UNIVERSIDAD DE MURCIA

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TESIS DOCTORAL

Estudio de la funcionalidad a través del entrenamiento de core y pliometría

D. Ekaitz Dudagoitia Barrio

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doctorando del Programa de Doctorado en

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Functional training through core training and plyometrics

Estudio de la funcionalidad a través del entrenamiento de core y pliometría

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The author of this doctoral thesis was not supported scholarship by any foundation during these years of study. Part of this thesis was carried out during the research stay at the Universidad Andrés Bello (Chile) at the Exercise and Rehabilitation Sciences Institute. School of Physical Therapy, Faculty of Rehabilitation Sciences, from 1st September 2022 to 30th November 2022, and funded by the Escuela Internacional de Doctorado (EIDUM) in terms of the grant named "Convocatoria de Ayudas para Estancias en el Exterior y en España EIDUM- CMN 2022". In addition, the study "Plyometric Jump Training Exercise Optimization for Maximizing Human Performance: A Systematic Scoping Review" was also supported by Instituto Tecnológico y de Estudios Superiores de Monterrey, Escuela de Medicina y Ciencias de la Salud, Chihuhua (México).

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AUTORIZA:

La presentación de la tesis doctoral titulada "Estudio de la funcionalidad a través del entrenamiento del core y pliometría" y realizada por **D. Ekaitz Dudagoitia Barrio**, bajo mi inmediata dirección y supervisión, y que presenta para la obtención del Grado de Doctor por la Universidad de Murcia.

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DEPARTAMENTO DE ACTIVIDAD FÍSICA Y DEPORTE

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La presentación de la tesis doctoral titulada: “Estudio de la funcionalidad a través del entrenamiento del core y pliometría” y realizada por **D. Ekaitz Dudagoitia Barrio**, bajo mi inmediata dirección y supervisión, y que presenta para la obtención del Grado de Doctor por la Universidad de Murcia.

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DEPARTAMENTO DE ACTIVIDAD FÍSICA Y DEPORTE

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D. Enrique Ortega Toro

A todos los que lo hicieron posible

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Después de toda una vida como estudiante, hoy es el día: escribo este apartado de agradecimientos para finalizar y concluir mis estudios de doctorado. No quiero dejar pasar estas líneas sin agradecer a todos los que han hecho posible esta graduación como doctor, no solo en estos últimos cinco años sino a lo largo de toda mi vida y no solo en el campo científico, sino también a nivel personal,

En primer lugar, agradecer al profesor Antonio García de Alcaraz, mi tutor durante este proyecto, por la confianza depositada en mí, por su apoyo y por enriquecerme como persona y como profesional desde el día en el primer día que entré en su despacho en el INEF de Madrid. Gracias a Rodrigo Ramírez Campillo por enseñarme tanto, depositar tanta confianza en mí y, a pesar de ser el mejor investigador, por ser todavía mejor persona. A Raquel Hernández, por arrojar esa luz de ideas cuando no las había y por recibirme tan bien en Murcia. Y a Enrique Ortega, gracias por permitir que hoy esté aquí y pueda presentar este trabajo.

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Preface

The doctoral thesis that the reader is holding in his/her hands is the result of my last six years of research on the exciting topic of human physical performance. Given the importance and the increased interest in physical activity during the recent years, promoting the practice of sport across the lifespan to increase performance and move efficiently and securely, the author of this thesis following his dreams and mentoring by the directors was involved in this amazing topic.

The thesis presented here is structured into four primary sections. *Part I* serves as an introduction, offering insights into the interrelation between core, stability, movement quality, plyometric training and performance. It outlines the issues this thesis aims to tackle and presents the research objectives and hypotheses. *Part II* comprises the five studies designed to investigate the research questions introduced in *Part I*. This section is further subdivided into five chapters, each dedicated to presenting an individual study. *Part III* presents the key findings derived from this thesis and outlines potential avenues for future research. Lastly, *Part IV* includes the reference list for all studies cited across the various chapters.

The scientific production of this research project is not limited to this document. During the five years up to the completion of this thesis, the author has also collaborated on different projects, has presented oral communications and posters at different international and national congresses, and has been involved in different courses related to research methodology, statistical analysis and languages. The author has served as a reviewer for several related studies in various prestigious journals within the scientific community. Additionally, this period has enabled the author to complete an international research stay in Santiago de Chile (three months), with the greatest world professionals in the field, to improve his scientific skills, allowing him at the same time to fulfil the necessary criteria to qualify for the International Mention in this thesis. Finally, the author, due to this amazing process was able to connect with different Universities and professionals across the world to continue with the investigation, follow the learning process and be able to continue contributing a grain of sand of knowledge.

I trust that you derive as much satisfaction from reading this thesis as I have from dedicating these years of effort to it.

Abreviaturas

Change of direction speed	**CODS**
Confidence interval	**CI**
Countermovement jump	**CMJ**
Dynamic balance stability	**DBS**
Effect size	**ES**
Entrenamiento pliométrico	**EP**
Evidence-gap map	**EGM**
Ground contact times	**GCT**
Human physical capabilities	**HPC**
Jump rope training	**JRT**
Low back pain	**LBP**
Maximal voluntary contraction	**MVC**
Meta-analysis	**MA**
Open Science Framework	**OSF**
Participants, Intervention, Comparators, Outcomes, and Study Design	**PICOS**
Physiotherapy Evidence Database	**PEDro**
Plyometric jump training	**PJT**
Preferred Reporting Items for Systematic Reviews and Meta-Analyses	**PRISMA**
Rate of perceived exertion	**RPE**
Reactive strength index	**RSI**
Real Academia Española	**RAE**
Repeated sprint ability	**RSA**
Repetition maximum	**RM**
Running economy	**RE**
School age participants	**SAP**
Sport specific performance	**SSP**
Standad deviations	**SD**
Star Excursion Balance Test	**SEBT**
Strech-shortening cycle	**SSC**
Systematic review	**SR**
Systematic review with meta-analysis	**SRMA**

Abstract

Human performance is a complex concept that encompasses various physiological, cognitive, and emotional factors. It is can be defined as the successful execution of a specific task within an available performance capacity that meets or exceeds the demands of the mission. The Royal Spanish Academy defines physical performance as the body's ability to carry out physical activities efficiently. Furthermore, human functionality is the ability of the body to perform functions under specific conditions. Thus, the core area of the body, known as the core, is particularly important for physical performance. The core provides the stable and strong base upon which body movements develop. A strong and well-trained core improves posture, balance, coordination, and strength, which in turn leads to more efficient movement and a reduced risk of injury. Core training and plyometrics are two different types of training that aim to improve the functionality of the human body. Core training focuses on strengthening and stabilizing the core muscles, while plyometrics is based on high-speed exercises that stimulate fast-twitch muscle fibers using the stretch-shortening cycle.

This doctoral thesis titled "Study of Functionality Through Core Training and Plyometrics" explores the combination of these two training methods to improve functionality and athletic performance. It presents five studies that explore different aspects of core training and plyometrics in relation to functionality. The studies are divided into two main areas:

1. Core Training and Its Effects (Studies 1 and 2):

Study 1: This study conducted a review and meta-analysis of the effects of core training on dynamic balance stability. The study found that core training significantly improved dynamic balance stability.

Study 2: This study conducted a review and meta-analysis of the effects of core training on core muscle endurance. The study found that core training significantly improved trunk muscles endurance.

2. Optimization of Plyometric Training for Athletic Performance (Studies 3, 4, and 5):

Study 3: This study used a systematic scoping review to examine the optimization of plyometric exercises to maximize performance. The study found that plyometric exercises should be varied in terms of movement patterns, intensity, and volume to maximize performance.

Study 4: This study conducted a review and meta-analysis of the effects of plyometric training on running economy. The study found that plyometric training significantly improved running economy. Running economy is a determining factor in the performance of long-distance runners, such as marathoners. A strong core and optimized plyometric training can contribute to greater running efficiency, which translates into better performance and reduced fatigue.

Study 5: This study used a scientific evidence map to evaluate the moderating variables of rope jumping that affect both performance and health adaptations. The study found that rope jumping can be an effective tool for improving both performance and health, but that the optimal training program will vary depending on individual goals and needs.

The five studies presented in this doctoral thesis provide strong evidence that core training and plyometrics are effective methods for improving functionality and athletic performance. In addition, practical recommendations are also offered for the implementation of these training methods in different contexts.

Resumen

El rendimiento humano es un concepto que abarca diversos factores fisiológicos, cognitivos y emocionales. Se puede definir como la ejecución exitosa de una tarea específica dentro de una capacidad de desempeño disponible que cumple o excede las demandas de la misión. La Real Academia Española define el rendimiento físico como la capacidad del cuerpo para llevar a cabo actividades físicas de manera eficiente. Además, la funcionalidad humana es la capacidad del cuerpo para ejercer funciones bajo condiciones específicas. La zona del tronco, conocida como core, es particularmente importante para el rendimiento físico. El core proporciona la base estable y fuerte sobre la cual se desarrollan los movimientos corporales. Un core fuerte y bien entrenado mejora la postura, el equilibrio, la coordinación y la fuerza, lo que a su vez se traduce en un movimiento más eficiente y una reducción del riesgo de lesiones. El entrenamiento del core y la pliometría son dos tipos de entrenamiento diferentes que pretenden mejorar la funcionalidad del cuerpo humano. El entrenamiento del core se centra en fortalecer y estabilizar la musculatura central del cuerpo, mientras que la pliometría se basa en ejercicios de alta velocidad que estimulan las fibras musculares de contracción rápida utilizando el ciclo estiramiento-acortamiento.

Esta tesis doctoral titulada "Estudio de la Funcionalidad a Través del Entrenamiento del Core y Pliometría" explora la combinación de estos dos métodos de entrenamiento para mejorar la funcionalidad y el rendimiento deportivo. Se presentan cinco estudios que exploran diferentes aspectos del entrenamiento del core y la pliometría en relación con la funcionalidad. Los estudios se dividen en dos áreas principales:

1. Entrenamiento del Core y sus Efectos (Estudios 1 y 2):

Estudio 1: Este estudio realizó una revisión y un meta-análisis de los efectos del entrenamiento del core sobre la estabilidad del equilibrio dinámico. Se encontró que el entrenamiento del core mejoró significativamente la estabilidad del equilibrio dinámico.

Estudio 2: Este estudio realizó una revisión y un meta-análisis de los efectos del entrenamiento del core sobre la resistencia muscular del core. Se encontró que el entrenamiento del core mejoró significativamente la resistencia muscular del core.

2. Optimización del Entrenamiento Pliométrico para el Rendimiento Deportivo (Estudios 3, 4 y 5):

Estudio 3: Este estudio utilizó una revisión de alcance sistemática para examinar la optimización de los ejercicios pliométricos para maximizar el rendimiento. Se encontró que los ejercicios pliométricos deben ser variados en términos de patrones de movimiento, intensidad y volumen para maximizar el rendimiento.

Estudio 4: Este estudio realizó una revisión y un meta-análisis de los efectos del entrenamiento pliométrico sobre la economía de carrera. Se encontró que el entrenamiento pliométrico mejoró significativamente la economía de carrera. La economía de carrera es un factor determinante en el rendimiento de corredores de larga distancia, como los maratonistas. Un core fuerte y un entrenamiento pliométrico optimizado pueden contribuir a una mayor eficiencia en la carrera, lo que se traduce en un mejor rendimiento y una menor fatiga.

Estudio 5: Este estudio utilizó un mapa de evidencia científica para evaluar las variables moderadoras del salto con cuerda que afectan tanto al rendimiento como a las adaptaciones para la salud. Se encontró que el salto con cuerda puede ser una herramienta eficaz para mejorar tanto el rendimiento como la salud, pero que el programa de entrenamiento óptimo variará según los objetivos y las necesidades individuales.

Los cinco estudios presentados en esta tesis doctoral proporcionan evidencia sólida de que el entrenamiento del core y la pliometría son métodos efectivos para mejorar la funcionalidad y el rendimiento deportivo. Además, se ofrecen recomendaciones prácticas para la implementación de estos métodos de entrenamiento en diferentes contextos.

PARTE I
PART I

INTRODUCCIÓN GENERAL, OBJETIVOS DE LA INVESTIGACIÓN E HIPÓTESIS

La funcionalidad es la capacidad que tiene el cuerpo de ejercer funciones bajo condiciones específicas, es decir, desempeñar actividades de la vida diaria, deportivas o laborales de manera eficiente y sin dolor. De esta manera, mejorar la funcionalidad humana se hace determinante para mejorar la calidad de vida (realizar tareas con mayor autonomía o discapacidades), aumentar el rendimiento deportivo (mejorando las capacidades físicas básicas), prevenir lesiones y retrasar el envejecimiento. Conforme los seres humanos van envejeciendo, de manera natural van perdiendo la capacidad de realizar funciones que requieren capacidades físicas como la fuerza, potencia, equilibrio, resistencia, agilidad, velocidad, amplitud de movimiento, etc. [1,2]. Si bien la fuerza es fundamental para el movimiento, no es la única capacidad física que necesita el ser humano. La flexibilidad, resistencia, velocidad, equilibrio, etc., son diferentes expresiones de fuerza aplicadas según el contexto. Por ello, aplicar fuerza únicamente no es suficiente y en un entrenamiento bien estructurado se debe trabajar estas capacidades enfocadas a la funcionalidad de cada contexto. Así, la finalidad del entrenamiento debe ser buscar la mejora de la función y no tanto la estructura, aunque ambas vayan de la mano. Teniendo esto en cuenta y sabiendo que para el desarrollo de estas capacidades básicas el entrenamiento debe ser multidisciplinar y tener un enfoque holístico y multi-componente [3], se hace de vital importancia revelar qué tipos de entrenamiento perseveran mejor en las funciones humanas. Así, con el fin de desarrollar programas de entrenamiento más específicos y eficaces, la presente tesis doctoral titulada la “Estudio de la funcionalidad a través del entrenamiento del core y pliometría” tiene como finalidad ofrecer un mejor entendimiento de qué tipos de entrenamiento y de qué manera contribuyen a la mejora de la funcionalidad humana con el fin de desarrollar programas de entrenamiento más específicos y eficaces. A continuación, se realizará una introducción de estos conceptos y de los trabajos que se han realizado para poder afianzar este gran objetivo primario.

El rendimiento humano es un concepto complejo que abarca diversos factores físicos, cognitivos y emocionales, y se puede definir como la finalización exitosa de una tarea específica dentro de una capacidad de desempeño disponible que cumple o excede las demandas de la misión [4]. La Real Academia Española (RAE) define el rendimiento físico como la capacidad del cuerpo para llevar a cabo actividades físicas de manera eficiente. Por ejemplo, un atleta de alto nivel que entrena regularmente y compite en eventos deportivos de élite demuestra su capacidad para realizar su actividad de manera eficiente y, por lo tanto, un alto rendimiento físico. Como se ha podido observar, el rendimiento físico no difiere demasiado con el concepto de funcionalidad humana, así, el rendimiento físico no tiene porqué estar unido a ninguna práctica deportiva, simplemente puede ayudar a las personas a ser más eficientes en las tareas que se realizan cotidianamente. Estas tareas que van desde caminar hasta levantar objetos o realizar actividades deportivas, requieren equilibrio, fuerza y coordinación que solo una musculatura central fuerte y bien entrenado puede proporcionar.

La zona del tronco (figura 1) es particularmente interesante para investigadores y entrenadores en el ámbito de la actividad física, el

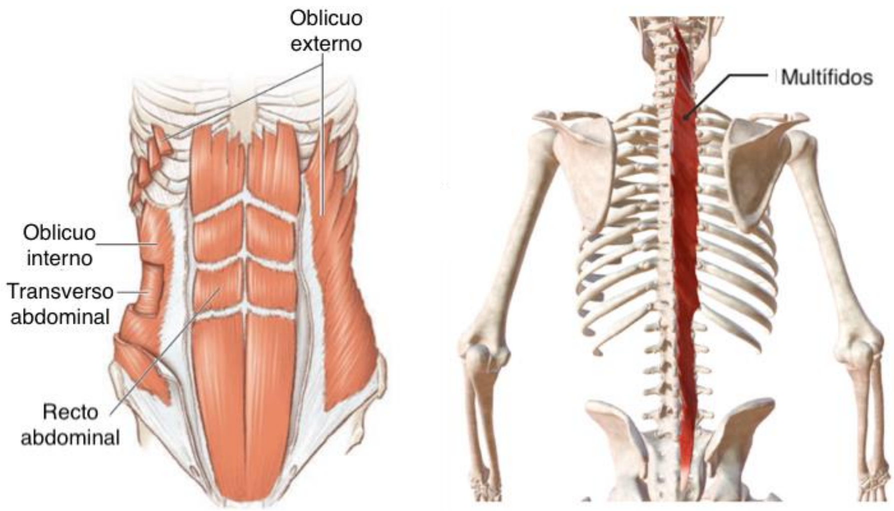


Figura 1 Principales músculos que componen la región del core. *Fuente: elaboración propia.*

rendimiento y la salud [5,6]. Si bien existe cierta discrepancia sobre los músculos que componen la región central del cuerpo, llamada core, el único estudio hasta la fecha que ha tratado de alcanzar un consenso entre expertos en la materia sobre los músculos que lo componen es el de Majewski-Schrage, Evans y Ragan (2014), en el que se determina que el core está formado por el transverso abdominal, el oblicuo interno, el oblicuo externo, el recto abdominal y los multífidos [7]. El término core se ha extendido popularmente en el ámbito de la actividad física; sin embargo, no suele emplearse correctamente o su significado sigue siendo confuso. Este término se refiere a la función y capacidad de la parte central del cuerpo, donde está implicada la musculatura anteriormente citada. Las principales funciones del core son generar fuerza y estabilidad proximal para la movilidad distal y movimientos interactivos [8]; en otras palabras, las funciones del core son generar, absorber y transmitir las fuerzas generadas para el movimiento humano [9], tanto en las funciones básicas de la actividad física diaria como en el rendimiento deportivo.

