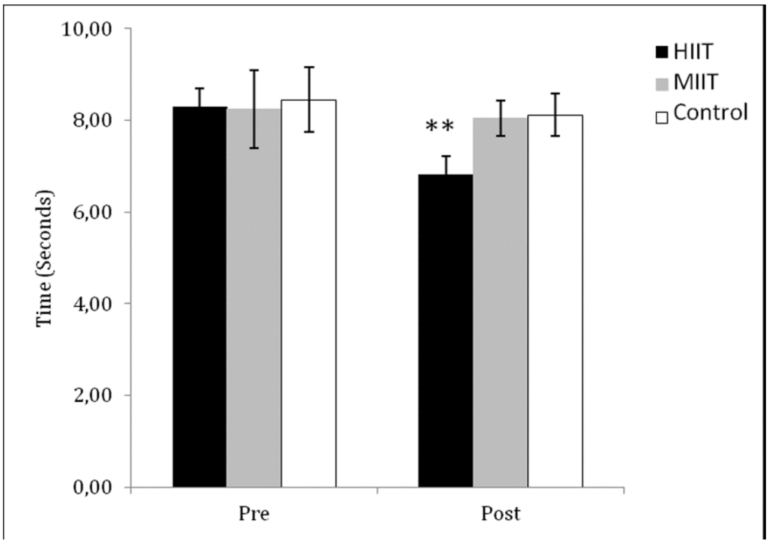

Figure 3: Pre- and post-intervention changes in dynamic balance assessed by the TUG Test. TUG Test = Timed Up and Go Test; HIIT = High Intensity Interval Training; MIIT = Moderate Intensity Interval Training. **p = 0.001.

Table 1: Subject characteristics.

	Total (n = 73)	HIIT (n = 26)	MIIT (n = 24)	Control (n = 23)	*F*(2, 70)	*p*
Age	68,49 (5,18)	68,23(2,97)	68,75(5,98)	68,52(6,33)	.06	> .05
Weight (kg)	76,51(12.15)	73,75(14,20)	76,48(12,09)	79,65(9.03)	1.46	> .05
Height (cm)	157,00(7,89)	155,65(7,60)	159,13(8,12)	156,3(7,85)	1.35	> .05
BMI	30,59(3,25)	29,48(3,69)	30,33(3,07)	32,13(2,30)	4.58	.01
Falls	0,56(0,87)	0,46(0,99)	0,46(0,72)	0,78(0,78)	1.10	> .05
PA time	1,70(0,54)	1,73(0,45)	1,75(0,53)	1,61(0,66)	.46	> .05
Gender (n, %)					$\chi^2(2)$	
Female	56 (76.7%)	24 (92.3%)	17 (70.8%)	15 (65.2%)	5.70	> .05
Male	17 (23.3%)	2 (7.7%)	7 (29.2%)	8 (34.8%)		

HIIT = High Intensity Interval Training Group; MIIT = Moderate Intensity Interval Training Group; BMI = Body Mass Index; PA time = physical activity time. Values are expressed as mean (standard deviation) and n (%).

“High-Intensity Interval Training Using TRX Lower-Body Exercises Improve the Risk of Falls in Healthy Older People” by Jiménez-García JD et al.
Journal of Aging and Physical Activity

Table 2: Average values and typical deviations (pre and post intervention), values of the contrast statistic, level of probability for the main effects and interactions, as well as size of the effect observed in the different parameters thrown by the Optogait technique.

	Control (n = 23)		MIIT (n = 24)		HIIT (n = 26)		Group	*p*	η^2	Time	*p*	η^2	Group x Time	*p*
	Pre	Post	Pre	Post	Pre	Post	*F*(2, 69)			*F*(1, 70)			*F*(2, 69)	
Step length (cm)	65.00(3.65)	66.48(5.28)	59.97(10.25)	62.25(10.14)	62.69(9.88)	60.81(10.10)	.97	.38	-	.03	.87	-	1.25	.29
Double support (s)	.27(.12)	.31(.11)	.27(.20)	.20(.09)	.25(.18)	.26(.08)	.56	.57	-	3.31	.07	-	3.44	**.038***
Step time (s)	.37(.09)	.45(.10)	.37(.13)	.40(.13)	.35(.13)	.43(.12)	.04	.96	-	1.39	.24	-	1.05	.36
Stride length (cm)	128.09(5.84)	137.22(14.68)	119.33(24.25)	126.71(20.96)	128.62(18.08)	121.69(19.78)	1.04	.36	-	.56	.46	-	3.02	.55
Gait speed (m/s)	1.29(.14)	1.29(.18)	1.30(.25)	1.17(.27)	1.29(.25)	1.32(.22)	1.00	.37	-	.32	.57	-	1.81	.17
Distance (cm)	4047.96(65.31)	4071.96(83.78)	3989.46(136.60)	4049.33(64.14)	4037.38(62.03)	4032.31(58.02)	3.42	**.037***	.09	.43	.51	-	3.75	**.028***

HIIT = High Intensity Interval Training Group; MIIT = Moderate Intensity Interval Training Group; T= Time. * p<0.05

ESTUDIO 2

Suspension training HIIT improves gait speed, strength and quality of life in older adults

Dear Prof.
Martínez-Amat,

Your manuscript entitled "Suspension training HIIT improves gait speed, strength and quality of life in older adults" has been successfully submitted for publication in the International Journal of Sports Medicine and will now go into the reviewing process.

Manuscript authors:

Jiménez-García, Jose Daniel; Martínez-Amat, Antonio; De la Torre-Cruz, MJ; Fábregas-Cuadros, Raquel; Cruz-Díaz, David; Aibar-Almazán, Agustín ; Achalandabaso-Ochoa, Alexander; Hita-Contreras, Fidel

The manuscript ID is IJSM-07-2018-7083-tt.R2.