Los expertos definen la funcionalidad del core como "la capacidad de lograr y mantener el control de la región del tronco en reposo y durante movimientos precisos" [7]. Poniendo en contexto la relevancia del core, se observó que la musculatura profunda de la región del core se activa previamente al deltoides durante el movimiento de flexión de hombro [10] y que esta activación profunda abdominal previa a la del movimiento principal es involuntaria [11]. Estos resultados muestran que un punto fuerte y estable es necesario para la correcta transferencia de fuerzas y, en consecuencia, para el rendimiento deportivo. Además, se conoce que antes de que se produzca un movimiento distal, existe una activación central de los músculos del core [12]. De esta forma, el entrenamiento del core puede ser esencial para una correcta transferencia de fuerzas, cumpliendo mejor su función de generar, absorber y transmitir fuerzas durante el movimiento y, en consecuencia, influir positivamente al rendimiento deportivo. En relación a esto, en un estudio llevado a cabo por Saeterbakken y col. (2011) se ha observado cómo un programa específico de entrenamiento del core podría mejorar el rendimiento, aumentando la velocidad de lanzamiento de las jugadoras de balonmano [13].

Una buena resistencia de estos músculos influye también en algunas tareas vitales de potencia y fuerza, así como en la calidad del movimiento [14]. La resistencia muscular del core se entiende como la capacidad de los músculos del tronco para mantener una posición durante el máximo tiempo posible, manteniendo la fuerza a lo largo del tiempo [15]. Además, niveles altos de resistencia muscular del core pueden beneficiar significativamente la salud musculoesquelética [16]. Usualmente los programas de entrenamiento enfocados en el core suelen utilizar el peso corporal o superficies inestables para practicar los ejercicios sin una clara justificación [17]. Estos protocolos de entrenamiento suelen utilizar ejercicios y variables de entrenamiento similares a las evaluaciones de los test para evaluar la resistencia de estos músculos [18]. Por ejemplo, la plancha frontal es un ejercicio común utilizado hasta el agotamiento entre atletas para evaluar la resistencia muscular del core. Sin embargo, algunas tareas deportivas suelen requerir otra capacidad diferente de estos músculos que componen el core, como puede ser una contracción voluntaria máxima en un momento concreto para poder transferir energía del tren inferior al superior o viceversa, como, por ejemplo, los pases a larga distancia en el rugby o un saque de banda en el fútbol. Este tipo de situaciones pueden ser más difíciles de reproducir en el entrenamiento habitual en los centros deportivos, por tanto, el entrenamiento habitual del core podría ser eficaz para mejorar la resistencia de los músculos del tronco, pero no reproduce tareas específicas que requieren los gestos deportivos más exigentes, con mayor velocidad y potencia. No obstante, el entrenamiento del core parece cubrir demandas específicas del deporte, así como promover ajustes en el movimiento lumbar y alteraciones de patrones de movimiento durante la carrera [19,20]. Por todo lo anterior, el entrenamiento del core y de su capacidad de resistencia parece proporcionar una base necesaria para el rendimiento de diversas actividades atléticas, siendo relevante en deportes donde estos músculos juegan un papel crítico [21].

Dentro de las diferentes funciones o capacidades de movimiento, la estabilidad está asociada con la mejora del rendimiento deportivo, así como a tareas de la vida cotidiana y la higiene postural [22]. Se pueden diferenciar dos tipos de estabilidad: estática y dinámica. La estabilidad estática se considera la capacidad de mantener una base de apoyo con un movimiento mínimo, mientras que la estabilidad dinámica se define como la capacidad del sujeto para reaccionar de forma eficiente a los movimientos de la base de apoyo [23]. La estabilidad dinámica es esencial para el rendimiento deportivo, especialmente en situaciones en las que la alineación adecuada del centro de masas se vuelve más relevante [24]. Esta desalineación del centro de masas está relacionada con una mala transmisión de fuerzas y un potencial riesgo de lesión [25]. A modo de ejemplo, en un salto de altura el atleta necesita una base de sustentación estable al tomar impulso y durante el despegue. Esto implica una fuerte activación de los músculos del core, además de piernas y tobillos. Posteriormente, en la fase aérea, el atleta debe ajustar su postura y controlar el movimiento para un aterrizaje seguro.

La prueba más habitual de medida de la estabilidad dinámica es el "Star Excursion Balance Test" (SEBT), donde se miden ocho direcciones angulares. Existe una variante del anterior conocida como "Y-Balance Test", donde únicamente se miden los ejes más relevantes: anterior, posteromedial y posterolateral. Ambas son una buena prueba de campo ya que no requieren ningún tipo de material ni mucho coste temporal. Asimismo, tienen una excelente fiabilidad intra e inter observador cuando se realiza en adultos sanos [26]. Por el contrario, esta prueba puede verse afectada por una hipermovilidad de las extremidades inferiores como en el caso de bailarinas con hipermovilidad articular [27]. En este sentido, una buena dorsiflexión de tobillo podría potencialmente mejorar los resultados en estos test en los que se trata de medir la estabilidad dinámica [28]. La literatura actual presenta un debate con diferentes resultados entre la resistencia de los músculos del core y la estabilidad dinámica [27,29].

La estabilidad y control del movimiento está en auge en el ámbito deportivo, empleando una evaluación y valoración del movimiento de los deportistas, tanto para la prevención de lesiones como para la mejora del rendimiento [30]. A pesar de ello, hay que tener en cuenta que las pruebas de rendimiento deportivo y las pruebas de la calidad del movimiento de los deportistas no son lo mismo y deben considerarse de manera diferente [31], siendo un reto el conocer la transferencia que puede haber entre ambos. En cualquier caso, tanto los desequilibrios de fuerza como los desequilibrios neuromusculares están directamente relacionados con factores de riesgo de lesiones [32,33]. Estos desequilibrios neuromusculares perjudican a la calidad del movimiento, definida como el movimiento ejecutado con postura, respiración, movilidad y coordinación adecuadas en actividades o tareas específicas realizadas de manera óptima y eficiente [34]. Para garantizar esta calidad del movimiento y detectar desequilibrios neuromusculares, la identificación de compensaciones durante el movimiento es fundamental para prevenir, mitigar y tratar las alteraciones del movimiento. La compensación se define como “una alteración en la estrategia de movimiento en relación con una línea de base (por ejemplo, un estado anterior o un grupo de control). La compensación en las estrategias de movimiento se origina por la redundancia en la arquitectura muscular del cuerpo humano. Los humanos compensan alterando su trayectoria de movimiento y/o alterando el reclutamiento muscular para completar una tarea" [35]. Por ello, la técnica y forma de ejecución de los ejercicios es fundamental, no solo únicamente para la mejora del rendimiento deportivo, si no que también para tener una larga vida deportiva (evitando lesiones) y una mejor calidad de vida (evitando compensaciones musculares). Dada la relevancia del core y de cómo este puede influir en la calidad de movimiento y la estabilidad dinámica, el primer trabajo de la presente tesis doctoral tiene como objetivo analizar los efectos del entrenamiento del core en la estabilidad dinámica.

La evidencia científica actual demuestra que el entrenamiento de fuerza bien programado es efectivo para la reducir la tasa de lesiones [36]. Las lesiones pueden clasificarse en dos tipos principales: lesiones agudas (producidas en un momento exacto durante el entrenamiento o competición) y lesiones por sobreuso/crónicas (provocadas por la repetición de un mismo movimiento) [37]. Por ambos tipos de riesgo, además de otros factores como el nivel del atleta o las variables de entrenamiento, el análisis del movimiento parece clave para tratar de minimizar el riesgo de lesión e incrementar el rendimiento deportivo. Como el core influye de manera directa en la calidad de movimiento, la resistencia de los músculos centrales parece fundamental para mantener en el tiempo la correcta higiene de los movimientos. Así, dada la relevancia del core y de cómo este puede influir en la calidad de movimiento y en el riesgo de lesiones, el segundo trabajo de la presente tesis doctoral tiene como objetivo analizar los efectos del entrenamiento del core en la resistencia de los movimientos del tronco.

Otros muchos métodos de entrenamiento de fuerza diferentes han sido propuestos con la intencionalidad de mejorar el rendimiento físico [38,39]. De entre ellos, el entrenamiento pliométrico (EP) proporciona algunas ventajas sobre otros métodos de entrenamiento (por ejemplo, el entrenamiento de fuerza tradicional), ofreciendo igual (o incluso más) efectividad para la mejora de varias capacidades físicas (por ejemplo: salto o sprint) [40,41]. A diferencia del entrenamiento de fuerza tradicional, la naturaleza balística del EP permite evitar la desaceleración al final de un movimiento realizado (por ejemplo, en la extensión de cadera o la rodilla [42,43]), lo que podría incidir directamente en las adaptaciones del entrenamiento y sus capacidades físicas, así como consecuencia específica del rendimiento deportivo [44–46]. Además, el EP puede ser "económico" y eficiente en comparación con otros métodos de entrenamiento de fuerza, ya que requiere poco o ningún tipo de material, y generalmente implica ejercicios en los que se utiliza la masa corporal como resistencia [47]. El EP puede realizarse en un espacio físico relativamente pequeño, lo que puede ser una ventaja esencial durante escenarios específicos (por ejemplo, al encontrarse con restricciones pandémicas) [48] y puede considerarse más divertido que otros métodos de entrenamiento (por ejemplo, flexibilidad, resistencia), especialmente entre los jóvenes [49]. Otra de las ventajas que ofrece el EP es que puede reducir el potencial riesgo de lesiones [50,51], e incluirse en programas de rehabilitación [52]. Además, puede imitar las acciones específicas de alta intensidad y corta duración tan características en los deportes, aumentando potencialmente el efecto de transferencia entre los propios ejercicios y el rendimiento deportivo [40]. De hecho, este tipo de entrenamiento ha demostrado un impacto favorable en las capacidades físicas de los atletas, como la potencia de salto, la velocidad de sprint lineal, la agilidad, la velocidad de cambio de dirección, la capacidad de sprint repetido con y sin cambio de dirección, la resistencia a corto plazo, la resistencia a largo plazo (por ejemplo, la prueba Yo-Yo), la fuerza máxima, el equilibrio, el rendimiento específico del deporte (por ejemplo, la velocidad de patada), la amplitud de movimiento y la coordinación, entre otros [40,41,53].

Un programa de EP abarca una gama de acciones (Tabla 1) que implican altas tasas de desarrollo de fuerza y con gran variedad de tiempos de contacto con el suelo, que van desde tiempos de contacto breves (<250 ms) [54], como los observados durante los saltos rápidos (<200 ms) [55] o los saltos de vallas [56], hasta tiempos de contacto más largos como el salto de profundidad (≥360-400 ms) [56–58] o el salto con contramovimiento (>800 ms) [56]. Un programa de EP también debe incluir diferentes tipos de acciones musculares: ciclo de estiramiento-acortamiento completo, movimiento solo concéntrico, solo excéntrico, ciclo de estiramiento-acortamiento rápido o ciclo de estiramiento-acortamiento lento, que pueden afectar de diferente manera a las adaptaciones de las capacidades físicas y al consecuente rendimiento deportivo. Los ejercicios de ciclo de estiramiento-acortamiento rápido pueden ejercer un mayor efecto en las últimas etapas de un sprint lineal, es decir, la fase de velocidad máxima, mientras que los ejercicios de ciclo de estiramiento-acortamiento lento lo hacen en las primeras etapas del sprint, es decir, en la aceleración inicial. Los diferentes ejercicios que conforman un programa de EP también involucran diferentes fuerzas excéntricas de impacto contra el suelo: bajas, como un salto a cajón; o altas, como un "drop jump", en las que se puede alcanzar hasta 10 veces la masa corporal, y se explota al máximo el mecanismo del ciclo de estiramiento-acortamiento [59–61].

Un programa de EP también debe involucrar movimientos unilaterales y bilaterales, sin carga externa (solamente la carga de masa corporal) y/o con carga externa (pesas, gomas, etc.), con la finalidad potencial de afectar el perfil fuerza-velocidad y aumentar el rendimiento [62]. El EP puede incluir ejercicios con diferente dirección de aplicación de fuerza (vertical u horizontal), lo que puede afectar el grado de adaptación de las capacidades físicas. Por ejemplo, los ejercicios de salto con predominio vertical puede tener un mayor impacto en las capacidades físicas con un mayor componente vertical [por ejemplo, *countermovement jump* (CMJ)], mientras que los ejercicios con predominio horizontal puede tener un mayor impacto en las capacidades físicas con un mayor componente horizontal (por ejemplo, sprint lineal) [63,64]. La especificidad del propio ejercicio utilizado como el patrón inter-repetición (cíclico o acíclico) [65] puede afectar a las adaptaciones de las capacidades y el rendimiento deportivo. Debido a todas estas variaciones que ofrece este tipo de entrenamiento, los entrenadores de acondicionamiento físico disponen de una amplia gama de ejercicios pliométricos para facilitar las adaptaciones deseadas [58,66–69].

Aunque existe una cantidad razonable de literatura científica sobre los efectos del tipo de entrenamiento en las adaptaciones de las capacidades físicas [47,70,71], es probable que la mayoría de los ejercicios que podrían incorporarse a un programa de entrenamiento no hayan sido investigados adecuadamente. De hecho, las decisiones de los entrenadores con respecto a los moderadores del EP potencialmente relevantes se basan con frecuencia en la experiencia práctica o en la evidencia proveniente de estudios transversales con poblaciones muy específicas [40,41,72]. A la luz de estos razonamientos el tercer trabajo de esta tesis doctoral tuvo como objetivo sintetizar la literatura científica publicada sobre el EP, con el foco en los tipos de salto en relación a las capacidades físicas y el rendimiento deportivo.

Tabla 1: Síntesis de tipos de acciones del entrenamiento pliométrico

Variable	*Descripción*	*Beneficios*	*Ejemplos de ejercicios*
Tiempo de contacto con el suelo	Corto (<250 ms)	Mayor velocidad	Saltos rápidos, saltos de vallas
	Largo (≥360-400 ms)	Mayor fuerza	Salto de profundidad, salto con contramovimiento
Tipo de acción muscular	Ciclo de estiramiento-acortamiento completo	Mayor rendimiento en la fase de velocidad máxima del sprint	Saltos con contramovimiento, lanzamientos
	Movimiento solo concéntrico	Mayor fuerza	Saltos sin contramovimiento, press de banca (solo fase concéntrica)
	Ciclo de estiramiento-acortamiento rápido	Mayor rendimiento en la fase de velocidad máxima del sprint	Saltos pliométricos, lanzamientos
	Ciclo de estiramiento-acortamiento lento	Mayor fuerza en la fase de aceleración inicial del sprint	Ejercicios con pesas, sentadillas
Fuerza excéntrica de impacto	Baja	Menor riesgo de lesiones	Saltos a cajón, step-ups
	Alta	Mayor rendimiento y carga excéntrica	Drop jumps, saltos con rebote
Carga externa	Sin carga	Menor impacto en las articulaciones	Saltos, sprints
	Con carga	Mayor fuerza	Saltos con pesas, sprints con lastre
Dirección de aplicación de fuerza	Vertical	Mayor fuerza y potencia vertical	Saltos, lanzamientos verticales
	Horizontal	Mayor fuerza y potencia horizontal	Sprints, lanzamientos horizontales
Patrón inter-repetición	Cíclico	Mayor resistencia a la fatiga	Saltos en serie, sprints en intervalos
	Acíclico	Mayor fuerza y rendimiento en el salto	Saltos con diferentes alturas

Fuente: elaboración propia.

En relación con el EP de carácter cíclico, y asociada al rendimiento deportivo en la carrera, la economía de carrera es una variable importante que se define como la demanda de oxígeno dada en una velocidad determinada, siendo a su vez uno de los factores determinantes del rendimiento deportivo en carreras de larga distancia [73]. Son varios los factores modificables que afectan a la mejora de la economía de carrera, entre ellos: el entrenamiento de resistencia, el entrenamiento de fuerza, los estiramientos, las condiciones ambientales y los factores nutricionales [74]. El entrenamiento de fuerza es uno de los métodos de entrenamiento que reporta mayores mejoras en este parámetro [75] debido a una mayor coordinación muscular (por ejemplo, coactivación), y rigidez de las piernas que hacen aumentar el almacenamiento de energía cinética en los tendones y mejora la propulsión [76]. Con esta lógica y las características descritas anteriormente del

EP, la hipótesis de que este tipo de entrenamiento podría mejorar considerablemente la economía de carrera parece razonable. Por ello, el cuarto trabajo trató de evaluar los efectos del EP en la variable de rendimiento de economía de carrera, estimando la efectividad de la duración del programa, la frecuencia del entrenamiento, las sesiones totales, la edad de los participantes, el estado del entrenamiento y la velocidad de carrera.

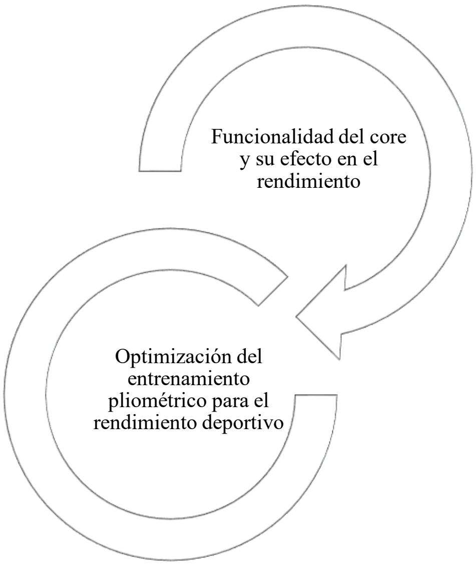
Otro tipo de ejercicios del EP son los saltos con cuerda, que son utilizados como un juego tradicional en muchos países del mundo, como parte de su propia cultura o como actividad física en niños en edad escolar [77]. Se ha demostrado que el entrenamiento con cuerda es seguro y eficiente, y aporta muchos beneficios como la mejora de la aptitud cardiovascular, resistencia, equilibrio, control motor, marcadores relacionados con la salud ósea, etc. [78,79]. Además, es accesible para todo tipo de poblaciones, desde niños hasta mayores, y con diferentes niveles de habilidad y patologías. Así, la literatura ha mostrado los diversos métodos en los que niños con discapacidad intelectual podría utilizar los saltos con cuerda y obtener los beneficios mencionados anteriormente [80–82]. Incluso las personas bien entrenadas pueden mejorar significativamente su condición física con 10-20 minutos de saltos con cuerda por semana [78]. Solo doce semanas de saltos de cuerda parecen ser eficaces para mejorar los marcadores de salud (porcentaje de grasa corporal, circunferencia de la cintura, presión arterial sistólica, glucosa en sangre, niveles de insulina y evaluación del modelo homeostático de la resistencia a la insulina) en niñas adolescentes obesas [83]. Incluso la simulación de saltos sin utilización de la cuerda durante ocho semanas (con tres sesiones por semana) ha demostrado mejorar la fuerza de las extremidades inferiores y el rendimiento de los golpes de los boxeadores escolares de nivel amateur [84].