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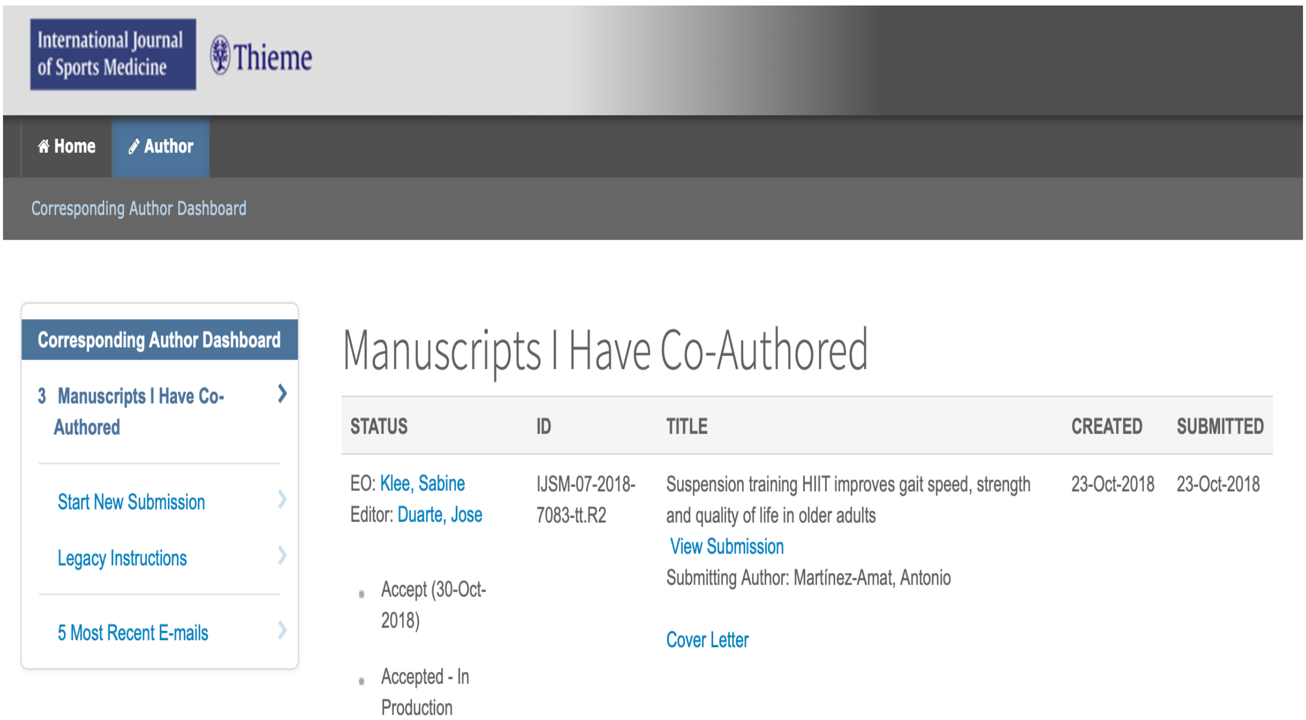

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Suspension training HIIT improves gait speed, strength and quality of life in older adults

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Manuscript ID	IJSM-07-2018-7083-tt.R2
Manuscript Type:	Training & Testing
Key word:	Older adults, HIIT, TRX, Gait Speed, Quality of Life, Handgrip Strength
Abstract:	This study aimed to evaluate the effects of a twelve-week high-intensity interval exercise (HIIT) training program involving suspension exercises (TRX) on the muscle strength, body composition, gait speed, and quality of life of older adults. A total of 82 older adults were randomly assigned to three groups: a HIIT group (n = 28), a continuous intensity training group (MIIT group, n = 27), or a control group (CG, n = 27). Compared to MIIT and CG, participants of the HIIT group showed significant post-intervention improvements in BMI (p = .002 and p < .001, respectively) and gait speed (p < .001 for both). Handgrip strength increase was also observed after HIIT (p = .002), but no differences were observed with MIIT and CG. Compared with MIIT and control groups, HIIT showed improvements in the SF-36 domains: general health (p < .001 for both) health changes (p < .001 for both), vitality (p = .002 and p = .001 respectively) and physical functioning (p = .036 and p < .001 respectively). Our results suggest that a HIIT training program with TRX have benefits in BMI, handgrip strength, gait speed, and quality of life in older adults.

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Suspension training HIIT improves gait speed, strength and quality of life in older adults

Abstract

This study aimed to evaluate the effects of a twelve-week high-intensity interval exercise (HIIT) training program involving suspension exercises (TRX) on the muscle strength, body composition, gait speed, and quality of life of older adults. A total of 82 older adults were randomly assigned to three groups: a HIIT group (n = 28), a continuous intensity training group (MIIT group, n = 27), or a control group (CG, n = 27). Compared to MIIT and CG, participants of the HIIT group showed significant post-intervention improvements in BMI ($p = .002$ and $p < .001$, respectively) and gait speed ($p < .001$ for both). Handgrip strength increase was also observed after HIIT ($p = .002$), but no differences were observed with MIIT and CG. Compared with MIIT and control groups, HIIT showed improvements in the SF-36 domains: general health ($p < .001$ for both) health changes ($p < .001$ for both), vitality ($p = .002$ and $p = .001$ respectively) and physical functioning ($p = .036$ and $p < .001$ respectively). Our results suggest that a HIIT training program with TRX have benefits in BMI, handgrip strength, gait speed, and quality of life in older adults.

KEYWORDS

Older adults – HIIT – TRX – Handgrip Strength – Gait Speed – Quality of Life

Introduction

In an increasingly aging population, the number of people over 65 is rising. In 2016, 18.7% of the Spanish population were over 65 years [24]. Worldwide, this amount is expected to increase over the fifth decade of the 21st century, with numbers reaching two billion people over 60 years old [26]. Aging is generally associated with a progressive deterioration of physical function and psychological health [31,24], as well as with a constant increase in the risk of disability, dependence [30], and comorbidity [40].

Aging process involves a reduction in the number and size of motor units and type-2 fibers, with a loss in muscle size of about 1% per year for people over 50 years of age [36]. These factors affect physical condition of older adults and induce the loss of muscle strength, which directly influences their degree of physical independence and health [52]. In this sense, grip strength and muscle strength have been shown to be more important than muscle mass in estimating mortality risk [48]. Previous studies have shown that a deficit in grip strength is associated with an increased risk of malnutrition and mental and physical deterioration [56], since these factors are relevant for the autonomy and quality of life of older adults [18,45].

Due to age, older people reduce their physical activity, increasing dependency. This can be prevented or treated by improving strength and several parameters of walking and balance through the practice of different types of exercises such as Pilates or proprioception training program [22,35]. In addition, physical exercise improves mobility, functional capacity, and therefore, personal autonomy [62]. With regard to body composition, the effects of exercising are conditioned by various aspects such as the characteristics of each person and the type of exercise they perform [27].