Las variables moderadoras de entrenamiento a considerar para periodizar un programa de entrenamiento con cuerda, como la intensidad o el volumen del entrenamiento, todavía no están bien descritas en la literatura científica [39]. Debido a estos factores, los entrenadores de acondicionamiento físico deberían de disponer de una amplia gama de variables de salto a la cuerda para facilitar la optimización del entrenamiento. Aunque existe una cantidad razonable de evidencia científica sobre los efectos del salto con cuerda [81,85,86], considerando la gran cantidad de variables moderadoras que tiene esta clase de EP, es probable que la mayoría de las variables que podrían incorporarse a un programa de entrenamiento no hayan sido investigadas adecuadamente. En este sentido, un enfoque de investigación alternativo podría implicar un nuevo mapa de evidencia científica, ofreciendo una imagen más clara de lo que se sabe y desconoce sobre las variables moderadoras del entrenamiento con cuerda. Por lo tanto, el último trabajo de esta tesis doctoral fue realizar un análisis para evaluar las variables moderadoras del salto con cuerda que afectan a las adaptaciones tanto de rendimiento como de salud.

Basado en lo anterior, y con la necesidad existente de seguir mejorando tanto la funcionalidad humana como el rendimiento deportivo, el entrenamiento del core y el EP representan pilares fundamentales para la mejora de la funcionalidad en la población general y en deportistas.

En base a lo mencionado anteriormente, esta tesis doctoral presenta como objetivo principal analizar la funcionalidad del entrenamiento del core en relación a la estabilidad (estudio 1) y la resistencia de los movimientos del tronco (estudio 2), y la optimización del entrenamiento pliométrico para la mejora del rendimiento deportivo (estudios 3, 4 y 5).

Para el cumplimiento de este objetivo la figura 2 presenta la línea de progreso seguida en esta tesis doctoral indicando el título de los estudios y a qué parte del objetivo hacen referencia.



- Estudio 1: Effects of core training on dynamic balance stability: A systematic review and meta-analysis
- Estudio 2: The effects of core training on endurance in different trunk movements: A systematic review and meta-analysis
- Estudio 3: Plyometric Jump Training Exercise Optimization for Maximizing Human Performance: A Systematic Scoping Review and Identification of Gaps in the Existing Literature
- Estudio 4: Effects of plyometric jump training on running economy in endurance runners: A systematic review and meta-analysis
- Estudio 5: Jump Rope Training for Health and Fitness in School-age Participants: Secondary Analyses from a Systematic Review

Figura 2: Línea de progreso de los estudios incluidos en la presente tesis doctoral.

El estudio 1 revisó y meta-analizó la incidencia del entrenamiento del core en la estabilidad de equilibrio dinámica. En este primer estudio también se analizaron las variables moderadoras que afectan al entrenamiento del core para la mejora de la estabilidad dinámica. La hipótesis de este estudio sería que los sujetos que realizan un entrenamiento específico del core serían más estables durante las tareas de equilibrio dinámicas. El estudio 2 realizó una revisión de la literatura con meta- análisis para evaluar los efectos del entrenamiento del tronco en diferentes medidas de resistencia de los músculos del core: flexión, extensión, flexión lateral derecha e izquierda. Este estudio planteó la hipótesis de que el entrenamiento del tronco mejora todas las mediciones de resistencia de los músculos centrales, especialmente los movimientos más entrenados durante las metodologías de entrenamiento.

Abordando el EP, el estudio 3 utilizó una revisión sistemática de alcance para examinar la optimización de los ejercicios pliométricos para maximizar el rendimiento. Adicionalmente se realizó el estudio 5 donde se llevó a cabo un mapa de evidencia científica para evaluar las variables moderadoras del salto con cuerda que afectan a las adaptaciones tanto de rendimiento como de salud. La hipótesis de estos dos estudios sería que los sujetos con un mayor espectro de movimientos tendrían un mejor desempeño deportivo. Por último, el estudio 4 revisó y meta-analizó los efectos del EP en la variable de rendimiento de economía de carrera, así como también se las variables moderadoras que afectaban al EP para la mejora de dicha economía de carrera. Se hipotizó que el EP mejoraría eficientemente la economía de carrera de los deportistas.

A continuación, se expone la lista de publicaciones científica que se presentan en la siguiente parte de esta tesis doctoral:

Artículo 1:

Dudagoitia-Barrio, E., Ramirez-Campillo, R., García-de-Alcaraz, A., & Hernandez-García, R. (2022). Effects of core training on dynamic balance stability: A systematic review and meta-analysis. *Journal of Sports Sciences*, 40(16), 1815-1823.

Journal Citation Report Impact Factor: 3.4

Scimago Journal Report: 1.141

Objetivos: El objetivo principal de esta investigación fue realizar una revisión sistemática y meta-análisis para analizar los efectos del entrenamiento del core en la estabilidad de equilibrio dinámica. El objetivo secundario fue examinar variables moderadoras como la duración del entrenamiento, la frecuencia, el total de sesiones, el equipo, la edad, el estado del entrenamiento y los movimientos durante la estabilidad de equilibrio dinámica.

Hipótesis: el entrenamiento del core es un sistema de entrenamiento eficaz para mejorar la estabilidad de equilibrio dinámica.

Artículo 2:

Dudagoitia-Barrio, E., Hernandez-García, R, Ramirez-Campillo, R., & García-de-Alcaraz, A. (2024). The effects of core training on endurance in different trunk movements: A systematic review and meta-analysis. *Kinesiology*, 56(1), 87-100.

Journal Citation Report Impact Factor: 1.2

Scimago Journal Report: 0.37

Objetivo: El objetivo principal de esta investigación fue realizar una revisión sistemática y meta-análisis para analizar los efectos del entrenamiento del core en la resistencia de los diferentes movimientos del tronco: flexión, extensión y flexiones laterales derecha e izquierda.

Hipótesis: el entrenamiento del core mejoraría todas las mediciones de resistencia de los movimientos del tronco.

Artículo 3:

Dudagoitia-Barrio, E. D., Thapa, R. K., Villanueva-Flores, F., Garcia-Atutxa, I., Santibañez-Gutierrez, A., Fernández-Landa, J., & Ramirez-Campillo, R. (2023). Plyometric Jump Training Exercise Optimization for Maximizing Human Performance: A Systematic Scoping Review and Identification of Gaps in the Existing Literature. *Sports*, 11(8), 150.

Journal Citation Report Impact Factor: 2.7

Scimago Journal Report: 0.88

Objetivo: resumir la literatura científica publicada relacionada con las adaptaciones del rendimiento físico, centrándose en el EP utilizando un enfoque de revisión sistemática del alcance.

Hipótesis: debido al enfoque y análisis de alcance utilizado en este artículo, no se realizó ninguna hipótesis de resultado, ya que su objetivo es identificar lagunas de conocimiento en la literatura.

Artículo 4:

Dudagoitia-Barrio, E., Fernández-Landa, J., Negra, Y., Ramirez-Campillo, R., & García-de-Alcaraz, A. (2023). Effects of plyometric jump training on running economy in endurance runners: A systematic review and meta-analysis. *Kinesiology*, 55(2), 270-281.

Journal Citation Report Impact Factor: 1.2

Scimago Journal Report: 0.37

Objetivo: evaluar los efectos del EP en la economía de carrera y estimar la efectividad de la duración del programa, la frecuencia del entrenamiento, las sesiones totales, la edad de los participantes, el estado del entrenamiento y la velocidad de carrera.

Hipótesis: el EP mejoraría eficientemente la economía de carrera de los deportistas.

Artículo 5:

Dudagoitia-Barrio, E. D., Alvarez, C., Thapa, R. K., Ramachandran, A. K., Singh, U., & Ramirez-Campillo, R. (2023). Jump Rope Training for Health and Fitness in

School-age Participants: Secondary Analyses from a Systematic Review. *International Journal of Kinesiology and Sports Science*, 11(1), 27-41.

Journal Citation Report Impact Factor: NA

Scimago Journal Report: 0.2

Objetivo: evaluar las variables moderadoras relacionadas con el entrenamiento de salto con cuerda para maximizar los parámetros de rendimiento físico y salud.

Hipótesis: la modificación de las diferentes variables moderadoras (por ejemplo, un mayor número de saltos) tendrá adaptaciones específicas tanto en rendimiento como en salud.

PART II

ESTUDIOS PRINCIPALES – MAIN STUDIES

Estudio 1

Título:

Effects of core training on dynamic balance stability: A systematic review and meta-analysis.

Coautores:

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Revista:

Journal of Sports Sciences

Resumen/Abstract:

Core stability has a strong relationship with dynamic balance stability (DBS). The purpose of this review with meta-analysis was to analyse the effects of core training programmes from different studies on DBS. A literature search was performed using different databases. Subgroups analyses on duration, training frequency, total sessions, chronological age, training status, equipment and movements were performed. A random-effects model for meta-analyses was used. Thirteen studies were selected for the systematic review and 10 for the meta-analysis, comprising 226 participants. A moderate effect was noted for core training on DBS ($p < 0.001$; ES = 0.634). Greater DBS improvements were found in core training interventions with ≤6 weeks (ES = 0.714), after high volume (ES = 0.787) and more frequent interventions (ES = 0.787), as well as in younger participants (ES = 0.832). In addition, body weight exercises may be better than med ball, swiss ball or band resisted exercises. Core training improves DBS among athletes and a non-trained population, creating a more solid stable base that allows better lower extremity movements. This could be more effective considering different modulators ≤6 weeks intervention, >2 sessions per week, >17 total sessions, body weight core programmes and applied to ≤18.0 years old.

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Estudio 2

Título:

The effects of core training on endurance in different trunk movements: A systematic review and meta-analysis

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Revista:

Kinesiology

Resumen/Abstract:

Core muscle endurance involves the trunk muscles' capability to maintain a particular position for as much time as possible. It is essential to know how specific training aimed at this area affects endurance of different trunk movements performance and to what extent. The objective was to assess the effects of trunk training on different core muscle endurance measurements in flexion, extension, and right and left lateral flexion. A literature search was performed using different databases. The studies included: (a) cohorts of healthy people or subjects with chronic low back pain; (b) a core training intervention; (c) pre-post intervention parameters of interest; (d) a minimum of 4 out of 10 on the PEDro scale, and (e) randomised controlled trials. A random- effects model for meta-analyses was used. Fifteen studies were selected for the systematic review and 11 for the meta-analysis, comprising 1,213 participants. Compared to the control condition, core training induced a moderate effect on trunk flexion endurance (ES = 0.67), right-lateral trunk flexion endurance (ES = 0.77), left-lateral trunk flexion endurance (ES = 0.94), and a small effect on trunk extension endurance (ES = 0.49). To back up the results presented in this study, more research into the effects of trunk training on core muscle endurance is needed to confirm these results significantly. Core training improves core muscle endurance in four trunk movements. Core training is more effective in participants with pre-intervention poor results.

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Estudio 3

Título:

Plyometric Jump Training Exercise Optimization for Maximizing Human Performance: A Systematic Scoping Review and Identification of Gaps in the Existing Literature

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Revista:

Sports

Resumen/Abstract:

Background: Plyometric jump training (PJT) encompasses a range of different exercises that may offer advantages over other training methods to improve human physical capabilities (HPC). However, no systematic scoping review has analyzed either the role of the type of PJT exercise as an independent prescription variable or the gaps in the literature regarding PJT exercises to maximize HPC. Objective: This systematic scoping review aims to summarize the published scientific literature and its gaps related to HPC adaptations (e.g., jumping) to PJT, focusing on the role of the type of PJT exercise as an independent prescription variable. Methods: Computerized literature searches were conducted in the PubMed, Web of Science, and SCOPUS electronic databases. Design (PICOS) framework: (P) Healthy participants of any age, sex, fitness level, or sports background; (I) Chronic interventions exclusively using any form of PJT exercise type (e.g., vertical, unilateral). Multimodal interventions (e.g., PJT + heavy load resistance training) will be considered only if studies included two experimental groups under the same multimodal intervention, with the only difference between groups being the type of

PJT exercise. (C) Comparators include PJT exercises with different modes (e.g., vertical vs. horizontal; vertical vs. horizontal combined with vertical); (O) Considered outcomes (but not limited to): physiological, biomechanical, biochemical, psychological, performance- related outcomes/adaptations, or data on injury risk (from prevention-focused studies); (S) Single- or multi-arm, randomized (parallel, crossover, cluster, other) or non-randomized. Results: Through database searching, 10,546 records were initially identified, and 69 studies (154 study groups) were included in the qualitative synthesis. The DJ (counter, bounce, weighted, and modified) was the most studied type of jump, included in 43 study groups, followed by the CMJ (standard CMJ or modified) in 19 study groups, and the SJ (standard SJ or modified) in 17 study groups. Strength and vertical jump were the most analyzed HPC outcomes in 38 and 54 studies, respectively. The effects of vertical PJT versus horizontal PJT on different HPC were compared in 21 studies. The effects of bounce DJ versus counter DJ (or DJ from different box heights) on different HPC were compared in 26 studies. Conclusions: Although 69 studies analyzed the effects of PJT exercise type on different HPC, several gaps were identified in the literature. Indeed, the potential effect of the PJT exercise type on a considerable number of HPC outcomes (e.g., aerobic capacity, flexibility, asymmetries) are virtually unexplored. Future studies are needed, including greater number of participants, particularly in groups of females, senior athletes, and youths according to maturity. Moreover, long-term (e.g., >12 weeks) PJT interventions are needed.

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Estudio 4

Título:

Effects of plyometric jump training on running economy in endurance runners: A systematic review and meta-analysis

Coautores:

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Revista:

Kinesiology

Resumen/Abstract:

Running economy (RE) has a strong relationship with distance running performance and is defined as the energy demand for a given velocity. Plyometric jump training may improve RE. The present study aimed to assess the effects of plyometric jump training on endurance runners' running economy and to estimate the effectiveness of program duration, training frequency, total sessions, age, training status and velocity. A literature search was performed using PubMed/MEDLINE, Web of Science, and SCOPUS databases. Subgroup and single training factor analyses of program duration, frequency, total sessions, chronological age, training status, and running velocity were performed. A random-effects model for meta-analyses was used. Eighteen studies were selected for the systematic review and 10 for the meta-analysis. A trivial effect was noted for plyometric jump training on running economy (ES=0.19). However, plyometric jump training combined with resistance training revealed a large effect on running economy (ES=1.34). Greater running economy improvements were noted after training interventions with >15 total sessions (ES=1.00), >7 weeks (ES=0.95) and >2 days/week (ES=0.89). The youngest (ES=0.95) and highly trained participants (ES=0.94) with faster velocities (ES=0.95) obtained better results. Our findings highlight the effect of plyometric jump training that may improve running economy, particularly in combination with resistance training, after longer- term interventions (i.e., >15 total sessions, >7 weeks), with greater frequency, and among younger and more highly trained runners, especially during running at higher competitive velocities.

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Estudio 5

Título:

Jump Rope Training for Health and Fitness in School-age Participants: Secondary Analyses from a Systematic Review

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Revista:

International Journal of Kinesiology & Sports Science

Resumen/Abstract:

Background: Altering moderator variables during a jump rope training (JRT) program can provide a novel training modification that can be used to modify the specific training outcomes. JRT is commonly implemented as a traditional game activity in many countries as an old culture of physical activity in school-age participants (SAP). However, strength and conditioning professionals need to know how JRT moderator variables affect these health- and physical fitness outcomes. Thus, an evidence-gap map (EGM) could provides a clearer picture of the design of an appropriate JRT based on scientific evidence. Objective: the purpose of this systematic review secondary analysis was to assess the moderator variables related to JRT effectiveness for health and physical fitness-related outcomes in SAP. Method: literature searches were conducted in the following electronic databases: PubMed, Web of Science and SCOPUS. The PICOS (participants, intervention, comparators, outcomes, and study design) approach was used to rate studies for eligibility. An EGM will be constructed to graphically represent the body of evidence and the current research gaps. Results: 10,546 records were initially identified and finally, 8 studies were considered. A total of 186 participants were analysed in the intervention groups (16 groups). Five of seven studies measured health-related parameters and five of eight included fitness-related parameters. Conclusion: rope weight (e.g., weighted rope i.e. 695 g), adequate post-exercise recovery strategies (e.g., dark chocolate supplementation), type of jump (e.g., freestyle), and total number of jumps, can be manipulated into JRT programs to optimise health and physical related capacities among SAP.

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PART III

CONCLUSIONES - CONCLUSIONS

Conclusiones generales

Los cinco estudios presentados en esta tesis doctoral (i) estudian la funcionalidad del entrenamiento del core, tanto para la mejora de la estabilidad dinámica como para la resistencia de los movimientos del tronco (estudios 1 y 2); (ii) sintetizan la literatura científica publicada del EP con el foco en los tipos y calidad de movimiento en relación a las capacidades físicas y el rendimiento deportivo (estudio 3); (iii) evalúan los efectos del EP en economía de carrera estimando la efectividad de la duración del programa, la frecuencia del entrenamiento, las sesiones totales, la edad de los participantes, el estado del entrenamiento y la velocidad de carrera (estudio 4); y (iv) presentan un análisis para evaluar las variables moderadoras del salto con cuerda que afectan a las adaptaciones tanto del rendimiento como de la salud (estudio 5). Estos hallazgos pueden ayudar a profesionales médicos, entrenadores y preparadores físicos en el proceso de toma de decisiones para la mejora del rendimiento y la prevención de lesiones.

Los resultados individuales de cada estudio se exponen en profundidad en sus respectivas secciones. No obstante, a continuación, se ofrece una visión general de las conclusiones más destacadas:

Estudio 1. *Effects of core training on dynamic balance stability: a systematic review and meta-analysis.*

Los resultados de esta revisión sistemática con meta-análisis respaldan que el entrenamiento del core es efectivo para mejorar la estabilidad dinámica. Las intervenciones de: ≤6 semanas, >2 sesiones por semana, >17 sesiones totales, y programas que emplean el propio peso corporal y actúan en sujetos de ≤18,0 años muestran los efectos más significativos sobre la estabilidad dinámica. Por tanto, el entrenamiento del core mejora de manera similar todos los movimientos de la estabilidad del equilibrio dinámico (anterior, posteromedial y posterolateral).

Estudio 2. *The effects of core training on endurance in different trunk movements: a systematic review and meta-analysis.*

El entrenamiento del core mejora la resistencia muscular de cuatro movimientos principales del tronco (flexión, extensión, y flexión lateral derecha e izquierda). Las mayores mejoras se observaron en los movimientos de flexión del tronco y flexión lateral derecha e izquierda. La resistencia en la extensión del tronco mejoró con un efecto menor.

Los deportistas con menor resistencia en los movimientos del tronco en la pre-intervención obtienen mejores resultados tras una intervención de entrenamiento específico del core, mientras que los atletas con el peor nivel de condición física previo se benefician más del entrenamiento del core que los atletas de alto nivel.

Estudio 3. *Plyometric jump training exercise optimization for maximizing human performance: a systematic review scoping review.*

Explorar las lagunas bibliográficas sobre las adaptaciones del rendimiento a través del EP revela la necesidad de realizar una investigación integral y de alta calidad en diferentes capacidades físicas, como la estabilidad, flexibilidad y capacidad aeróbica.

El salto vertical es el aspecto más investigado con 54 estudios comparativos. Por el contrario, las variables de rendimiento como la capacidad aeróbica, la flexibilidad y las asimetrías son las menos investigadas con sólo dos estudios realizados para cada variable.

Los tipos de ejercicios pliométricos más investigados son el DJ versus CMJ, DJ focalizando en el mínimo rebote posible versus DJ centrado en saltar lo máximo posible, los saltos bilaterales versus saltos verticales y saltos verticales versus saltos horizontales.

Estudio 4. *Effects of plyometric jump training on running economy in endurance runners: a systematic review and meta-analysis.*

Los resultados no mostraron un efecto significativo del EP sobre la economía de carrera. Sin embargo, cuando se combina con el entrenamiento de fuerza tradicional, el EP demuestra una influencia positiva sustancial en la economía de carrera.

Las intervenciones de: >7 semanas, >2 sesiones por semana, >15 sesiones totales presentan una mayor incidencia en la mejora de la economía de carrera. De esta forma, el EP tiene más incidencia en la mejora de la economía de carrera en carreras de >13 km/h y en sujetos de <25 años y con mayor nivel de entrenamiento.

Estudio 5. *Jump rope training for health and fitness in school-age participants: secondary analyzes of a systematic review.*

Debido al número limitado de estudios de alta calidad (p. ej., ensayos controlados aleatorios) actualmente disponibles en relación con los efectos de las variables de programación del salto con cuerda (p. ej., intensidad; duración), no existe una recomendación sólida con respecto a su prescripción óptima.

Limitaciones y futuras líneas de investigación

La presente tesis doctoral no está exenta de limitaciones. La mayoría de ellas han sido comentadas en cada uno de los diferentes estudios desarrollados anteriormente (Parte II). No obstante, en este apartado se destacan algunas limitaciones generales que pueden servir de punto de partida para futuras investigaciones:

Si bien está claro que trabajar los músculos del core mejora el equilibrio dinámico, sería interesante comparar la importancia relativa de las diferentes cualidades del core, como la fuerza y la resistencia. Esto nos ayudaría a determinar qué aspecto del core es más decisivo. De esta manera, los entrenadores y expertos tendrían más información sobre cómo implementar este tipo de entrenamiento en sus programas de ejercicio.

Mejora de las pruebas de estabilidad dinámica. El SEBT es la prueba más utilizada para medir este parámetro; no obstante, puede tener algunas limitaciones dependiendo en qué sujetos se aplica y verse afectados los resultados debido a otras capacidades como la flexibilidad [128].

A pesar de haber concluido que fortalecer el core mejora la estabilidad y la resistencia de los músculos del tronco, aún no está claro si esto se traduce en movimientos deportivos más eficientes. Podría resultar interesante investigar si existe una relación entre desequilibrios musculares, debilidad del core y patrones de movimiento incorrectos.

El EP parece una herramienta muy eficaz para la mejora del rendimiento deportivo. A pesar de ello, todavía existen muchas capacidades físicas de este tipo de entrenamiento por investigar (tabla 9). Como se observó en los estudios 3 y 5, todavía existe una laguna de conocimiento debido al *número limitado de estudios de alta calidad* (por ejemplo, ensayos controlados aleatorios) actualmente disponibles, por lo que no hay una recomendación sólida con respecto a su prescripción óptima.

Una vez identificadas las debilidades de los sujetos, aplicar realmente relaciones entre puntos débiles y rendimiento. Otra limitación de esta tesis y una posible futura línea de investigación es la necesidad de corroborar en el contexto deportivo los resultados de los estudios, estableciendo así una relación real entre la fuerza de los músculos del core, la estabilidad y la calidad del movimiento de un gesto deportivo. Además, habría que clarificar si el rendimiento deportivo se ve influenciado por las mejoras en las variables medidas en los estudios. En los anexos de esta tesis doctoral se ha planteado una futura línea de investigación que se está desarrollando para solventar esta laguna de conocimiento (ver Anexo 1).

Faltan herramientas de campo para medir la calidad de movimiento en movimientos rápidos que puedan reproducir los gestos deportivos. En base a esto, una línea de investigación anexa a esta tesis doctoral se está desarrollando con el primer artículo científico recientemente publicado titulado “Single-Leg Countermovement Jump Compensation Assessment: Content Validity of a Checklist” [409].

General conclusions

The five studies presented in this doctoral thesis (i) investigate the functionality of core training for both improving dynamic stability and trunk movement endurance (studies 1 and 2); (ii) synthesize the published scientific literature on PJT , focusing on movement types and quality in relation to physical capacities and athletic performance (study 3); (iii) evaluate the effects of PJT on running economy, estimating the effectiveness of program duration, training frequency, total sessions, participant age, training status, and running speed (study 4); and (iv) present an analysis to evaluate the moderating variables of jump rope that affect both performance and health adaptations (study 5). These findings can assist medical professionals, coaches, and strength and conditioning coaches in decision-making for performance enhancement and injury prevention.

The individual results of each study are presented in depth in their respective sections. However, an overview of the most notable findings is provided below:

Study 1. *Effects of core training on dynamic balance stability: a systematic review and meta-analysis.*

· The results of this systematic review with meta-analysis support that core training is effective in improving dynamic stability.

· Interventions of: ≤6 weeks, >2 sessions per week, >17 total sessions, and bodyweight programs performed on subjects ≤18.0 years of age show the most significant effects on dynamic stability.

· Core training similarly improves all dynamic balance stability movements (anterior, posteromedial, and posterolateral).

Study 2. *The effects of core training on endurance in different trunk movements: a systematic review and meta-analysis.*

· Core training improves muscular endurance in four major trunk movements (flexion, extension, and right and left lateral flexion).

· The greatest improvements were seen in trunk flexion and right and left lateral flexion movements. Trunk extension endurance improved with a minor effect.

· Athletes with lower pre-intervention trunk movement endurance perform better after a core-specific training intervention.

· Athletes with the lowest pre-intervention fitness level benefit more from core training than high-level athletes.

Study 3. *Plyometric jump training exercise optimization for maximizing human performance: a systematic review scoping review.*

· Exploring the literature gaps on performance adaptations through PE reveals the need for comprehensive, high-quality research on different physical capacities, such as stability, flexibility, and aerobic capacity.

· Vertical jump is the most researched aspect with 54 comparative studies. In contrast, performance variables such as aerobic capacity, flexibility, and asymmetries are the least researched with only two studies conducted for each variable.

· The most researched types of plyometric exercises are DJ versus CMJ, DJ focusing on the least possible bounce versus DJ focusing on jumping as much as possible, bilateral jumps versus vertical jumps, and vertical jumps versus horizontal jumps.

Study 4. *Effects of plyometric jump training on running economy in endurance runners: a systematic review and meta-analysis.*

· The results did not show a significant effect of plyometric training on running economy. However, when combined with traditional strength training, plyometric training demonstrates a substantial positive influence on running economy.

· Interventions of >7 weeks, >2 sessions per week, >15 total sessions have a greater incidence in improving running economy.

· Plyometric training has a greater incidence in improving running economy in races of >13 km/h and in subjects aged <25 years and with a higher level of training.

Study 5. *Jump rope training for health and fitness in school-age participants: secondary analyzes of a systematic review.*

· Due to the limited number of high-quality studies (e.g., randomized controlled trials) currently available on the effects of jump rope programming variables (e.g., intensity; duration), there is no strong recommendation for its optimal prescription.

Limitations and future research lines

This doctoral thesis is not without limitations. Most of them have been commented on in each of the different studies developed previously (Part II). In this section, therefore, some general limitations are highlighted that can serve as a starting point for future research:

Although it is evident that core muscle training enhances dynamic balance, a comparative analysis of the relative significance of various core attributes, including strength and endurance, would be beneficial. This would enable us to ascertain which core quality is most pivotal. Consequently, fitness professionals would be equipped with more comprehensive knowledge to incorporate core training effectively into their exercise regimens.

Improvement of dynamic stability tests; the SEBT is the most used test to measure this parameter, however, it may have some limitations depending on which subjects it is applied and the results may be affected by other capacities such as flexibility.

Despite the established finding that core strengthening enhances trunk muscle stability and endurance, it remains uncertain whether this translates into improved athletic performance. It would be pertinent to investigate whether there is a correlation between muscular imbalances, core weakness, and faulty movement patterns

Plyometric training seems to be a very effective tool for improving sports performance. Despite this, there are still many physical capabilities of this type of training to be investigated (see Table 9).

As observed in studies 3 and 5, there is still a knowledge gap due to the limited number of high-quality studies (e.g. randomized controlled trials) currently available, so there is *no solid recommendation regarding its optimal prescription*. Nevertheless, as an alternative to traditional plyometric jump training, rope training can offer significant improvements in health and fitness measures. Once the subjects' weaknesses have been identified, it is necessary to actually apply relationships between weaknesses and performance. Another limitation of this thesis and a possible future line of research is the need to corroborate the results of the studies in the sports context, thus establishing a real relationship between core muscle strength, stability and the quality of movement of a sports gesture. In addition, it would be necessary to clarify whether sports performance is influenced by improvements in the variables measured in the studies. In the appendices of this doctoral thesis, a future line of research has been proposed that is being developed to solve this knowledge gap (see Appendix 1).

There is a lack of field tools to measure the quality of movement in fast movements that can reproduce sports gestures. Based on this, a line of research annexed to this doctoral thesis is being developed with the first scientific article recently published entitled "Single-Leg Countermovement Jump Compensation Assessment: Content Validity of a Checklist" [409].

PART IV

Referencias

1. Westcott WL. Resistance training is medicine: effects of strength training on health. Current sports medicine reports. 2012;11:209–16.

2. Gault ML, Willems ME. Aging, functional capacity and eccentric exercise training. Aging and disease. 2013;4:351.

3. Izquierdo M, Cadore EL. Multicomponent exercise with power training: A vital intervention for frail older adults. The Journal of nutrition, health and aging. 2023;100008.

4. Travis TW, Brown DL. Human Performance Optimization: A Framework for the Military Health System. Military Medicine. 2023;188:44–8.

5. Hibbs AE, Thompson KG, French D, Wrigley A, Spears I. Optimizing performance by improving core stability and core strength. Sports medicine (Auckland, NZ). 2008;38:995–1008.

6. Hodges PW. Core stability exercise in chronic low back pain. Orthopedic Clinics of North America. 2003;34:245–54.

7. Majewski-Schrage T, Evans TA, Ragan B. Development of a Core-Stability Model: A Delphi Approach. Journal of Sport Rehabilitation. 2014;23:95–106.

8. Kibler WB, Press J, Sciascia A. The Role of Core Stability in Athletic Function. Sports Medicine. 2006;36:189–98.

9. Cook G. Movement. Santa Cruz. CA: On Target Publications; 2010.

10. Allison GT, Morris SL. Transversus abdominis and core stability: Has the pendulum swung? British Journal of Sports Medicine. 2008;42:630–1.

11. Vasseljen O, Unsgaard-tøndel M, Westad C. Effect of Core Stability Exercises on Feed-Forward. Spine. 2012;37:1101–8.

12. Allison GT, Morris SL, Lay B. Feedforward responses of transversus abdominis are directionally specific and act asymmetrically: Implications for core stability theories. Journal of Orthopaedic and Sports Physical Therapy. 2008;38:228–37.

13. Saeterbakken AH, Van Den Tillaar R, Seiler S. Effect of core stability training on throwing velocity in female handball players. Journal of Strength and Conditioning Research. 2011;25:712–8.

14. Santos MS, Behm DG, Barbado D, DeSantana JM, Da Silva-Grigoletto ME. Core Endurance Relationships With Athletic and Functional Performance in Inactive People. Frontiers in physiology. 2019;10:1490.

15. McGill SM, Childs A, Liebenson C. Endurance times for low back stabilization exercises: Clinical targets for testing and training from a normal database. Archives of Physical Medicine and Rehabilitation. 1999;80:941–4.

16. Sibson BE, Tobolsky VA, Kistner TM, Holowka NB, Jemutai J, Sigei TK, et al. Trunk muscle endurance, strength and flexibility in rural subsistence farmers and urban industrialized adults in western Kenya. Am J Hum Biol. 2021;ajhb.23611.

17. Granacher U, Schellbach J, Klein K, Prieske O, Baeyens JP, Muehlbauer T. Effects of core strength training using stable versus unstable surfaces on physical fitness in adolescents: A randomized controlled trial. BMC Sports Science, Medicine and Rehabilitation. 2014;6.

18. Hung KC, Chung HW, Yu CCW, Lai HC, Sun FH. Effects of 8-week core training on core endurance and running economy. PLoS ONE. 2019;14:1–12.

19. Hsu S-L, Oda H, Shirahata S, Watanabe M, Sasaki M. Effects of core strength training on core stability. Journal of Physical Therapy Science. 2018;30:1014–8.

20. Ogaya S, Suzuki M, Yoshioka C, Nakamura Y, Kita S, Watanabe K. The effects of trunk endurance training on running kinematics and its variability in novice female runners. Sports Biomechanics. 2021;1–12.

21. Reed CA, Ford KR, Myer GD, Hewett TE. The effects of isolated and integrated 'core stability'training on athletic performance measures. Sports medicine. 2012;42:697–706.

22. Hrysomallis C. Balance ability and athletic performance. Sports medicine. 2011;41:221–32.

23. Rizzato A, Paoli A, Marcolin G. Different gymnastic balls affect postural balance rather than core-muscle activation: A preliminary study. Applied Sciences (Switzerland). 2021;11:1–8.

24. Gebel A, Lesinski M, Behm DG, Granacher U. Effects and dose–response relationship of balance training on balance performance in youth: a systematic review and meta-analysis. Sports Medicine. 2018;48:2067–89.

25. Anderson K, Behm DG. The impact of instability resistance training on balance and stability. Sports medicine. 2005;35:43–53.

26. Powden CJ, Dodds TK, Gabriel EH. The reliability of the star excursion balance test and lower quarter y-balance test in healthy adults: a systematic review. International journal of sports physical therapy. 2019;14:683.

27. Ambegaonkar JP, Cortes N, Caswell SV, Ambegaonkar GP, Wyon M. Lower extremity hypermobility, but not core muscle endurance influences balance in female collegiate dancers. International journal of sports physical therapy. 2016;11:220.

28. Nakagawa TH, Petersen RS. Relationship of hip and ankle range of motion, trunk muscle endurance with knee valgus and dynamic balance in males. Physical Therapy in Sport. 2018;34:174–9.

29. Özmen T, Gafuroğlu Ü, Aliyeva A, Elverici E. Relationship between core stability and dynamic balance in women with postmenopausal osteoporosis. Turkish journal of physical medicine and rehabilitation. 2018;64:239–45.

30. Chang W-D, Chou L-W, Chang N-J, Chen S. Comparison of functional movement screen, star excursion balance test, and physical fitness in junior athletes with different sports injury risk. BioMed research international. 2020;2020.

31. Fitton Davies K, Sacko RS, Lyons MA, Duncan MJ. Association between functional movement screen scores and athletic performance in adolescents: A systematic review. Sports. 2022;10:28.

32. Hewett TE, Ford KR, Hoogenboom BJ, Myer GD. Understanding and preventing acl injuries: current biomechanical and epidemiologic considerations-update 2010. North American journal of sports physical therapy. 2010;5:234.

33. Jeong J, Choi D-H, Shin CS. Core Strength Training Can Alter Neuromuscular and Biomechanical Risk Factors for Anterior Cruciate Ligament Injury. Am J Sports Med. 2021;49:183–92.

34. Hernández-García R, Gil-López MI, Martínez-Pozo D, Martínez-Romero MT, Aparicio-Sarmiento A, Cejudo A, et al. Validity and Reliability of the New Basic Functional Assessment Protocol (BFA). IJERPH. 2020;17:4845.

35. van der Kruk E, Silverman AK, Koizia L, Reilly P, Fertleman M, Bull AMJ. Age-related compensation: Neuromusculoskeletal capacity, reserve & movement objectives. Journal of Biomechanics. 2021;122:110385.

36. Carrasco-Huenulef C, Poblete-Garrido M, Monrroy-Uarac M, Ramirez-Campillo R, Moran J, Gajardo-Burgos R. Effects of a neuromuscular training program on anterior cruciate ligament injury risk factors in youth female basketball players: a pilot study. Gazz Med Ital - Arch Sci Med [Internet]. 2019 [cited 2022 Sep 21];178. Available from: https://www.minervamedica.it/index2.php?show=R22Y2019N03A0137

37. Bengtsson V, Berglund L, Aasa U. Narrative review of injuries in powerlifting with special reference to their association to the squat, bench press and deadlift. BMJ Open Sport—Exercise Medicine. 2018;4.

38. Foran, B. High-Performance Sports Conditioning. Human Kinetics.

39. Krzysztofik, Wilk, Wojdała, Gołaś. Maximizing Muscle Hypertrophy: A Systematic Review of Advanced Resistance Training Techniques and Methods. IJERPH. 2019;16:4897.

40. Ramirez-Campillo R, Álvarez C, García-Hermoso A, Ramírez-Vélez R, Gentil P, Asadi A, et al. Methodological Characteristics and Future Directions for Plyometric Jump Training Research: A Scoping Review. Sports Medicine. 2018;48:1059–81.

41. Ramirez-Campillo R, Moran J, Chaabene H, Granacher U, Behm DG, Garcia-Hermoso A and IM. Methodological characteristics and future directions for plyometric jump training research: A scoping review update. Scandinavian Journal of Medicine & Science in Sports. 2020;30:983–97.

42. Suchomel TJ, Taber CB, Sole CJ, Stone MH. Force-time differences between ballistic and non-ballistic half-squats. Sports. 2018;6:79.

43. Cormie P, McGuigan MR, Newton RU. Developing maximal neuromuscular power: part 2—training considerations for improving maximal power production. Sports medicine. 2011;41:125–46.