High-intensity interval training (HIIT) has attracted attention in recent years as an exercise option for both young and adult population. This type of exercise is characterized by brief and intermittent sessions of high-intensity activity alternated with periods of rest or low intensity. The number of studies looking into this type of training in the elderly population has increased lately [28,29]. It has recently been shown that postural control and risk of falls can improve after HIIT compared to the effects of a continuous exercise program in healthy and untrained young people [25], and also in patients with some type of pathology [6]. In the elderly, some randomized trials have studied the effects on cardiovascular and anthropometric outcomes after HIIT interventions [41,53].

Recent studies have described the benefits of a HIIT program on physical fitness and quality of life in healthy and diseased populations [1,43]. Nevertheless, a systematic review and meta-analysis published in 2018 concluded that there were no evidence supporting important differences in health-related quality of life in heart failure patients with reduced ejection [17]. Benefits in physical functioning have been also described after HIIT training in healthy older adults [15].

Suspension training has become increasingly popular as a training tool. [11]. In this activity the intensity of the exercise can be varied depending on the position of the body and the effects of gravity, with body weight acting as resistance. Suspension training can be individually adapted for each older adult according to its precondition, demands and preference [14], and it has been shown to have beneficial effects on muscle activation and balance [2,7]. To the best of our knowledge, this is the first randomized controlled trial to use HIIT with suspension training exercises in older adults.

In the light of the above considerations, the aim of the present study was to evaluate the effects of a twelve-week adapted HIIT program involving suspension exercises (TRX) on muscle strength, body composition, gait speed, and quality of life of older adults over

60 years, as well as to establish a comparison with a moderate intensity interval training (MIIT). Given the information mentioned above, we hypothesized that HIIT with a TRX suspension exercise system can be an efficient exercise choice and an effective training method for older adults.

Method

Design and Participants

This is a randomized controlled clinical trial (RCT) which is part of a research project that analyzed the effects of two different TRX suspension training programs (HIIT and MIIT) on different physical and psychological health indicators in community-dwelling older adults, registered at clinicaltrials.gov as NCT03404830 (https://clinicaltrials.gov/ct2/show/NCT03404830), so there may be some overlap with respect to participants and general methodology. The recruitment of participants was carried out through the sports service of the Town Hall of Xxxxxxx (Xxxxxx, Xxxxx) and participants were contacted using municipal records (e-mail, and telephone calls), local media and social networks. From a total of 90 persons who were initially contacted, and after medical screening by a certified physician, 82 (68.23 ± 2.97 years, 75.61% women) met the eligibility criteria and accepted to be enrolled.

In order to participate in the study, participants were required to be over 60 years old and able to understand the instructions, programs, and protocols of this project. An informed written consent was obtained from each participant before enrollment. Exclusion criteria were conditions that contraindicated the performance of physical tests, diseases that could alter balance and functional activity (such as auditory or vestibular alterations), psychiatric or neurological disorders, systemic diseases (i.e. diabetes mellitus, cancer or heart disease or skeletal conditions), or were already included in other training program. This study was approved by the local Human Ethics Committee (DIC.17/5.TES University of Jaen), according with the Declaration of Helsinki, good clinical practices, and applicable laws and regulations, and in accordance with the Ethical Standards in Sport and Exercise Science Research [19]. Informed consent was obtained from all participants, and the rights of the participants were protected.

Procedures

Measurements were recorded before training (pre-intervention) and just after the intervention period (post-intervention). Participants included in the study were randomly assigned to a high-intensity interval training group (HIIT group), to a moderate intensity interval training (MIIT group), or to a control group (CG) in a 1:1:1 ratio using a computer-generated table of numbers, each one of which had been previously assigned to one of the three groups (28 numbers per group). Assignments were kept at a locked location in a sealed, opaque envelope, to be later opened by an independent part not involved in subject selection, evaluation of results, or treatment. A total of 28 people were assigned to the HIIT group, 27 to the MIIT group and 27 to the CG. These numbers were later reduced to 26 for the HIIT group (68.23 ± 2.97 years, 92.3% women), 24 for the MIIT group (68.75 ± 5.98 years, 70.8% women), and 23 for the CG (68.52 ± 6.33 years, 65.2% women) for various reasons, showed in figure 1. Participants assigned to the HIIT and MIIT groups participated in a 12-week suspension training program, while those assigned to the CG maintained their daily lifestyle and received a series of guidelines to encourage physical activity, but were instructed to refrain from participating in any systematized exercise activity

Anthropometry

All anthropometric data were collected by a physician specifically trained according to a standardized protocol [32]. Height was recorded to the nearest 0.01 cm with a stadiometer. The participants wore light clothing and were barefoot when measured. Relaxed waist, hip, and calf circumferences were taken and rounded to the nearest 0.1 cm using a non-stretchable measuring tape. Body mass index (BMI) was calculated as body mass in kilograms divided by the square of height in meters.

Body Composition

Bioelectrical impedance analysis was used to measure body composition. Skeletal muscle mass (SMM) and percentage of body fat (PBF) were examined using the InBody 720 (Biospace Co., Ltd.; Seoul, Korea) bioelectrical impedance analyzer, with an operating frequency of 50 kHz at 800 μA. Participants stood upright with their arms abducted apart from their trunk and legs slightly spread.

Handgrip strength

Muscle strength, measured by an analogue handgrip dynamometer (TKK 5001, Grip-A, Takei, Tokyo, Japan) with a grip span of 4.5 cm, was employed for muscle strength [3]. Participants were asked to apply their maximum grip strength three times with both left and right hand, with 30s resting intervals between measurements. The maximal measured effort was regarded as their grip strength [31].

Gait speed

The Timed Up-and-Go test (TUG) is a simple, valid, and reliable method to assess functional mobility and balance [49], which has already been used in elderly women [51]. It is based on everyday activities and requires standing from a chair, walking three meters, turning around, and sitting down again [48]. The time required by the subject to complete this task is recorded. In addition, the time scored in the TUG test was converted to an estimate of gait speed using the formula [6 / (TUG time) * 1.62] [31].

Health-related quality of life

The generic 36-item Short-Form Health Survey (SF-36) is a valid and reliable instrument that is widely used to measure generic health-related quality of life [58]. It consists of nine scales or domains: physical functioning (ten items), role-physical (four items), bodily pain (two items), general health (five items), vitality (four items), social functioning (two items), role-emotional (three items), and mental health (five items). The SF-36 also provides two summary measures: a physical component summary (PCS) and a mental component summary (MCS). Total score ranges from 0 to 100, where 0 represents the worse quality of life and 100 represents the best quality of life. The Spanish version of the SF-36 was translated and validated in the Spanish population by Alonso et al. [4], and its reliability has been demonstrated in several age ranges, including that of the present study [59].

Suspension exercise training program

The suspension training tool consists of two straps and two handles, which require continuous grip. The exercise regimen presented here was developed using the TRX (TRX; Fitness Anywhere LLC, San Francisco, California, USA). Before the intervention, participants of the HIIT and MIIT groups performed a 4-week familiarization period (2 session/week with video demonstrations and 6 repetition practice trial). The main work was performed in squat position and strap was adjusted at mid length. Participants started in standing position, looking at the anchor point, grasping the handles with the whole hand, and with elbows bent at 90º. Participants squatted down to a knee angle of approximately 90°, and then extended the knee in one continuous movement to reach the starting position.

Participants assigned to the MIIT group and the HIIT group received two sessions per week of TRX for twelve weeks. In the HIIT group, each session was divided into three periods: warm-up (10 minutes), main squat activity with suspension system divided into four four-minute intervals at an intensity of 90-95% of the maximum HR followed by active rest intervals at an intensity of 90-95% of the maximum HR followed by active rest intervals of three minutes at 50-70% (25 minutes), and a cool-down period (10 minutes). In the MIIT group, participants followed the same protocol that HIIT group, but intensities were lower: 70% and 50% of the maximum HR for the main squat activity and the active rest intervals respectively. In order to assess maximum HR, we followed instructions provided by Elligsen et al. [12]. The intensity of exercise was controlled through a Polar V800 (Polar Electro, Oy, Kempele, Finland), thus ensuring that their heart rate (HR) was kept in the range determined according to each participant's age and assigned group. The intensity was individually adjusted to HR at moderate or vigorous efforts and maintained constant during the intervention. The training sessions were conducted and supervised by a well-trained sports instructor. Two physical therapists supporting each class ensured that instructors were doing correctly. HIIT sessions took place on Tuesday and Thursday, and MIIT sessions took place on Monday and Wednesday, always at the same time (10:00-11:00 a.m.), meaning this a 24h-rest between sessions. Participants were excluded if more than five sessions were lost during the twelve-week intervention. During the intervention, injuries and other effects reported by the participants were observed.

Statistical analyses

Data were analyzed with the statistical program SPSS v.21.0 for Windows (SPSS Inc., Chicago, USA) and the level of statistical significance stood at $p < .05$. Descriptive statistics are shown as means and standard deviations. The chi-square test was used to compare sociodemographic variables between groups. The analysis of variance of a single factor was used to verify the non-existence of statistically significant differences in the pre-intervention measures. When pre-test differences existed a univariate analysis of variance was used, considering post-intervention measures as a dependent variable and pre-intervention measures as a covariate. Likewise, the 3x2 mixed variance analysis was used, considering as the inter-group variable the type of intervention received (group to which the participant was assigned) and as the intra-subject variable the time of measurement (pre- and post-intervention) for each of the dependent variables (anthropometry, bioimpedance, handgrip strength, gait speed, and quality of life). The analysis of possible interactions was carried out by analysis of variance and *t* tests for repeated measures. Finally, the effect size of the differences between values was interpreted using Cohen's d statistic [9]. An effect size <0.2 reflects a negligible difference, ≥ 0.2 but ≤ 0.5 a small difference, ≥ 0.5 but ≤ 0.8 a moderate difference, and ≥ 0.8 a large difference.

Results

Subjects showed high adherence to the exercise training programs, participating in at least 83,33% of the sessions. As showed in Figure 1, a total of 9 participants were lost in the follow-up, 2 (HIIT group), 3 (MIIT group) and 4 (CG).

Anthropometry

There were statistically significant differences between groups concerning hip circumference measurements, $F(2, 70) = 11.17$, $p < .001$; and body mass index, $F(2, 70) = 4.19$, $p = .019$, prior to the intervention. Therefore, these two variables were employed as covariates in subsequent analysis. Pre- and post-intervention values are presented in table 1. After the intervention, only BMI showed significant differences between groups, $t(25) = 5.68$, $P < .001$. More specifically, post-intervention values were lower in the HIIT group compared with the MIIT group, $t(48) = -3.27$, $p = .002$; and CG, $t(47) = -5.86$, $p < .001$. Additionally, the values observed in the MIIT group were lower than those of the

CG, $t(45) = -2.70$, $p = .01$. No significant differences were observed for the other anthropometric variables.

Body composition

As for body composition analysis, pre- and post-intervention values are showed in table 1. The analysis did not reveal the existence of main effects or statistically significant interactions for the dependent variables body weight, SMM, and PBF.

Handgrip strength

When the values reached in the dynamometry test were the dependent variable, a main effect of the independent variable was obtained, $F(1, 70) = 6.42$, $p = .01$, $\eta 2 = .08$, as a statistically significant interaction of group x measurement time, $F(2, 70) = 4.48$, $p = .01$, $\eta 2 = .11$. Group, $F(2, 70) = .14$, $p = .872$, did not appear to be statistically significant. The detailed analysis of the interaction revealed the existence of statistically significant differences between both measurement times in the HIIT group, $t(25) = -3.39$, $p = .002$, $d = .41$. No other comparison reached statistical significance (Fig. 2).

Gait speed

When the dependent variable considered was the gait speed evaluated by the TUG test, a statistically significant main effect of the group variables was observed, $F(2, 70) = 65.45$, $p = .006$, $\eta 2 = .14$; as well as for time of measurement, $F(1, 70) = 12.79$, $p = .001$. In turn, the interaction of group x time was statistically significant, $F(2, 70) = 9.52$, $p <.001$, $\eta 2 = .21$. The detailed analysis of the interaction revealed the existence of statistically significant differences between both measurement times for the HIIT group, $t(25) = -4.81$, $p = .002$, $d = -1.51$. Also, in post-intervention measures gait speed differed significantly between the participants in groups HIIT and MIIT, $t(48) = 4.72$, $p <.001$, $d = 1.23$, as well as between groups HIIT and control, $t(48) = 4.64$, $p <.001$, $d = 1.27$ (Fig.3).