44. Ramirez-Campillo R, Alvarez C, García-Pinillos F, Gentil P, Moran J, Pereira LA, et al. Effects of plyometric training on physical performance of young Male soccer players: Potential effects of different drop jump heights. Pediatric Exercise Science. 2019;31:306–13.

45. Loturco I, Pereira LA, Kobal R, Zanetti V, Kitamura K, Abad CCC, et al. Transference effect of vertical and horizontal plyometrics on sprint performance of high-level U-20 soccer players. Journal of sports sciences. 2015;33:2182–91.

46. Loturco I, Tricoli V, Roschel H, Nakamura FY, Abad CCC, Kobal R, et al. Transference of traditional versus complex strength and power training to sprint performance. Journal of human kinetics. 2014;41:265.

47. Chu D, Myer G. Anatomy and physiology of plyometrics. Plyometrics Champaign, IL: Human Kinetics. 2013;13–4.

48. Gentil P, Ramirez-Campillo R, Souza D. Resistance training in face of the coronavirus outbreak: Time to think outside the box. Frontiers in physiology. 2020;11:859.

49. Ward P, Hodges NJ, Starkes JL, Williams MA. The road to excellence: Deliberate practice and the development of expertise. High ability studies. 2007;18:119–53.

50. Hewett TE, Myer GD. Reducing knee and anterior cruciate ligament injuries among female athletes–a systematic review of neuromuscular training interventions. The journal of knee surgery. 2005;18:82–8.

51. Rössler R, Donath L, Verhagen E, Junge A, Schweizer T, Faude O. Exercise-based injury prevention in child and adolescent sport: a systematic review and meta-analysis. Sports medicine. 2014;44:1733–48.

52. Yuill EA, Pajaczkowski JA, Howitt SD. Conservative care of sports hernias within soccer players: a case series. Journal of bodywork and movement therapies. 2012;16:540–8.

53. Ramirez-Campillo R, Miñano J, Sanchez-Sanchez J. Efecto del entrenamiento pliométrico sobre el rendimiento del futbolista. Rev Prep Física Fútbol. 2019;30:1–10.

54. Flanagan EP, Comyns TM. The use of contact time and the reactive strength index to optimize fast stretch-shortening cycle training. Strength & Conditioning Journal. 2008;30:32–8.

55. Lloyd RS, Oliver JL, Hughes MG, Williams CA. The effects of 4-weeks of plyometric training on reactive strength index and leg stiffness in male youths. The Journal of Strength & Conditioning Research. 2012;26:2812–9.

56. Cappa DF, Behm DG. Neuromuscular characteristics of drop and hurdle jumps with different types of landings. The Journal of Strength & Conditioning Research. 2013;27:3011–20.

57. Ebben WP, Fauth ML, Garceau LR, Petushek EJ. Kinetic quantification of plyometric exercise intensity. The Journal of Strength & Conditioning Research. 2011;25:3288–98.

58. Pedley JS, Lloyd RS, Read P, Moore IS, Oliver JL. Drop jump: A technical model for scientific application. Strength & conditioning journal. 2017;39:36–44.

59. Radnor JM, Oliver JL, Waugh CM, Myer GD, Moore IS, Lloyd RS. The influence of growth and maturation on stretch-shortening cycle function in youth. Sports Medicine. 2018;48:57–71.

60. Taube W, Leukel C, Gollhofer A. How neurons make us jump: the neural control of stretch-shortening cycle movements. Exercise and sport sciences reviews. 2012;40:106–15.

61. Komi PV. Stretch-shortening cycle. Strength and power in sport. 2003;3:184–202.

62. Jiménez-Reyes P, Samozino P, Brughelli M, Morin J-B. Effectiveness of an individualized training based on force-velocity profiling during jumping. Frontiers in physiology. 2017;677.

63. Moran J, Ramirez R, Bernard C, Helmi L, Behm DG. Effects of Vertically and Horizontally Orientated Plyometric Training on Physical Performance : A Meta - analytical Comparison. Sports Medicine. 2020;1–15.

64. Ramírez-Campillo, R., Gallardo, F., Henriquez-Olguín, C., Meylan, C. M., Martínez, C., Álvarez, C., Caniuqueo, A., Cadore EL, & Izquierdo M. Effect of vertical, horizontal, and combined plyometric training on explosive, balance, and endurance performance of young soccer players. The Journal of Strength & Conditioning Research. 2015;29:1784–95.

65. Bouguezzi R, Chaabene H, Negra Y, Moran J, Sammoud S, Ramirez-Campillo R, et al. Effects of jump exercises with and without stretch-shortening cycle actions on components of physical fitness in prepubertal male soccer players. Sport Sciences for Health. 2020;16:297–304.

66. Bobbert MF. Drop jumping as a training method for jumping ability. Sports medicine. 1990;9:7–22.

67. Bobbert MF, Gerritsen KG, Litjens MC, Van Soest AJ. Why is countermovement jump height greater than squat jump height? Medicine and science in sports and exercise. 1996;28:1402–12.

68. Bobbert MF, Huijing PA, Van Ingen Schenau GJ. Drop jumping. II. The influence of dropping height on the biomechanics of drop jumping. Medicine and science in sports and exercise. 1987;19:339–46.

69. Bobbert MF, Huijing PA, Schenau G. Drop jumping. I. The influence of jumping technique on the biomechanics of jumping. Medicine & Science in Sports & Exercise. 1987;19:332–8.

70. Chu DA. Jumping into plyometrics. Human Kinetics; 1998.

71. Kraemer W, Comstock B, Clark J, Dunn-Lewis C, Hoffman J. NSCA's Guide to Program Design. Champain, IL: Human Kinetics. 2012;10–26.

72. NSCA A. Position statement: Explosive/plyometric exercises. NSCA Journal. 1993;15:514.

73. Saunders PU, Pyne DB, Telford RD, Hawley JA. Factors affecting running economy in trained distance runners. Sports medicine. 2004;34:465–85.

74. Barnes KR, Kilding AE. Strategies to Improve Running Economy. Sports medicine. 2015;45:37–56.

75. Balsalobre-Fernández, C., Santos-Concejero, J., & Grivas GV. Effects of strength training on running economy in highly trained runners: a systematic review with

meta-analysis of controlled trials. Journal of strength and conditioning research. 2016;30:2361–8.

76. Paavolainen, L., Hakkinen, K., Hamalainen, I., Nummela, A., & Rusko H. Explosive-strength training improves 5-km running time by improving running economy and muscle power. Journal of applied physiology. 1999;86:1527–33.

77. Goodwin MH. The serious side of jump rope: Conversational practices and social organization in the frame of play. The Journal of American Folklore. 1985;98:315–30.

78. García-Pinillos, F., Lago-Fuentes, C., Latorre-Román, P. A., Pantoja-Vallejo, A., & Ramirez-Campillo, R. Jump-rope training: Improved 3-km time-trial performance in endurance runners via enhanced lower-limb reactivity and foot-arch stiffness. International journal of sports physiology and performance. 2020;15:927–33.

79. Hamid A, Jalali-Fard A, Abdinejad H. A comparison of two aerobic training methods (running vs rope jumping) on health-related physical fitness in 10 to 12 years old boys. Physical Activity Review. 2016;4:9–17.

80. Chen, Chao-Chien, Chen, C. C., & Lin, Y. C. Jumping Rope Intervention on Health-Related Physical Fitness in Students with Intellectual Impairment. The Journal of Human Resource and Adult Learning. 2012;8:56–62.

81. Singh, U., Ramachandran, A. K., Ramirez-Campillo, R., Perez-Castilla, A., Afonso, J., Manuel Clemente, F., & Oliver, J. Jump rope training effects on health-and sport-related physical fitness in young participants: A systematic review with meta-analysis. Journal of Sports Sciences. 2022;1–14.

82. Sortwell A, Newton M, Marinho DA, Ferraz R, Perlman D. The effects of an eight week plyometric-based program on motor performance skills and muscular power

in 7–8-year-old primary school students. International Journal of Kinesiology and Sports Science. 2021;9:1–12.

83. Kim J, Son W-M, Headid III RJ, Pekas EJ, Noble JM, Park S-Y. The effects of a 12-week jump rope exercise program on body composition, insulin sensitivity, and academic self-efficacy in obese adolescent girls. Journal of Pediatric Endocrinology and Metabolism. 2020;33:129–37.

84. Chottidao, M., Kuo, C. H., Tsai, S. C., Hwang, S., Lin, J. J., & Tsai, Y. S. A Comparison of Plyometric and Jump Rope Training Programs for Improving Punching Performance in Junior Amateur Boxers. Frontiers in Bioengineering and Biotechnology. 2022;10.

85. Jahromi MS, Gholami M. The effect of jump-rope training on the physical fitness of 9 to 10 years old female students. Advances in Applied Science Research. 2015;6:135–40.

86. Trecroci A, Cavaggioni L, Caccia R, Alberti G. Jump rope training: Balance and motor coordination in preadolescent soccer players. Journal of sports science & medicine. 2015;14:792.

87. Dolphens M, Cagnie B, Coorevits P, Vanderstraeten G, Cardon G, D'hooge R, et al. Sagittal standing posture and its association with spinal pain: a school-based epidemiological study of 1196 Flemish adolescents before age at peak height velocity. Spine. 2012;37:1657–66.

88. Chaudhari AMW, VAN Horn MR, Monfort SM, Pan X, Oñate JA, Best TM. Reducing Core Stability Influences Lower Extremity Biomechanics in Novice Runners. Medicine and science in sports and exercise. 2020;52:1347–53.

89. Trampas A, Mpeneka A, Malliou V, Godolias G, Vlachakis P. Immediate effects of Core-Stability exercises and clinical massage on Dynamic-Balance performance of patients with chronic specific low back pain. Journal of Sport Rehabilitation. 2015;24:373–83.

90. Prieske O, Muehlbauer T, Borde R, Gube M, Bruhn S, Behm DG, et al. Neuromuscular and athletic performance following core strength training in elite youth soccer: Role of instability. Scandinavian Journal of Medicine and Science in Sports. 2016;26:48–56.

91. Saeterbakken AH, Loken E, Scott S, Hermans E, Vereide VA, Andersen V. Effects of ten weeks dynamic or isometric core training on climbing performance among highly trained climbers. PLOS ONE. 2018;13:e0203766.

92. Benis R, Bonato M, La Torre A. Elite female basketball players' body-weight neuromuscular training and performance on the Y-balance test. Journal of Athletic Training. 2016;51:688–95.

93. Örgün E, Kurt C, Özsu I. The effect of static and dynamic core exercises on dynamic balance, spinal stability, and hip mobility in female office workers. Turkish Journal of Physical Medicine and Rehabilitation. 2020;66:271–80.

94. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. Declaración PRISMA 2020: una guía actualizada para la publicación de revisiones sistemáticas. Revista Española de Cardiología. 2021;74:790–9.

95. Coar JT, Sewell JP. Zotero: harnessing the power of a personal bibliographic manager. Nurse educator. 2010;35:205–7.

96. de Morton NA. The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. Australian Journal of Physiotherapy. 2009;55:129–33.

97. Schardt C, Adams MB, Owens T, Keitz S FP. Utilization of the PICO framework to improve searching PubMed for clinical questions. BMC Med Inform Decis Mak. 2007;7.

98. García-Hermoso A, Ramírez-Campillo R, Izquierdo M. Is muscular fitness associated with future health benefits in children and adolescents? A systematic review and meta-analysis of longitudinal studies. Sports Medicine. 2019;49:1079–94.

99. Deeks, J. J., Higgins, J. P., Altman, D. G. & CSMG. Analysing data and undertaking meta-analyses. Cochrane handbook for systematic reviews of interventions. 2019;241–84.

100. Kontopantelis, E., Springate, D. A., & Reeves D. A re-analysis of the Cochrane Library data: the dangers of unobserved heterogeneity in meta-analyses. PloS one. 2013;8:e69930.

101. Hardy, R. J., & Thompson SG. A likelihood approach to meta-analysis with random effects. Statistics in medicine. 1996;15:619–29.

102. Hopkins W, Marshall S, Batterham A, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Medicine+ Science in Sports+ Exercise. 2009;41:3.

103. Higgins, J. P., Thompson, S. G., Deeks, J. J., & Altman DG. Measuring inconsistency in meta-analyses. Bmj. 2003;327:557–60.

104. Higgins, J. P., & Thompson SG. Quantifying heterogeneity in a meta-analysis. Statistics in medicine. 2002;21:1539–58.

105. Egger, M., Smith, G. D., Schneider, M., & Minder C. Bias in meta-analysis detected by a simple, graphical test. Bmj. 1997;315:629–34.

106. Aggarwal A, Kumar S, Kumar D. Effect of core stabilization training on the lower back endurance in recreationally active individuals. Journal of Musculoskeletal Research. 2010;13:167–76.

107. Bagherian S, Ghasempoor K, Rahnama N, Wikstrom EA. The effect of core stability training on functional movement patterns in college athletes. Journal of Sport Rehabilitation. 2019;28:444–9.

108. Chuter VH, Janse De Jonge XAK, Thompson BM, Callister R. The efficacy of a supervised and a home-based core strengthening programme in adults with poor core stability: A three-arm randomised controlled trial. British Journal of Sports Medicine. 2015;49:395–9.

109. Granacher U, Lacroix A, Muehlbauer T, Roettger K. Effects of Core Instability Strength Training on Trunk Muscle Strength , Spinal Mobility , Dynamic Balance and Functional Mobility in Older Adults. Gerontology. 2013;59:105–13.

110. Junker D, Stöggl T. The Training Effects of Foam Rolling on Core Strength Endurance , Balance , Muscle Performance and Range of Motion : A Randomized Controlled Trial. Journal of sports science & medicine. 2019;18:229–38.

111. Ozmen T, Aydogmus M. Effect of core strength training on dynamic balance and agility in adolescent badminton players. Journal of Bodywork and Movement Therapies. 2016;20:565–70.

112. Ozmen T, Aydogmus M, Yana M, Simsek A. Effect of core strength training on balance, vertical jump height and throwing velocity in adolescent male handball players. Journal of Sports Medicine and Physical Fitness. 2020;60:693–9.

113. Park J-M, Hyun G-S, Jee Y-S. Effects of Pilates core stability exercises on the balance abilities of archers. Journal of exercise rehabilitation. 2016;12:553–8.

114. Sato K, Mokha M. Does core strength training influence running kinetics, lower-extremity stability, and 5000-m performance in Runners? Journal of Strength and Conditioning Research. 2009;23:133–40.

115. Bashir SF, Nuhmani S, Dhall R, Muaidi QI. Effect of core training on dynamic balance and agility among Indian junior tennis players. Journal of back and musculoskeletal rehabilitation. 2019;32:245–52.

116. Kachanathu S, Tyagi P, Anand P, Hameed U, Algarni A. Effect of core stabilization training on dynamic balance in professional soccer players. Physikalische Medizin, Rehabilitationsmedizin, Kurortmedizin. 2014;24:299–304.

117. Kahle N, Tevald MA. Core muscle strengthening's improvement of balance performance in community-dwelling older adults: A pilot study. Journal of aging and physical activity. 2014;22:65–73.

118. Motealleh A, Mohamadi M, Moghadam MB, Nejati N, Arjang N, Ebrahimi N. Effects of core neuromuscular training on pain, balance, and functional performance in women with patellofemoral pain syndrome: a clinical trial. Journal of chiropractic medicine. 2019;18:9–18.

119. Hodges PW, Richardson CA. Contraction of the abdominal muscles associated with movement of the lower limb. Physical therapy. 1997;77:132–42.

120. Behm DG, Drinkwater EJ, Willardson JM, Cowley PM. The use of instability to train the core musculature. Applied physiology, nutrition, and metabolism. 2010;35:91–108.

121. Folland JP, Williams AG. Morphological and neurological contributions to increased strength. Sports medicine. 2007;37:145–68.

122. Vera-Garcia FJ, Irles-Vidal B, Prat-Luri A, García-Vaquero MP, Barbado D, Juan-Recio C. Progressions of core stabilization exercises based on postural control challenge assessment. European journal of applied physiology. 2020;120:567–77.

123. Imai A, Kaneoka K, Okubo Y, Shiraki H. Effects of two types of trunk exercises on balance and athletic performance in youth soccer players. Int J Sports Phys Ther. 2014;9:47–57.

124. Sandrey MA, Mitzel JG. Improvement in Dynamic Balance and Core Endurance After a 6-Week Core-Stability-Training Program in High School Track and Field Athletes. Journal of sport rehabilitation. 2013;22:264–71.

125. Pizzigalli L, Cremasco MM, Mulasso A, Rainoldi A. The contribution of postural balance analysis in older adult fallers: a narrative review. Journal of bodywork and movement therapies. 2016;20:409–17.

126. Reyburn RJ, Powden CJ. Dynamic balance measures in healthy and chronic ankle instability participants while wearing ankle braces: systematic review with meta-analysis. Journal of Sport Rehabilitation. 2020;30:660–7.

127. Earl JE, Hertel J. Lower-extremity muscle activation during the star excursion balance tests. Journal of sport rehabilitation. 2001;10:93–104.

128. Larsson L, Baum J, Mudholkar GS. Hypermobility: features and differential incidence between the sexes. Arthritis & Rheumatism: Official Journal of the American College of Rheumatology. 1987;30:1426–30.

129. Stuber KJ, Bruno P, Sajko S, Hayden JA. Core Stability Exercises for Low Back Pain in Athletes. Clinical Journal of Sport Medicine. 2014;24:448–56.

130. Fernández-Rodríguez R, Álvarez-Bueno C, Cavero-Redondo I, Torres-Costoso A, Pozuelo-Carrascosa DP, Reina-Gutiérrez S, et al. Best exercise options for reducing pain and disability in adults with chronic low back pain: pilates, strength, core-based, and mind-body. a network meta-analysis. journal of orthopaedic & sports physical therapy. 2022;52:505–21.

131. Wang XQ, Zheng JJ, Yu ZW, Bi X, Lou SJ, Liu J, et al. A Meta-Analysis of Core Stability Exercise versus General Exercise for Chronic Low Back Pain. PLoS ONE. 2012;7:1–7.

132. Abdelraouf OR, Abdel-Aziem AA. The relationship between core endurance and back dysfunction in collegiate male athletes with and without nonspecific low back pain. International journal of sports physical therapy. 2016;11:337–44.

133. Nadler SF, Malanga GA, Bartoli LA, Feinberg JH, Prybicien M, DePrince M. Hip muscle imbalance and low back pain in athletes: influence of core strengthening. Medicine & Science in Sports & Exercise. 2002;34:9–16.

134. Barrio ED, Ramirez-Campillo R, Garcia de Alcaraz Serrano A, RaquelHernandez-García R. Effects of core training on dynamic balance stability: A systematic review and meta-analysis. Journal of Sports Sciences. 2022;1–9.

135. Juan-Recio C, López-Plaza D, Barbado Murillo D, García-Vaquero MP, Vera-García FJ. Reliability assessment and correlation analysis of 3 protocols to measure trunk muscle strength and endurance. Journal of sports sciences. 2018;36:357–64.

136. Friedrich J, Brakke R, Akuthota V, Sullivan W. Reliability and Practicality of the Core Score: Four Dynamic Core Stability Tests Performed in a Physician Office Setting. Clinical Journal of Sport Medicine. 2017;27:409–14.

137. Martínez-Romero MT, Ayala F, De Ste Croix M, Vera-Garcia FJ, Sainz de Baranda P, Santonja-Medina F, et al. A meta-analysis of the reliability of four field-based trunk extension endurance tests. International journal of environmental research and public health. 2020;17:3088.

138. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6:e1000097.

139. Schardt C, Adams MB, Owens T, Keitz S, Fontelo P. Utilization of the PICO framework to improve searching PubMed for clinical questions. BMC medical informatics and decision making. 2007;7:1–6.

140. García-Hermoso A, Ramírez-Campillo R, Izquierdo M. Is Muscular Fitness Associated with Future Health Benefits in Children and Adolescents? A Systematic Review and Meta-Analysis of Longitudinal Studies. Sports Med. 2019;49:1079–94.

141. Deeks JJ, Higgins JP, Altman DG, Group CSM. Analysing data and undertaking meta-analyses. Cochrane handbook for systematic reviews of interventions. 2019;241–84.

142. Kontopantelis E, Springate DA, Reeves D. A re-analysis of the Cochrane Library data: the dangers of unobserved heterogeneity in meta-analyses. PLoS One. 2013;8:e69930.

143. Hopkins, W., Marshall, S., Batterham, A., & Hanin J. Progressive statistics for studies in sports medicine and exercise science. Medicine+ Science in Sports+ Exercise. 2009;41:3.

144. Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ. 2003;327:557–60.

145. Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med. 2002;21:1539–58.

146. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997;315:629–34.

147. Toprak Çelenay Ş, Özer Kaya D. An 8-week thoracic spine stabilization exercise program improves postural back pain, spine alignment, postural sway, and core endurance in university students: A randomized controlled study. Turkish Journal of Medical Sciences. 2017;47:504–13.

148. Chuter VH, de Jonge XAKJ, Thompson BM, Callister R. The efficacy of a supervised and a home-based core strengthening programme in adults with poor core stability: a three-arm randomised controlled trial. Br J Sports Med. 2015;49:395–9.

149. Jamison ST, McNeilan RJ, Young GS, Givens DL, Best TM, Chaudhari AMW. Randomized controlled trial of the effects of a trunk stabilization program on trunk control and knee loading. Med Sci Sports Exerc. 2012;44:1924–34.

150. Kuhn, L., Weberruß, H., & Horstmann T. Effects of core stability training on throwing velocity and core strength in female handball players. The Journal of sports medicine and physical fitness. 2018;59:1479–86.

151. Lust KR, Sandrey MA, Bulger SM, Wilder N. The effects of 6-week training programs on throwing accuracy, proprioception, and core endurance in baseball. Journal of Sport Rehabilitation. 2009;18:407–26.

152. Mayer JM, Quillen WS, Verna JL, Chen R, Lunseth P, Dagenais S. Impact of a supervised worksite exercise program on back and core muscular endurance in firefighters. American Journal of Health Promotion. 2014;29:165–72.

153. Mayer JM, Childs JD, Neilson BD, Chen H, Koppenhaver SL, Quillen WS. Effect of lumbar progressive resistance exercise on lumbar muscular strength and core muscular endurance in soldiers. Military Medicine. 2016;181:e1615–22.

154. Ozmen T, Aydogmus M. Effect of core strength training on dynamic balance and agility in adolescent badminton players. J Bodyw Mov Ther. 2016;20:565–70.

155. Sannicandro I. Effects of strength and core stability training versus strength and aerobic training in subjects aged over 65 | Effetti dell'allenamento di forza e core stability versus allenamento di forza e aerobico a intensità controllata in soggetti over 65. Medicina dello Sport. 2017;70:410–8.

156. Shamsi MB, Sarrafzadeh J, Jamshidi A, Zarabi V, Pourahmadi MR. The effect of core stability and general exercise on abdominal muscle thickness in non-specific chronic low back pain using ultrasound imaging. Physiotherapy Theory and Practice. 2016;32:277–83.

157. Stanton R, Reaburn PR, Humphries B. The effect of short-term swiss ball training on core stability and running economy. Journal of Strength and Conditioning Research. 2004;18:522–8.

158. Tse MA, McManus AM, Masters RSW. Development and validation of a core endurance intervention program: Implications for performance in college-age rowers. Journal of Strength and Conditioning Research. 2005;19:547–52.

159. Weston M, Coleman NJ, Spears IR. The effect of isolated core training on selected measures of golf swing performance. Med Sci Sports Exerc. 2013;45:2292–7.

160. Stanton R, Reaburn PR, Humphries B. The effect of short-term Swiss ball training on core stability and running economy. J Strength Cond Res. 2004;18:522–8.

161. Michailidis Y, Venegas P, Metaxas T. Effects of Combined Horizontal Plyometric and Change of Direction Training on Anaerobic Parameters in Youth Soccer Players. Sports. 2023;11:27.

162. Dos' Santos T, McBurnie A, Thomas C, Comfort P, Jones PA. Biomechanical determinants of the modified and traditional 505 change of direction speed test. The Journal of Strength & Conditioning Research. 2020;34:1285–96.

163. Barrio ED, Alvarez C, Thapa RK, Ramachandran AK, Singh U, Ramirez-Campillo R. Jump Rope Training for Health and Fitness in School-age Participants: Secondary Analyses from a Systematic Review. International Journal of Kinesiology and Sports Science. 2023;11:27–41.

164. Ebben WP. Practical guidelines for plyometric intensity. NSCA's Performance training Journal. 2007;6:12–6.

165. Abt G, Boreham C, Davison G, Jackson R, Nevill A, Wallace E, et al. Power, precision, and sample size estimation in sport and exercise science research. Journal of Sports Sciences. 2020;38:1933–5.

166. Meylan CM, Cronin JB, Oliver JL, Hughes MG, Manson S. An evidence-based model of power development in youth soccer. International Journal of Sports Science & Coaching. 2014;9:1241–64.

167. Tack C. Evidence-based guidelines for strength and conditioning in mixed martial arts. Strength & Conditioning Journal. 2013;35:79–92.

168. Murad MH, Asi N, Alsawas M, Alahdab F. New evidence pyramid. BMJ Evidence-Based Medicine. 2016;21:125–7.

169. Ramirez-Campillo RR, Castillo D, Raya J, Jason G. Effects of Plyometric Jump Training on Jump and Sprint Performance in Young Male Soccer Players : A Systematic Review and Meta - analysis. Sports Medicine. 2020;1–19.

170. Ramirez-Campillo R, Sanchez-Sanchez J, Romero-Moraleda B, Yanci J, García-Hermoso A, Manuel Clemente F. Effects of plyometric jump training in female soccer player's vertical jump height: A systematic review with meta-analysis. Journal of Sports Sciences. 2020;38:1475–87.

171. Gentil P, Arruda A, Souza D, Giessing J, Paoli A, Fisher J, et al. Is there any practical application of meta-analytical results in strength training? Frontiers in physiology. 2017;8:1.

172. Rao G, Lopez-Jimenez F, Boyd J, D'Amico F, Durant NH, Hlatky MA, et al. Methodological standards for meta-analyses and qualitative systematic reviews of cardiac prevention and treatment studies: a scientific statement from the American Heart Association. Circulation. 2017;136:e172–94.

173. Doleman B, Williams JP, Lund J. Why most published meta-analysis findings are false. Techniques in Coloproctology. 2019;23:925–8.

174. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Annals of internal medicine. 2018;169:467–73.

175. Peters MD, Godfrey C, McInerney P, Khalil H, Larsen P, Marnie C, et al. Best practice guidance and reporting items for the development of scoping review protocols. JBI evidence synthesis. 2022;20:953–68.

176. Schuller-Martínez B, Meza N, Pérez-Bracchiglione J, Franco JVA, Loezar C, Madrid E. Graphical representation of the body of the evidence: the essentials for understanding the evidence gap map approach. Medwave. 2021;21:e8164–e8164.

177. Snilstveit B, Vojtkova M, Bhavsar A, Stevenson J, Gaarder M. Evidence & Gap Maps: A tool for promoting evidence informed policy and strategic research agendas. Journal of clinical epidemiology. 2016;79:120–9.

178. Miake-Lye IM, Hempel S, Shanman R, Shekelle PG. What is an evidence map? A systematic review of published evidence maps and their definitions, methods, and products. Systematic reviews. 2016;5:1–21.

179. Tayfur A, Haque A, Salles JI, Malliaras P, Screen H, Morrissey D. Are landing patterns in jumping athletes associated with patellar tendinopathy? A systematic review with evidence gap map and meta-analysis. Sports Medicine. 2022;1–15.

180. Budarick AR, Moyer RF. Linking physical activity with clinical, functional, and structural outcomes: an evidence map using the Osteoarthritis Initiative. Clinical Rheumatology. 2022;41:965–75.

181. Alsaleh S, Murphy N, Miller S, Morrissey D, Lack S. Local neuromuscular characteristics associated with patellofemoral pain: A systematic review and meta-analysis. Clinical Biomechanics. 2021;90:105509.

182. Ramirez-Campillo R, Moran J, Oliver JL, Pedley JS, Lloyd RS, Granacher U. Programming plyometric-jump training in soccer: a review. Sports. 2022;10:94.

183. Van Der Vlist AC, Winters M, Weir A, Ardern CL, Welton NJ, Caldwell DM, et al. Which treatment is most effective for patients with Achilles tendinopathy? A living systematic review with network meta-analysis of 29 randomised controlled trials. British journal of sports medicine. 2021;55:249–56.

184. Elliott JH, Synnot A, Turner T, Simmonds M, Akl EA, McDonald S, et al. Living systematic review: 1. Introduction—the why, what, when, and how. Journal of clinical epidemiology. 2017;91:23–30.

185. Winters M, de Vos R-J, Van Middelkoop M, Rathleff MS, Weir A. Stay alive! What are living systematic reviews and what are their advantages and challenges? British journal of sports medicine. 2021;55:519–20.

186. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. Journal of clinical epidemiology. 2009;62:e1–34.

187. Brooker J, Synnot A, McDonald S, Elliott J, Turner T, Hodder R. Guidance for the production and publication of Cochrane living systematic reviews: Cochrane Reviews in living mode. Cochrane Collaboration. 2019;

188. Vergara-Merino L, Verdejo C, Carrasco C, Vargas-Peirano M. Living systematic review: new inputs and challenges. Medwave. 2020;20:e8092–e8092.

189. Waffenschmidt S, Knelangen M, Sieben W, Bühn S, Pieper D. Single screening versus conventional double screening for study selection in systematic reviews: a methodological systematic review. BMC medical research methodology. 2019;19:1–9.

190. Higgins JP, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, et al. Cochrane handbook for systematic reviews of interventions. John Wiley & Sons; 2019.

191. Rambaud AJ, Ardern CL, Thoreux P, Regnaux J-P, Edouard P. Criteria for return to running after anterior cruciate ligament reconstruction: a scoping review. British Journal of Sports Medicine. 2018;52:1437–44.

192. Abass AO. Comparative effect of three modes of plyometric training on leg muscle strength of university male students. European Journal of Scientific Research. 2009;31:577–82.

193. Andrew DP, Kovaleski JE, Heitman RJ, Robinson TL. Effects of Three Modified Plyometric Depth Jumps and Periodized Weight Training on Lower Extremity Power. Sport Journal. 2010;13.

194. Asadi A. Effects of six weeks depth jump and countermovement jump training on agility performance. Sport Science. 2012;5:67–70.

195. Berger RA. Effects of dynamic and static training on vertical jumping ability. Research Quarterly American Association for Health, Physical Education and Recreation. 1963;34:419–24.

196. Blakey JB, Southard D. The combined effects of weight training and plyometrics on dynamic leg strength and leg power. Journal of Applied Sports Science Research. 1987;1:14–6.

197. Bogdanis GC, Tsoukos A, Kaloheri O, Terzis G, Veligekas P, Brown LE. Comparison between unilateral and bilateral plyometric training on single-and double-leg jumping performance and strength. The Journal of Strength & Conditioning Research. 2019;33:633–40.

198. Byrne PJ, Moran K, Rankin P, Kinsella S. A comparison of methods used to identify ‘optimal’drop height for early phase adaptations in depth jump training. The Journal of Strength & Conditioning Research. 2010;24:2050–5.

199. Clutch D, Wilton M, McGown C, Bryce GR. The effect of depth jumps and weight training on leg strength and vertical jump. Research quarterly for exercise and sport. 1983;54:5–10.

200. Cronin J, McNAIR P, MARSHALL R. The effects of bungy weight training on muscle function and functional performance. Journal of sports sciences. 2003;21:59–71.

201. Dello Iacono A, Martone D, Milic M, Padulo J. Vertical-vs. horizontal-oriented drop jump training: chronic effects on explosive performances of elite handball players. Journal of strength and conditioning research. 2017;31:921–31.

202. Earp JE, Newton RU, Cormie P, Blazevich AJ. Inhomogeneous quadriceps femoris hypertrophy in response to strength and power training. Med Sci Sports Exerc. 2015;47:2389–97.

203. Emamian A, Oskouei AH, Azreh R, Carroll K. Effects of Task Constraints on Countermovement Jump Kinematics Following a Short-Term Training. Journal of Motor Learning and Development. 2022;1:1–16.

204. Gehri DJ, Ricard MD, Kleiner DM, Kirkendall DT. A comparison of plyometric training techniques for improving vertical jump ability and energy production. Journal of Strength and Conditioning Research. 1998;12:85–9.

205. Gonzalo-Skok O, Sánchez-Sabaté J, Izquierdo-Lupón L, Sáez de Villarreal E. Influence of force-vector and force application plyometric training in young elite basketball players. European Journal of Sport Science. 2019;19:305–14.

206. Hawkins FJA. The comparative effects on vertical jump of three different depth jump programs. 1978;

207. Hoffman JR, Ratamess NA, Cooper JJ, Kang J, Chilakos A, Faigenbaum AD. Comparison of loaded and unloaded jump squat training on strength/power performance in college football players. The Journal of Strength & Conditioning Research. 2005;19:810–5.

208. Holcomb WR, Lander JE, Rutland RM, Wilson GD. The effectiveness of a modified plyometric program on power and the vertical jump. The Journal of Strength & Conditioning Research. 1996;10:89–92.

209. Hori N, Newton RU, Kawamori N, McGuigan MR, Andrews WA, Chapman DW, et al. Comparison of weighted jump squat training with and without eccentric braking. The Journal of Strength & Conditioning Research. 2008;22:54–65.

210. Hortobagyi T, Havasi J, Varga Z. Comparison of 2 stretch-shorten exercise programs in 13-year-old boys-nonspecific training effects. Journal of Human Movement Studies. 1990;18:177–88.

211. Khodaei K, Mohammadi A, Badri N. A comparison of assisted, resisted, and common plyometric training modes to enhance sprint and agility performance. Journal of Sports Medicine and Physical Fitness. 2017;57:1237–44.

212. King JA, Cipriani DJ. Comparing preseason frontal and sagittal plane plyometric programs on vertical jump height in high-school basketball players. The Journal of Strength & Conditioning Research. 2010;24:2109–14.

213. Kusuma AI, Setijono H, Mintarto E, Indra A, Setijono H. Effects of Jump Rope and High Jump Training with 1:1 Intervals on Increasing Vo2 Max and Anaerobic Threshold. International Journal of Innovation. 2020;12:14.

214. Laurent C, Baudry S, Duchateau J. Comparison of plyometric training with two different jumping techniques on achilles tendon properties and jump performances. The Journal of Strength & Conditioning Research. 2020;34:1503–10.

215. Loturco I, Pereira LA, Reis VP, Zanetti V, Bishop C, McGuigan M. Traditional free-weight vs. variable resistance training applied to elite young soccer

players during a short preseason: effects on strength, speed, and power performance. Journal of Strength and Conditioning Research. 2020;

216. Machado AF, De Castro JBP, Bocalini DS, JUNIOR AJF, Nunes RDAM, Vale RGDS. Effects of plyometric training on the performance of 5-km road runners. Journal of Physical Education and Sport. 2019;19:691–5.

217. Makaruk H, Czaplicki A, Sacewicz T, Sadowski J. The effects of single versus repeated plyometrics on landing biomechanics and jumping performance in men. Biology of sport. 2014;31:9–14.

218. Makaruk H, Winchester JB, Sadowski J, Czaplicki A, Sacewicz T. Effects of unilateral and bilateral plyometric training on power and jumping ability in women. The Journal of Strength & Conditioning Research. 2011;25:3311–8.

219. Manouras N, Papanikolaou Z, Karatrantou K, Kouvarakis P, Gerodimos V. The efficacy of vertical vs. Horizontal plyometric training on speed, jumping performance and agility in soccer players. International Journal of Sports Science and Coaching. 2016;11:702–9.

220. Markovic S, Mirkov DM, Knezevic OM, Jaric S. Jump training with different loads: effects on jumping performance and power output. European journal of applied physiology. 2013;113:2511–21.

221. Markovic G, Vuk S, Jaric S. Effects of jump training with negative versus positive loading on jumping mechanics. International journal of sports medicine. 2011;32:365–72.

222. Marshall BM, Moran KA. Which drop jump technique is most effective at enhancing countermovement jump ability,"countermovement" drop jump or "bounce" drop jump? Journal of sports sciences. 2013;31:1368–74.

223. Mastalerz A, Lutosławska G, Urbanik C. Power training efficiency after single joint and multiple joint exercises. HUMAN. 2009;153.

224. Masterson GL, Brown SP. Effects of weighted rope jump training on power performance tests in collegians. The Journal of Strength & Conditioning Research. 1993;7:108–14.

225. Matavulj D, Kukolj M, Ugarkovic D, Tihanyi J, Jaric S. Effects of pylometric training on jumping performance in junior basketball players. Journal of sports medicine and physical fitness. 2001;41:159–64.