Health-related quality of life

Given the initial differences between groups, as well as their potential influence on the perception of quality of life associated with health, BMI was introduced as a covariate in the different analyzes, although, it was only statistically significant for the dependent variable PCS. In the analysis of the SF-36 dimensions (Table 2), statistically significant differences after the intervention were observed in the HIIT group regarding general health: t (25) = -3.02, p = .006, d = .64; health changes: t (25) = -2.89, p = .009, d = .76; and vitality: t (25) = -3.23, p = .003, d = .66. Participants of the HIIT group showed statistically higher values after the intervention compared to CG in general health: t (47) = 4.05, p <.001, d = 1.15; health changes: t (47) = 4.20, p <.001, d = 1.19 and vitality: t (47) = 3.49, p = .001, d = 1.00. Finally, statistical differences with MIIT were also found in the HIIT group regarding general health: t (48) = 5.16, p <.001, d = 1.47; health changes: t (48) = 3.84, p <.001, d = 1.08 and vitality: t (48) = 3.33, p = .002, d = .94.

Due to the existence of statistically significant differences between groups in physical functioning prior to the intervention, a unifactorial ANOVA was performed using baseline physical functioning score as covariate. The dependent variable was the post-intervention values in physical functioning. We found a statistically significant main effect of the covariate, F (1,68) = 8.04, p = .006, as well as of the independent variable group, F (2, 68) = 7. 64, p = .001, $\eta 2$ = .18. Significant differences were observed between CG and both MIIT group: t (45) = 2.14, p = .032, d = .59; and HIIT group: t (47) = 4.54, p <.001, d = 1.13. Statistically differences were also observed between HIIT and MIIT: t (48) = 2.15, p = .036, d = .57.

Finally, as for the SF-36 summary component scores (Table 2), the analysis of MCS showed a significant effect for BMI covariate, $F(1, 69)$ = 4.21, p = .044, $\eta 2$ = .06, as well as a significant main effect for the variable time, $F(1, 69)$ = 5.19, p = .026, $\eta 2$ = .07. In

PCS analysis, only a significant effect for group was observed, $F(2, 69) = 5.68$, $p = .005$, $\eta 2 = .14$. No other main effect or statistically significant interaction was obtained for the rest of the SF-36 dimensions (Table 2).

Discussion

The results of the present study highlight the benefits of an adapted HIIT program with TRX suspension training exercises on handgrip strength, gait speed, BMI and health-related quality of life in older adults over 60 years. No significant changes were found in body composition.

The number of articles focused on HIIT in older adults has increased in recent years. Regarding body composition and anthropometric parameters, a study by Garcia Pinillos et al. [15] found significant differences in body composition for older people (-2.15% body mass, -4.20% fat mass, +6.23% muscle mass) after a 12-week low-volume HIIT-based concurrent training programme. However Ramirez et al. [51], in a study with the same intensity of HIIT and the same duration of intervention did not find significant improvements in waist and hip circumference in adults with metabolic syndrome and Bartlett et al. [5], in a recent study involving elderly people over 64 years, described no significant improvement in fat percentage after ten weeks of HIIT intervention. On the other hand, very few studies have analyzed the effects of suspension training, especially in older adults, and thus a recent study performed on older women (aged 66.1 ± 4.7 years) showed that a 12-week suspension exercise training program led to significant decrease in percentage of fat mass, as well as in triceps, biceps and subscapular skinfolds [8]. The results of the present study indicated that a HIIT with suspension training had significant improvements in BMI, while in SMM and PBF decreased but these differences did not reach statistical significance.

Most of the studies on suspension training have focused on muscle activation [20,37]. In this respect, a recent systematic review concluded that suspension training increases muscle activation compared with traditional exercises, except for inverted row exercises, where no differences were observed for certain muscles such as biceps brachii, posterior deltoid and middle trapezius [2]. Handgrip strength has been strongly linked to lower limb muscle power, torsion and extension of the knee, and the transverse muscles of the calf [40]. Max et al. in a study carried out in Sanda athletes concluded that compared with traditional core strength training methods, suspension training can improve the explosive power of trunk extension and flexion muscles [33]. In our study, the HIIT group achieved significant improvements in handgrip strength after the intervention. Our results are in accordance with those found by Campa et al. [8], and we agree with them when they suggest that this may be considered to be a consequence of constantly having to grab the handles of the suspension training system. Similar increases in grip strength after a HIIT training period were highlighted by Onambelé et al. [47], when comparing their results with those of a control group and by García-Pinillos et al. [15], which showed a significant increase in grip strength after HIIT. In addition, Nemoto et al. [42] reported an increase in lower body strength, increasing knee extension in the HIIT group by 13% in comparison with the MIIT and control groups. All these studies were performed in populations over 60 years of age.

Adult population experiences a decrease in muscle mass, which is associated with low levels of muscle strength and poor physical performance [10]. Emara et al. [13] described that, compared to treadmill-training, a three-month body-weight suspension training was more effective in improving walking and locomotor capabilities in children with spastic diplegia, and Gaedtke et al. [14] found, after 12 weeks of TRX-suspension training in older adults, self-rated improvements in strength, gait, and balance. In our study, we used gait speed assessed with the TUG test to determine physical performance, and we observed a post-treatment increase in the HIIT group (18.03%), with a large effect size (d = 1.51). This is in accordance with those of other studies involving HIIT treatments in both healthy and chronic stroke survivors older adults [15,47].

Regarding the practical applications of the strength and gait speed results, one of the concerns most commonly cited in previous research is their link to the risk of falling. It has been shown that common gait deficits observed in older adults, such as a greater stride width [63] and stride-to-stride variability are independent predictors of falls [31], and gait speed of people who do not experience falls is significantly higher than that of those who do [23,61,57,55,58]. With respect to handgrip strength data, Moreira et al. [38] concluded that the probability of falling was lower among those with greater grip strength. In addition, this study showed that muscle strength, balance deficiencies, fear of falling, and a previous history of falls have been described as the main independent predictors of the risk of future falls [40].