226. Mazurek K, Zmijewski P, Makaruk H, Mróz A, Czajkowska A, Witek K, et al. Effects of Short-Term Plyometric Training on Physical Performance in Male Handball Players. Journal of Human Kinetics. 2018;63:137–48.

227. McBride JM, Triplett-McBride T, Davie A, Newton RU. The effect of heavy- vs. light-load jump squats on the development of strength, power, and speed. The Journal of Strength & Conditioning Research. 2002;16:75–82.

228. McClenton LS, Brown LE, Coburn JW, Kersey RD. The effect of short-term VertiMax vs. depth jump training on vertical jump performance. The Journal of Strength & Conditioning Research. 2008;22:321–5.

229. McCormick BT, Hannon JC, Newton M, Shultz B, Detling N, Young WB. The effects of frontal-and sagittal-plane plyometrics on change-of-direction speed and power in adolescent female basketball players. International journal of sports physiology and performance. 2016;11:102–7.

230. McCurdy KW, Langford GA, Doscher MW, Wiley LP, Mallard KG. The effects of short-term unilateral and bilateral lower-body resistance training on measures of strength and power. The Journal of Strength & Conditioning Research. 2005;19:9–15.

231. McGuigan MR, Sharman MJ, Newton RU, Davie AJ, Murphy AJ, McBride JM. Effect of explosive resistance training on titin and myosin heavy chain isoforms in trained subjects. Journal of Strength and Conditioning Research. 2003;17:645–51.

232. Mirzaei B, Asghar Norasteh A, Saez de Villarreal E, Asadi A. Effects of six weeks of depth jump vs. countermovement jump training on sand on muscle soreness and performance. Kinesiology. 2014;46:97–108.

233. Mirzaei B, Norasteh AA, Asadi A. Neuromuscular adaptations to plyometric training: depth jump vs. countermovement jump on sand. Sport Sciences for Health. 2013;9:145–9.

234. Ramirez-Campillo R, Alvarez C, García-Pinillos F, Sanchez-Sanchez J, Yanci J, Castillo D, et al. Optimal reactive strength index: is it an accurate variable to optimize plyometric training effects on measures of physical fitness in young soccer players? The Journal of Strength & Conditioning Research. 2018;32:885–93.

235. Ramírez-Campillo, R., Burgos, C. H., Henríquez-Olguín, C., Andrade, D. C., Martínez, C., Álvarez, C., Cástro-Sepúlveda, M., Marqués MC, & Izquierdo M. Effect of unilateral, bilateral, and combined plyometric training on explosive and endurance performance of young soccer players. he Journal of Strength & Conditioning Research. 2015;29:1317–28.

236. Rosas F, Ramirez-Campillo R, Diaz D, Abad-Colil F, Martinez-Salazar C, Caniuqueo A, et al. Jump training in youth soccer players: effects of haltere type handheld loading. International journal of sports medicine. 2016;37:1060–5.

237. Ruffieux J, Wälchli M, Kim K-M, Taube W. Countermovement jump training is more effective than drop jump training in enhancing jump height in non-professional female volleyball players. Frontiers in physiology. 2020;11:231.

238. Sheppard J, Hobson S, Barker M, Taylor K, Chapman D, McGuigan M, et al. The effect of training with accentuated eccentric load counter-movement jumps on strength and power characteristics of high-performance volleyball players. International Journal of Sports Science & Coaching. 2008;3:355–63.

239. Singh J, Appleby B, Lavender A. Effect of Plyometric Training on Speed and Change of Direction Ability in Elite Field Hockey Players. Sports. 2018;6:144–58.

240. Singh D, Singh S. Effects of vertical and horizontal plyometric exercises on running speed. Human movement. 2013;14:144–7.

241. Singh D, Singh S. Iinfluence of Exercise Specifity on Depth Jump Performance. Brazilian Journal of Biomotricity. 2012;6:261–8.

242. Singh D, Singh S. Effects of vertical, horizontal, and combination depth jump training on long jump performance. Biomedical Human Kinetics. 2012;4:107–11.

243. Sotiropoulos K, Smilios I, Barzouka K, Christou M, Bogdanis G, Douda H, et al. Effects of Drop Jump Training from Different Heights and Weight Training on Vertical Jump and Maximum Strength Performance in Female Volleyball Players. The Journal of Strength & Conditioning Research. 2022;10–1519.

244. Staniszewski M, Hammoud N, Zybko P, Witek K, Tkaczyk J, Urbanik C. Effect of concentric vs. eccentric variant of lower limbs plyometric training on biomechanical and biochemical parameters. European Journal of Sport Science. 2021;21:351–8.

245. Stern D, Gonzalo-Skok O, Loturco I, Turner A, Bishop C. A comparison of bilateral vs. unilateral-biased strength and power training interventions on measures of physical performance in elite youth soccer players. The Journal of Strength & Conditioning Research. 2020;34:2105–11.

246. Stien N, Strate M, Andersen V, Saeterbakken AH. Effects of overspeed or overload plyometric training on jump height and lifting velocity. Sports Medicine International Open. 2020;4:E32–8.

247. Strate M, Stien N, Saeterbakken AH, Andersen V. The effects of assisted and resisted plyometric training on jump height and sprint performance among physically active females. European Journal of Sport Science. 2022;22:1569–76.

248. Taube W, Leukel C, Lauber B, Gollhofer A. The drop height determines neuromuscular adaptations and changes in jump performance in stretch-shortening cycle training. Scandinavian journal of medicine & science in sports. 2012;22:671–83.

249. Thomas K, French D, Hayes PR. The effect of two plyometric training techniques on muscular power and agility in youth soccer players. The Journal of Strength & Conditioning Research. 2009;23:332–5.

250. Trzaskoma L, Tihanyi J, Trzaskoma Z. The effect of a short-term combined conditioning training for the development of leg strength and power. The Journal of Strength & Conditioning Research. 2010;24:2498–505.

251. Watkins CM, Gill ND, Maunder E, Downes P, Young JD, McGuigan MR, et al. The Effect of Low-Volume Preseason Plyometric Training on Force-Velocity Profiles in Semiprofessional Rugby Union Players. The Journal of Strength & Conditioning Research. 2021;35:604–15.

252. Weakley JJ, Till K, Read DB, Leduc C, Roe GA, Phibbs PJ, et al. Jump training in rugby union players: barbell or hexagonal bar? The Journal of Strength & Conditioning Research. 2021;35:754–61.

253. Weltin E, Gollhofer A, Mornieux G. Effects of perturbation or plyometric training on core control and knee joint loading in women during lateral movements. Scandinavian Journal of Medicine and Science in Sports. 2017;27:299–308.

254. Wilson GJ, Newton RU, Murphy AJ, Humphries BJ. The optimal training load for the development of dynamic athletic performance. Medicine and science in sports and exercise. 1993;25:1279–86.

255. Yang X, Lee J, Gu X, Zhang X, Zhang T. Physical Fitness Promotion among Adolescents: Effects of a Jump Rope-Based Physical Activity Afterschool Program. Children. 2020;7:95.

256. Young W, Wilson C, Byrne C. A comparison of drop jump training methods: effects on leg extensor strength qualities and jumping performance. International journal of sports medicine. 1999;20:295–303.

257. Cumming SP, Lloyd RS, Oliver JL, Eisenmann JC, Malina RM. Bio-banding in sport: applications to competition, talent identification, and strength and conditioning of youth athletes. Strength & Conditioning Journal. 2017;39:34–47.

258. Granacher U, Lesinski M, Büsch D, Muehlbauer T, Prieske O, Puta C, et al. Effects of resistance training in youth athletes on muscular fitness and athletic performance: a conceptual model for long-term athlete development. Frontiers in physiology. 2016;164.

259. Moran JJ, Sandercock GR, Ramírez-Campillo R, Meylan CM, Collison JA, Parry DA. Age-related variation in male youth athletes' countermovement jump after plyometric training: a meta-analysis of controlled trials. The Journal of Strength & Conditioning Research. 2017;31:552–65.

260. Nobre GG, De Almeida MB, Nobre IG, Dos Santos FK, Brinco RA, Arruda-Lima TR, et al. Twelve weeks of plyometric training improves motor performance of 7- to 9-year-old boys who were overweight/obese: A randomized controlled intervention. Journal of Strength and Conditioning Research. 2017;31:2091–9.

261. Racil G, Zouhal H, Elmontassar W, Abderrahmane AB, De Sousa MV, Chamari K, et al. Plyometric exercise combined with high-intensity interval training improves metabolic abnormalities in young obese females more so than interval training alone. Applied Physiology, Nutrition and Metabolism. 2016;41:103–9.

262. Stojanović E, Ristić V, McMaster DT, Milanović Z. Effect of Plyometric Training on Vertical Jump Performance in Female Athletes: A Systematic Review and Meta-Analysis. Sports Medicine. 2017;47:975–86.

263. Meylan, C., & Malatesta D. Effects of in-season plyometric training within soccer practice on explosive actions of young players. The Journal of Strength & Conditioning Research. 2009;23:2605–13.

264. Ahmadi M, Nobari H, Ramirez-Campillo R, Pérez-Gómez J, Ribeiro AL de A, Martínez-Rodríguez A. Effects of plyometric jump training in sand or rigid surface on jump-related biomechanical variables and physical fitness in female volleyball players. International Journal of Environmental Research and Public Health. 2021;18:13093.

265. Ducrocq GP, Hureau TJ, Meste O, Blain GM. Similar cardioventilatory but greater neuromuscular stimuli with interval drop jump than with interval running. International Journal of Sports Physiology and Performance. 2020;15:330–9.

266. Silva AF, Clemente FM, Lima R, Nikolaidis PT, Rosemann T, Knechtle B. The effect of plyometric training in volleyball players: A systematic review. International Journal of Environmental Research and Public Health. 2019;16:1–23.

267. Blagrove RC, Howatson G, Pedlar CR, Hayes PR. Quantification of aerobic determinants of performance in post-pubertal adolescent middle-distance runners. European Journal of Applied Physiology. 2019;119:1865–74.

268. Beattie K, Carson BP, Lyons M, Rossiter A, Kenny IC. The effect of strength training on performance indicators in distance runners. The Journal of Strength & Conditioning Research. 2017;31:9–23.

269. Davies G, L. Riemann B, Mankse R. Clinical Commnetary. Current Concepts of Plyometric Exericse. The International Journal of Sports Physical Therapy. 2015;10:768–86.

270. Lum D, Tan F, Pang J, Barbosa TM. Effects of intermittent sprint and plyometric training on endurance running performance. Journal of Sport and Health Science. 2019;8:471–7.

271. Ramírez-Campillo, R., Andrade, D. C., & Izquierdo M. Effects of plyometric training volume and training surface on explosive strength. The Journal of Strength & Conditioning Research. 2013;27:2714–22.

272. Nicol C, Avela J KP. The stretch-shortening cycle. Sports medicine. 2006;36:977–99.

273. Seiberl W, Hahn D, Power GA, Fletcher JR, Siebert T. The Stretch-Shortening Cycle of Active Muscle and Muscle-Tendon Complex: What, Why and How It Increases Muscle Performance? Frontiers in physiology. 2021;12:693141.

274. Giovanelli N, Taboga P, Rejc E, Lazzer S. Effects of strength, explosive and plyometric training on energy cost of running in ultra-endurance athletes. European Journal of Sport Science. 2017;17:805–13.

275. Spurrs RW, Murphy AJ, Watsford ML. The effect of plyometric training on distance running performance. European Journal of Applied Physiology. 2003;89:1–7.

276. Pellegrino J, Ruby BC, Dumke CL. Effect of plyometrics on the energy cost of running and MHC and titin isoforms. Medicine & Science in Sports & Exercise. 2016;48:49–56.

277. Moran, J., Clark, C. C., Ramirez-Campillo, R., Davies, M. J., & Drury B. A meta-analysis of plyometric training in female youth: Its efficacy and shortcomings in the literature. The Journal of Strength & Conditioning Research. 2019;33:1996–2008.

278. Cunningham, R., Hunter, I., Seeley, M. K., & Feland B. Variations in running technique between female sprinters , middle , and long-distance runners. International Journal of Exercise Science. 2013;6:43–51.

279. Blagrove RC, Howe LP, Cushion EJ, Spence A, Howatson G, Pedlar CR, et al. Effects of Strength Training on Postpubertal. Medicine & Science in Sports & Exercise. 2018;50:1224–32.

280. Li F, Wang R, Newton RU, Sutton D, Shi Y. Effects of complex training versus heavy resistance training on neuromuscular adaptation , running economy and 5-km performance in well-trained distance runners. PeerJ. 2019;7:e6787.

281. Lundstrom CJ, Betker MR, Ingraham SJ. Effects of Plyometric and Explosive Speed Training on Recreational Marathoners. Journal of Sports Science. 2017;5:1–13.

282. Sedano, S., Marín, P. J., Cuadrado, G., & Redondo JC. Concurrent training in elite male runners: the influence of strength versus muscular endurance training on performance outcomes. The Journal of Strength & Conditioning Research. 2013;27:2433–43.

283. Saunders, P. U., Telford, R. D., Pyne, D. B., Peltola, E. M., Cunningham, R. B., Gore, C. J., & Hawley JA. Short-term plyometric training improves running economy in highly trained middle and long distance runners. Journal of Strength and Conditioning Research. 2006;20:947–54.

284. Taipale RS, Mikkola J, Nummela A, Vesterinen V, Capostagno B, Walker S, et al. Strength Training in Endurance Runners. International journal of sports medicine. 2010;31:468–76.

285. Taipale, R. S., Mikkola, J., Vesterinen, V., Nummela, A., & Häkkinen K. Neuromuscular adaptations during combined strength and endurance training in endurance runners : maximal versus explosive strength training or a mix of both. European journal of applied physiology. 2013;113:325–35.

286. Kraemer J, Patton JF, Gordon SE, Reynolds K, Newton U, Triplett NT, et al. Compatibility of high-intensity strength and endurance training on hormonal and skeletal muscle adaptations. Journal of applied physiology. 1995;78:976–89.

287. JA H. Specificity of training adaptation: time for a rethink? The journal of physiology. 2008;586:1–2.

288. Ramirez-Campillo R, Alvarez C, Gentil P, Moran J, García-Pinillos F, Alonso-Martínez AM, et al. Inter-individual variability in responses to 7 weeks of plyometric jump training in male youth soccer players. Frontiers in Physiology. 2018;9:1–11.

289. Turner, A. M., Owings, M., & Schwane JA. Improvement in running economy after 6 weeks of plyometric training. The Journal of Strength & Conditioning Research. 2003;17:60–7.

290. Berryman, N., Maurel, D., & Bosquet L. Effect of plyometric vs. dynamic weight training on the energy cost of running. The Journal of Strength & Conditioning Research. 2010;24:1818–25.

291. Andrade DC, Beltrán AR, Labarca-Valenzuela C, Manzo-Botarelli O, Trujillo E, Otero-Farias P, et al. Effects of plyometric training on explosive and endurance performance at sea level and at high altitude. Frontiers in Physiology. 2018;9:1–9.

292. Gómez-Molina J, Ogueta-Alday A, Camara J, Stickley C, García-lópez J. Effect of 8 weeks of concurrent plyometric and running training on spatiotemporal and physiological variables of novice runners. European Journal of Sport Science. 2018;18:162–9.

293. Barnes, K. R., Hopkins, W. G., Mcguigan, M. R., Northuis, M. E., & Kilding AE. Effects of resistance training on running economy and cross-country performance. Medicine & Science in Sports & Exercise. 2013;45:2322–31.

294. Bonacci J, Green D, Saunders PU, Franettovich M, Blanch P, Vicenzino B. Plyometric training as an intervention to correct altered neuromotor control during running after cycling in triathletes: A preliminary randomised controlled trial. Physical Therapy in Sport. 2011;12:15–21.

295. Markovic, G., & Mikulic P. Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. Sports medicine. 2010;40:859–95.

296. Chaput J-P, Willumsen J, Bull F, Chou R, Ekelund U, Firth J, et al. 2020 WHO guidelines on physical activity and sedentary behaviour for children and adolescents aged 5–17 years: summary of the evidence. Int J Behav Nutr Phys Act. 2020;17:141.

297. Caspersen CJ, Powell KE, Christenson GM. Physical Activity, Exercise, and Physical Fitness: Definitions and Distinctions for Health-Related Research. Public Health Rep. 1985;6.

298. Faigenbaum AD, Myer GD. Resistance training among young athletes: safety, efficacy and injury prevention effects. British journal of sports medicine. 2010;44:56–63.

299. Zwolski C, Quatman-Yates C, Paterno MV. Resistance training in youth: laying the foundation for injury prevention and physical literacy. Sports health. 2017;9:436–43.

300. Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Physical Fitness, Injuries, and Team Performance in Soccer: Medicine & Science in Sports & Exercise. 2004;36:278–85.

301. Anand SP. Training during a pandemic. Cell Reports. 2021;2:100258.

302. Ache-Dias J, Dellagrana RA, Teixeira AS, Dal Pupo J, Moro AR. Effect of jumping interval training on neuromuscular and physiological parameters: a randomized controlled study. Applied Physiology, Nutrition, and Metabolism. 2015;41:20–5.

303. Albers JA, Lewis BA. Afterschool jump rope program: time and intensity of physical activity. Journal of Physical Education and Sport. 2020;20:877–82.

304. Sekhon BS, Maniazhagu D. Effects of aerobic training and jump rope training on flexibility of overweight children. J Emerg Technol Innov Res. 2018;5:385–9.

305. Grudniewicz A, Moher D, Cobey KD, Bryson GL, Cukier S, Allen K, et al. Predatory journals: no definition, no defence. 2019;

306. Arnett MG, Lutz B. Effects of rope-jump training on the os calcis stiffness index of postpubescent girls: Medicine & Science in Sports & Exercise. 2002;34:1913–9.

307. Colakoglu F, Karacan S, Guzel N, Baltaci G. Does the Weighted Rope Jump Training Affect the Motor Skills in Adolescent Female Volleyball Players? Arch Sports Med Physiother. 2017;2:005–9.

308. Duzgun I, Baltaci G, Colakoglu F, Tunay VB, Ozer D. The Effects of Jump-Rope Training on Shoulder Isokinetic Strength in Adolescent Volleyball Players. Journal of Sport Rehabilitation. 2010;19:184–99.

309. Eskandari M, Hooshmand Moghadam B, Bagheri R, Ashtary-Larky D, Eskandari E, Nordvall M, et al. Effects of Interval Jump Rope Exercise Combined with Dark Chocolate Supplementation on Inflammatory Adipokine, Cytokine Concentrations, and Body Composition in Obese Adolescent Boys. Nutrients. 2020;12:3011.