Finally, as for health-related quality of life, a recent study performed in healthy inactive adults (31.7 ± 2.6 years) reported that a HIIT with low and moderate training frequency (two and three times per week) showed significant improvements in the SF-36 physical health component, but only moderate-intensity training improved the mental component of quality of life [54]. In the present study, we found significant benefits after HIIT compared to both MIIT and CG with regards to the SF-36 domains general health, health changes, vitality and physical functioning, with large size effects (Cohen's d values ranging from .94 to 1.47) and physical functioning domain with compared to the MIIT and CG group (Cohen's d values of 1.13 and .57 respectively). However any significant improvement in the mental component of quality of life was observed after both HIIT and MIIT programs. In a study by Globas et al. [16] demonstrated improvements in mental health after a treadmill high-intensity training program for an chronic stroke survivors > 60 years, measured through a more concise questionnaire (SF-12). In addition, the study by Knowles et al. [28] with the two-way repeated measures ANOVA revealed a significant main effect for group and an interaction between group and measurement phase in the "physical functioning" and "general health" constructs, of the SF-36 (physical function and general health) after a cycle ergometer low-volume HIIT intervention in sedentary and active older adults, which appeared to cause these improvements in healthy sedentary ageing male aged 55 years and older.

These findings could reinforce the theory that high-intensity is an appropriate training system for the elderly population. There are some limitations in this study that must be addressed: the participants were healthy older adults, and the results may not be generalized to older adults with clinical conditions. We were not able to monitor physical activity levels outside the study setting nor to track dietary intake, although individuals were asked to maintain their usual lifestyle habits.

Conclusions

A HIIT program with suspension exercises was effective to improve gait speed, thus improving lower-body performance, grip strength and subjective perception of health-related quality of life in adults aged 60 years and over. A significant decrease in BMI was also found after HIIT with suspension exercises. Therefore, suspension exercise training could be a very valuable method to achieve improvements in the health of the elderly. In addition, this tool is economical and portable. Our findings may be useful for exercise physiologists, especially those working with older people, wishing to implement specific training plans for the geriatric population.

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Figure Legends

Figure 1. Flow chart of the participants.

Figure 2. Values of the controlled hand grip strength test with dynamometer. * = $p = 0.01$ vs pre-intervention in group HIIT, # = Significance group by interaction time ($p = 0.001$). Pre = Pre-intervention period, Post = Post-intervention period.

Figure 3. Gait speed controlled through the Tug Test. Pre = Explanation of the data are reported as mean and standard deviation. * = $p < 0.02$ vs pre-intervention in group HIIT, # = Significance group by time of interaction ($p < 0.001$). Pre-intervention period, Post = Post-intervention period.

Table 1. Pre- and post-intervention values for anthropometry and body composition.

	Control (n = 23)		MICT (n = 24)		HIIT (n =26)	
	Pre	Post	Pre	Post	Pre	Post
BMI (kg(m^2)	32.13 ± 2.30	32.07 ± 2.02	30.33 ± 3.07	30.15 ± 2.77	29.82 ± 3.17	27.25 ± 3.44
Waist Circumference (cm)	10.87 ± 7.02	101.00 ± 6.78	96.79 ± 1.75	96.42 ± 1.38	94.96 ± 1.97	94.50 ± 1.24
Hip Circumference (cm)	112.48 ± 5.10	112.57 ± 5.03	104.42 ± 7.51	103.75 ± 7.46	105.42 ± 6.24	105.04 ± 6.22
Waist/Hip ratio	.90 ± .06	.90 ± .05	.93 ± .08	.93 ± .08	.90 ± .08	.90 ± .08
Fat Mass (%)	43.89 ± 4.83	43.94 ± 4.75	41.39 ± 6.69	43.06 ± 5.78	42.65 ± 9.12	41.64 ± 5.29
SMM (kg)	24.58 ± 4.82	23.77 ± 4.53	25.59 ± 6.58	24.53 ± 6.28	24.88 ± 5.68	25.70 ± 6.66

Note: Data are expressed as mean and standard deviation. MIIT: Moderate Intensity Interval Training. HIIT: High-Intensity Interval Training. BMI: Body Mass Index. SMM: Skeletal Muscle Mass.

Table 2. Effects of HIIT and MIIT on Health-related quality of life assessed by the SF-36 questionnaire.

	Control (n = 23)		MIIT (n = 24)		HIIT (n = 26)		Group			Time			Group x Time		
	Pre	Post	Pre	Post	Pre	Post	$F(2, 69)$	p	η^2	$F(1,70)$	p	η^2	$F(2, 69)$	p	η^2
General Health	60.09	57.61	60.42	58.33	66.69	75.96 *	7.45	.001	.18	3.58	> .05	-	3.87	.026	.10
	21.10	18.02	12.59	10.07	15.42	13.54									
Health Changes	43.48	39.13	44.79	41.67	47.12	63.46 *	4.88	.010	.12	1.22	> .05	-	4.13	.020	.11
	26.35	16.56	22.09	15.93	19.14	23.70									
Physical Functioning	60.87	60.87	75.00	71.88	73.65	82.69 *	7.64	.001	.18					> .05	
	21.09	16.56	19.15	18.52	21.84	16.98									
Physical Role	63.17	554.48	68.75	82.29	63.46	84.62 *	3.63	.032	.10	1.43	> .05	-	1.69	> .05	-
	37.64	39.71	38.48	30.82	40.76	29.22									
Emotional Role	72.48	76.83	59.75	84.67	59.00	78.23	.02	> .05	-	1.64	> .05	-	1.04	> .05	-
	39.79	34.03	39.35	27.89	44.55	37.65									
Social Functioning	77.48	75.87	75.04	82.96	76.08	80.96	.24	> .05	-	2.37	> .05	-	.45	> .05	-
	30.19	21.60	25.80	15.05	25.72	17.31									
Bodily Pain	57.30	52.00	56.58	51.54	61.11	63.12	1.23	> .05	-	.84	> .05	-	1.23	> .05	-
	29.54	22.00	26.40	19.55	23.93	22.81									
Vitality	68.30	59.96	70.33	61.67	65.77	78.50 *	2.00	> .05	-	1.95	> .05	-	7.60	.001	.18
	22.51	19.02	21.15	17.54	20.53	18.19									
Mental Health	66.74	66.96	62.71	70.83	73.69	73.65	1.46	> .05	-	4.55	.036	.06	1.34	> .05	-
	28.03	21.78	23.26	22.63	19.65	21.24									
Physical component summary	60.31	56.13	65.14	65.83	66.21	76.65	5.68	.005	.14	.89	> .05	-	2.82	> .05	-
	22.98	20.39	18.92	11.56	17.71	13.92									
Mental component summary	71.19	69.91	66.90	75.13	68.60	77.73	.30	> .05	-	5.19	.026	.07	.84	> .05	-
	24.40	19.67	21.76	15.11	22.97	18.44									

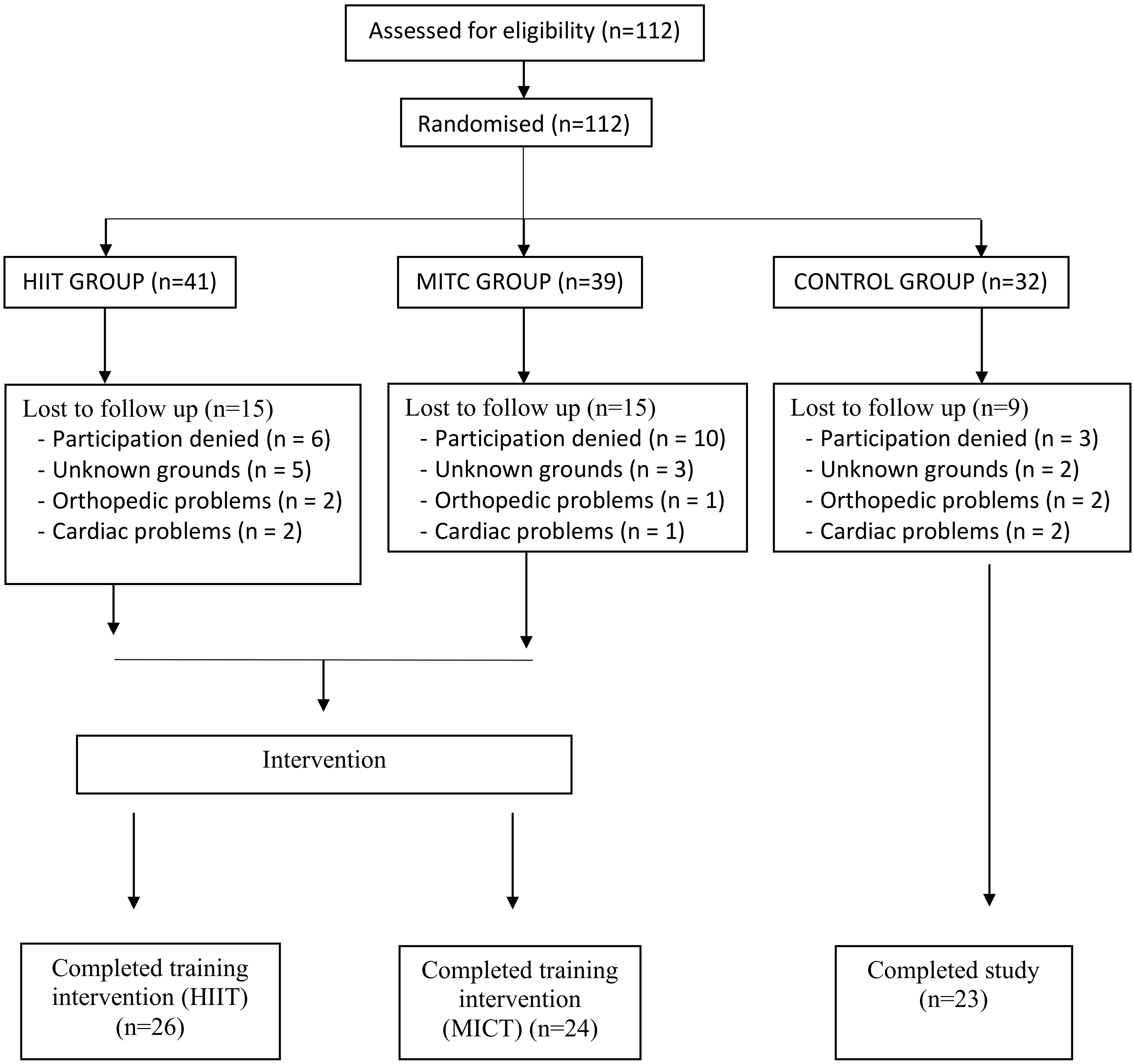

Fig. 1 Flow chart.

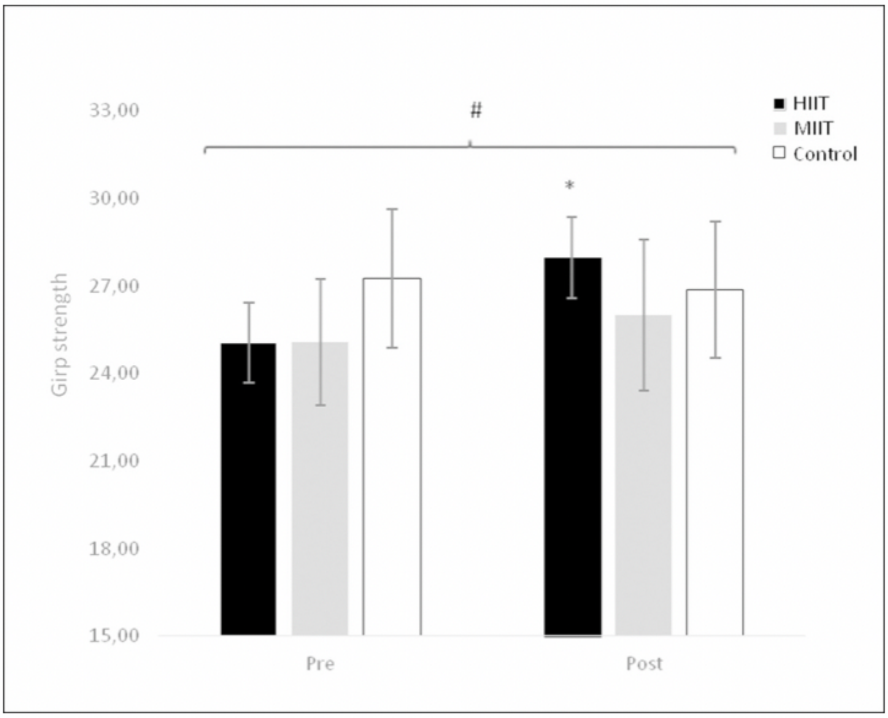

Figure 2. Values of the controlled hand grip strength test with dynamometer. * = p = 0.01 vs pre-intervention in group HIIT, # = Significance group by interaction time (p = 0.001). Pre = Pre-intervention period, Post = Post-intervention period.

96x77mm (600 x 600 DPI)

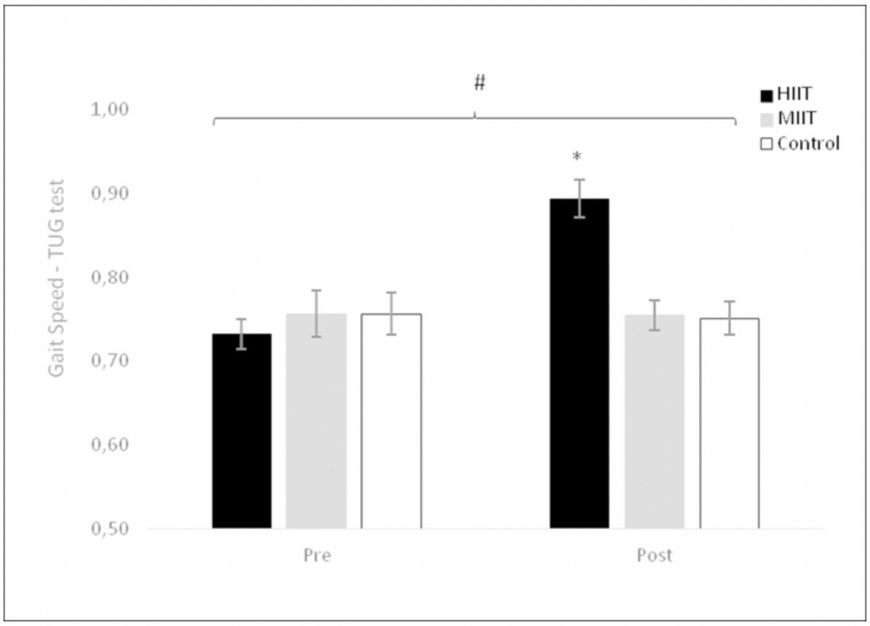

Figure 3. Gait speed controlled through the Tug Test. Pre = Explanation of the data are reported as mean and standard deviation. * = p <0.02 vs pre-intervention in group HIIT, # = Significance group by time of interaction (p <0.001). Pre-intervention period, Post = Post-intervention period.

85x60mm (600 x 600 DPI)

CAPÍTULO 7: CONCLUSIONES

Teniendo en cuenta los datos obtenidos de las investigaciones que conforman esta tesis, podemos afirmar que en nuestra muestra de sujetos sanos:

- Un entrenamiento en suspensión HIIT de 12 semanas provocó un aumento significativo de la Confianza del Equilibrio para Actividades Específicas (ABC) en personas mayores de 60 años.
- Un entrenamiento en suspensión MIIT de 12 semanas produce un aumento significativo de la Confianza del Equilibrio para Actividades Específicas (ABC) en personas mayores de 60 años.
- Un entrenamiento en suspensión HIIT de 12 semanas produce una disminución significativa del miedo a caerse en personas mayores de 60 años.
- Un entrenamiento en suspensión HIIT de 12 semanas provocó mejoras en las variables doble apoyo y distancia del análisis de la marcha en personas mayores de 60 años.
- Un entrenamiento en suspensión HIIT de 12 semanas mejoró el equilibrio dinámico de manera significativa en personas mayores de 60 años.
- Un entrenamiento en suspensión HIIT de 12 semanas aumento la fuerza de agarre de manera significativa en personas mayores de 60 años.
- Un entrenamiento en suspensión HIIT de 12 semanas aumentó la velocidad de la marcha de manera significativa en personas mayores de 60 años.
- Un entrenamiento en suspensión HIIT de 12 semanas generó una mayor puntuación en las variables de la calidad de vida subjetiva de las variables Salud General, Cambio de Salud, Función Física, Rol Físico y Vitalidad de manera significativa en personas mayores de 60 años.

Conclusión general:

Los resultados de la presente tesis doctoral muestran que un programa de entrenamiento en suspensión por intervalos (HIIT y MIIT) tienen efectos beneficiosos en varios factores de riesgo de caída, más precisamente en comparación con el grupo de control. Tanto los programas HIIT Y MIIT mejoraron el equilibrio confianza, mientras que los participantes de HIIT obtuvieron significativamente mejor resultados que los de los otros grupos con respecto al miedo a caer, análisis de la marcha, equilibrio dinámico, fuerza de agarre, velocidad de la marcha y la calidad de vida relacionada con la salud. Por el contrario los resultados obtenidos con el mismo entrenamiento en la composición corporal muestran que las adaptaciones producidas no fueron significativas, mostrando sólo diferencias significativas PRE intervención en la circunferencia de cadera y el IMC, debido principalmente a las dificultados asociadas a las mejoras de los valores antropométricos de una población mayor en un corto periodo de tiempo. Independientemente de la edad y el IMC, este programa de entrenamiento físico mejoró la función física de los ancianos, como lo demuestran los cambios operados en las variables en estudio y la percepción subjetiva de los participantes sobre su calidad de vida. El entrenamiento en suspensión contribuye a mejorar la fuerza de agarre, aumento de la velocidad de la marcha y el equilibrio dinámico, lo que mejora el rendimiento de la parte inferior del cuerpo en adultos mayores.

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LISTA DE ABREVIATURAS

HIIT	Grupo de entrenamiento por intervalos de alta intensidad
MIIT	Grupo de entrenamiento por intervalos de intensidad moderada
CONTROL	Grupo Control
IMC	Indice de Masa Corporal
AVD	Actividades de la Vida Diaria
ABC	Cuestionario de Escala de Confianza del Equilibrio
FES-I	Cuestionario de Escala de Eficacia de Caídas Internacional
SF-36	Cuestionario de Calidad de Vida Subjetiva
TUG TEST	Prueba Funcional del Equilibrio Dinámico
OS	Obesidad Sarcopénica