310. Ozer D, Duzgun I, Baltaci G, Karacan S, Colakoglu F. The effects of rope or weighted rope jump training on strength, coordination and proprioception in adolescent female volleyball players. The Journal of Sports Medicine and Physical Fitness. 2011;51:9.

311. Reaper F, Bandy WD, Longinotti S, Carson AP, Hattlestad M, Culpepper H, et al. The effect of using frontal shoe orthotics and plyometric training on selected functional measurements in junior high school football players. IES. 1996;6:45–9.

312. Turgut E, Çolakoğlu FF, Atalay Güzel N, Karacan S, Baltacı G. Effects of Weighted Versus Standard Jump Rope Training on Physical Fitness in Adolescent Female Volleyball Players: A Randomized Controlled Trial. Türk Fizyoterapi ve Rehabilitasyon Dergisi. 2016;27:108–108.

313. Hooshmand Moghadam B, Bagheri R, Ghanavati M, Khodadadi F, Cheraghloo N, Wong A, et al. The Combined Effects of 6 Weeks of Jump Rope Interval Exercise and Dark Chocolate Consumption on Antioxidant Markers in Obese Adolescent Boys. Antioxidants. 2021;10:1675.

314. Sung K-D, Pekas EJ, Scott SD, Son W-M, Park S-Y. The effects of a 12-week jump rope exercise program on abdominal adiposity, vasoactive substances, inflammation, and vascular function in adolescent girls with prehypertension. European Journal of Applied Physiology. 2019;119:577–85.

315. Lee B. Jump Rope Training 2nd Edition. Human Kinetics; 2003.

316. Boettcher CE, Cathers I, Ginn KA. The role of shoulder muscles is task specific. Journal of Science and Medicine in Sport. 2010;13:651–6.

317. Travis SK, Ishida A, Taber CB, Fry AC, Stone MH. Emphasizing task-specific hypertrophy to enhance sequential strength and power performance. Journal of Functional Morphology and Kinesiology. 2020;5:76.

318. Bellver M, Drobnic F, Jovell E, Ferrer-Roca V, Abalos X, Del Rio L, et al. Jumping rope and whole-body vibration program effects on bone values in Olympic artistic swimmers. Journal of Bone and Mineral Metabolism. 2021;39:858–67.

319. Hernandez BLM, Gober D, Boatwright D, Strickland G. Jump rope skills for fun and fitness in grades K-12. Journal of Physical Education, Recreation & Dance. 2009;80:15–41.

320. Kato T, Terashima T, Yamashita T, Hatanaka Y, Honda A, Umemura Y. Effect of low-repetition jump training on bone mineral density in young women. Journal of applied physiology. 2006;100:839–43.

321. Aminaei M, Yazdani S, Amirseifadini M. Effects of Plyometric and Cluster Resistance Training on Explosive Power and Maximum Strength in Karate Players. International Journal of Applied Exercise Physiology. 2017;6:34–44.

322. Arazi H, Coetzee B, Asadi A. Comparative effect of land- and aquatic-based plyometric training on jumping ability and agility of young basketball players. South African Journal for Research in Sport, Physical Education and Recreation. 2012;34:1–14.

323. Blazevich AJ, Gill ND, Bronks R, Newton RU. Training-specific muscle architecture adaptation after 5-wk training in athletes. Medicine and science in sports and exercise. 2003;35:2013–22.

324. Carlson K, Magnusen M, Walters P. Effect of various training modalities on vertical jump. Research in Sports Medicine. 2009;17:84–94.

325. Chakshuraksha P, Apanukul S. Effects of Accentuated Eccentric Loading Combined with Plyometric Training on Strength, Power, Speed, and Agility in Male Rugby Players. Journal of Exercise Physiology Online. 2021;24.

326. Chaouachi A, Othman AB, Hammami R, Drinkwater EJ, Behm DG. The combination of plyometric and balance training improves sprint and shuttle run performances more often than plyometric-only training with children. The Journal of Strength & Conditioning Research. 2014;28:401–12.

327. Chmielewski TL, George SZ, Tillman SM, Moser MW, Lentz TA, Indelicato PA, et al. Low-versus high-intensity plyometric exercise during rehabilitation after anterior cruciate ligament reconstruction. The American journal of sports medicine. 2016;44:609–17.

328. Ciacci S, Bartolomei S. The effects of two different explosive strength training programs on vertical jump performance in basketball. The Journal of Sports Medicine and Physical Fitness. 2017;58:1375–82.

329. Coratella G, Beato M, Milanese C, Longo S, Limonta E, Rampichini S, et al. Specific adaptations in performance and muscle architecture after weighted jump-squat vs. body mass squat jump training in recreational soccer players. The Journal of Strength & Conditioning Research. 2018;32:921–9.

330. Elias A. Sprungtraining nach Kreuzband-Rekonstruktion verbessert die physische Funktion.

331. Álvarez JAE, García JPF, Da Conceição FA, Jiménez-Reyes P. Individualized training based on force–velocity profiling during jumping in ballet dancers. International Journal of Sports Physiology and Performance. 2019;15:788–94.

332. Escobar-Álvarez JA, Jiménez-Reyes P, Da Conceição FA, Fuentes-García JP. Effect of Supplementary Physical Training on Vertical Jump Height in Professional Ballet Dancers. International Journal of Sports Physiology and Performance. 2022;17:1257–63.

333. Escrivá-Sellés F, González-Badillo J. Effect of two periods of power training on performance in the thrust, barracuda and boost exercises in synchronised swimming. Apunts Ed Fis Deport. 2020;142:35–45.

334. Fathi A, Hammami R, Moran J, Borji R, Sahli S, Rebai H. Effect of a 16-week combined strength and plyometric training program followed by a detraining period on athletic performance in pubertal volleyball players. The Journal of Strength & Conditioning Research. 2019;33:2117–27.

335. Fatouros IG, Jamurtas AZ, Leontsini D, Taxildaris K, Aggelousis N, Kostopoulos N, et al. Evaluation of plyometric exercise training, weight training, and their combination on vertical jumping performance and leg strength. The Journal of Strength & Conditioning Research. 2000;14:470–6.

336. Fowler NE, Trzaskoma Z, Wit A, Iskra L, Lees A. The effectiveness of a pendulum swing for the development of leg strength and counter-movement jump performance. Journal of sports sciences. 1995;13:101–8.

337. Gauffin H, Ekstrand J, Arnesson L, Tropp H. Vertical jump performance in soccer players: a comparative study of two training programs. Journal of Human Movement Studies. 1989;16:215–24.

338. Gonzalo-Skok O, Tous-Fajardo J, Valero-Campo C, Berzosa C, Bataller AV, Arjol-Serrano JL, et al. Eccentric-Overload Training in Team-Sport Functional Performance: Constant Bilateral Vertical Versus Variable Unilateral Multidirectional Movements. International Journal of Sports Physiology & Performance. 2017;12.

339. Hammami M, Gaamouri N, Shephard RJ, Chelly MS. Effects of contrast strength vs. plyometric training on lower-limb explosive performance, ability to change direction and neuromuscular adaptation in soccer players. The Journal of strength & conditioning research. 2019;33:2094–103.

340. Helland C, Hole E, Iversen E, Olsson MC, Seynnes OR, Solberg PA, et al. Training strategies to improve muscle power: is olympic-style weightlifting relevant? 2017;

341. Hortobagyi T, Sio A, Fodor T, Merkely B. Effects of targeted skill development and plyometric conditioning on long jump performance in 16-year-old boys. Journal of Human Movement Studies. 1991;21:1–17.

342. Huang P-Y, Jankaew A, Lin C-F. Effects of plyometric and balance training on neuromuscular control of recreational athletes with functional ankle instability: a randomized controlled laboratory study. International journal of environmental research and public health. 2021;18:5269.

343. Huang P-Y, Chen W-L, Lin C-F, Lee H-J. Lower extremity biomechanics in athletes with ankle instability after a 6-week integrated training program. Journal of Athletic Training. 2014;49:163–72.

344. Huang P, Lin C. Effects of balance training combined with plyometric exercise in postural control: Application in individuals with functional ankle instability. Springer; 2010. p. 232–5.

345. Jafari M, Zolaktaf V, Marandi SM. Determination of the best pre-jump height for improvement of two-legged vertical jump. International journal of preventive medicine. 2013;4:S104.

346. Jiménez-Reyes P, Samozino P, Morin J-B. Optimized training for jumping performance using the force-velocity imbalance: Individual adaptation kinetics. PloS one. 2019;14:e0216681.

347. Kamalakkannan K, Azeem K, Arumugam C. The effect of aquatic plyometric training with and without resistance on selected physical fitness variables among volleyball players. Journal of Physical Education and Sport. 2011;11:205.

348. Kamandulis S, Snieckus A, Venckunas T, Aagaard P, Masiulis N, Skurvydas A. Rapid increase in training load affects markers of skeletal muscle damage and mechanical performance. The Journal of Strength & Conditioning Research. 2012;26:2953–61.

349. Kamandulis S, Skurvydas A, Brazaitis M, Stanislovaitis A, Duchateau J, Stanislovaitienė J. Effect of a periodized power training program on the functional performances and contractile properties of the quadriceps in sprinters. Research quarterly for exercise and sport. 2012;83:540–5.

350. Kasmi S, Zouhal H, Hammami R, Clark CC, Hackney AC, Hammami A, et al. The Effects of Eccentric and Plyometric Training Programs and Their Combination on Stability and the Functional Performance in the Post-ACL-Surgical Rehabilitation Period of Elite Female Athletes. Frontiers in Physiology. 2021;12:688385.

351. Katsikari K, Bassa E, Skoufas D, Lazaridis S, Kotzamanidis C, Patikas DA. Kinetic and kinematic changes in vertical jump in prepubescent girls after 10 weeks of plyometric training. Pediatric Exercise Science. 2020;32:81–8.

352. Keller S, Koob A, Corak D, von Schöning V, Born D-P. How to improve change-of-direction speed in junior team sport athletes—horizontal, vertical, maximal, or explosive strength training? The Journal of Strength & Conditioning Research. 2020;34:473–82.

353. Kukrić A, Karalejić M, Jakovljević S, Petrović B, Mandić R. Impact of different training methods to the maximum vertical jump height in junior basketball players. Fizička kultura. 2012;66:25–31.

354. Lievens M, Bourgois JG, Boone J. Periodization of Plyometrics: Is There an Optimal Overload Principle? Journal of Strength and Conditioning Research. 2021;35:2669–76.

355. Lindberg K, Solberg P, Rønnestad BR, Frank MT, Larsen T, Abusdal G, et al. Should we individualize training based on force-velocity profiling to improve physical

performance in athletes? Scandinavian Journal of Medicine & Science in Sports. 2021;31:2198–210.

356. Lloyd RS, Radnor JM, Croix MBDS, Cronin JB, Oliver JL. Changes in sprint and jump performances after traditional, plyometric, and combined resistance training in male youth pre-and post-peak height velocity. The Journal of Strength & Conditioning Research. 2016;30:1239–47.

357. Lyttle AD, Wilson GJ, Ostrowski KJ. Enhancing performance: Maximal power versus combined weights and plyometrics training. Journal of strength and conditioning research. 1996;10:173–9.

358. Mero AM, Häkkinen K, Kyröläinen H, Mero AA. Effects of training on bone metabolism in young athletes. Human Movement. 2021;22:105–12.

359. Myklebust G, Engebretsen L, Brækken IH, Skjølberg A, Olsen O-E, Bahr R. Prevention of anterior cruciate ligament injuries in female team handball players: a prospective intervention study over three seasons. Clinical journal of sport medicine. 2003;13:71–8.

360. Ogiso K, Miki S. Consecutive rebound jump training with electromyostimulation of the calf muscle efficiently improves jump performance. Translational Sports Medicine. 2020;3:454–63.

361. Pamuk O, Hancı E, Ucar N, Hasanlı N, Gundogdu A, Ozkaya YG. Exercícios Pliométricos Resistidos Aumentam a Força Muscular em Jovens Jogadores de Basquetebol. Revista Brasileira de Medicina do Esporte. 2022;28:331–6.

362. Radnor JM, Lloyd RS, Oliver JL. Individual response to different forms of resistance training in school-aged boys. Journal of strength and conditioning research. 2017;31:787–97.

363. Ramirez-Campillo R, Sanchez-Sanchez J, Gonzalo-Skok O, Rodríguez-Fernandez A, Carretero M, Nakamura FY. Specific changes in young soccer player's fitness after traditional bilateral vs. unilateral combined strength and plyometric training. Frontiers in Physiology. 2018;9:1–10.

364. Rhea MR, Peterson MD, Lunt KT, Ayllón FN. The effectiveness of resisted jump training on the VertiMax in high school athletes. The Journal of Strength & Conditioning Research. 2008;22:731–4.

365. Rhea MR, Peterson MD, Oliverson JR, Ayllón FN, Potenziano BJ. An examination of training on the VertiMax resisted jumping device for improvements in lower body power in highly trained college athletes. The Journal of Strength & Conditioning Research. 2008;22:735–40.

366. de Villarreal ES, Suarez-Arrones L, Requena B, Haff GG, Veliz RR. Enhancing performance in professional water polo players: dryland training, in-water training, and combined training. The Journal of Strength & Conditioning Research. 2015;29:1089–97.

367. de Villarreal, S. E E, Requena B, Izquierdo M, Gonzalez-Badillo JJ. Enhancing sprint and strength performance: Combined versus maximal power, traditional heavy-resistance and plyometric training. Journal of Science and Medicine in Sport. 2013;16:146–50.

368. de Villarreal ESS, Izquierdo M, Gonzalez-Badillo JJ. Enhancing jump performance after combined vs. maximal power, heavy-resistance, and plyometric training alone. The Journal of Strength & Conditioning Research. 2011;25:3274–81.

369. Sanchez-Sanchez J, Ramirez-Campillo R, Petisco C, Hernandez D, Nakamura FY. Effects of short-term strength and jumping exercises distribution on soccer player’s physical fitness. Kinesiology. 2021;53:236–44.

370. Sánchez-Sixto A, Harrison AJ, Floría P. Effects of Plyometric vs. Combined Plyometric Training on Vertical Jump Biomechanics in Female Basketball Players. Journal of Human Kinetics. 2021;77:25–35.

371. Simpson A, Waldron M, Cushion E, Tallent J. Optimised force-velocity training during pre-season enhances physical performance in professional rugby league players. Journal of Sports Sciences. 2021;39:91–100.

372. Siti MI, Saat MI, Krasilshchikov O, Shaw I, Shaw BS. Enhancing jump ground reaction forces in children through jump training. South African Journal for Research in Sport, Physical Education and Recreation. 2014;36:199–209.

373. Smilios I, Sotiropoulos K, Christou M, Douda H, Spaias A, Tokmakidis SP. Maximum power training load determination and its effects on load-power relationship, maximum strength, and vertical jump performance. The Journal of Strength & Conditioning Research. 2013;27:1223–33.

374. Zaras ND, Angeliki-nikoletta ES, Krase AA, Methenitis SK, Karampatsos GP, Georgiadis GV, et al. Effects of tapering with light vs. heavy loads on track and field throwing performance. The Journal of Strength & Conditioning Research. 2014;28:3484–95.

375. Ache-Dias, J., Dal Pupo, J., Dellagrana, R. A., Teixeira, A. S., Mochizuki, L., & Moro AR. Effect of Jump Interval Training on Kinematics of the Lower Limbs and Running Economy. The Journal of Strength & Conditioning Research. 2018;32:416–22.

376. Zheng Y, Ke S, Lin C, Li X, Liu C, Wu Y, et al. Effect of core stability training monitored by rehabilitative ultrasound image and surface electromyogram in local core muscles of healthy people. Pain Research and Management. 2019;2019:8 pages.

377. Barahona-Fuentes GDF, Huerta Ojeda Á, Galdames Maliqueo SA. Influencia de la pliometría basada en un Entrenamiento Intervalado de Alta Intensidad sobre la altura de salto y pico de potencia en futbolistas Sub - 17. Educación Física y Ciencia. 2019;21:e080.

378. Cinar-Medeni O, Baltaci G, Bayramlar K, Yanmis I. Core stability, knee muscle strength, and anterior translation are correlated with postural stability in anterior cruciate ligament-reconstructed patients. American Journal of Physical Medicine and Rehabilitation. 2015;94:280–7.

379. Behringer M, Neuerburg S, Matthews M, Mester J. Effects of two different resistance-training programs on mean tennis-serve velocity in adolescents. Pediatric exercise science. 2013;25:370–84.

380. Buchheit M, Rabbani A, Beigi HT. Predicting changes in high-intensity intermittent running performance with acute responses to short jump rope workouts in children. Journal of sports science & medicine. 2014;13:476.

381. Chen C-C, Lin S-Y. The impact of rope jumping exercise on physical fitness of visually impaired students. Research in developmental disabilities. 2011;32:25–9.

382. de Souza RM, da Silva Lourenço CA, dos Santos MB, Fiori H, de Azevedo Cardoso M, Antunes MA, et al. O exercício de pular corda como forma de treinamento de força para goleiros. RBFF-Revista Brasileira de Futsal e Futebol. 2020;12:166–72.

383. Dimarucot HC, Soriano GP. Effectiveness of the Multistage Jumping Rope Program in Enhancing the Physical Fitness Levels among University Students. International Journal of Human Movement and Sports Sciences. 2020;8:235–9.

384. Eler N, Acar H. The Effects of the Rope Jump Training Program in Physical Education Lessons on Strength, Speed and VO 2 Max in Children. Universal Journal of Educational Research. 2018;6:340–5.

385. Engelke K, Kemmler W, Lauber D, Beeskow C, Pintag R, Kalender W. Exercise maintains bone density at spine and hip EFOPS: a 3-year longitudinal study in early postmenopausal women. Osteoporosis international. 2006;17:133–42.

386. Fernandes M, Hans V. Effect of Jump Rope Program on the Skills of Elementary Students. Effect of Jump Rope Program on the Skills of Elementary Students (May 15, 2022). 2022;

387. Formenti D, Rossi A, Bongiovanni T, Campa F, Cavaggioni L, Alberti G, et al. Effects of non-sport-specific versus sport-specific training on physical performance and perceptual response in young football players. International journal of environmental research and public health. 2021;18:1962.

388. Ghorbanian B, Ravassi A, Kordi MR, Hedayati M. The effects of rope training on lymphocyte ABCA1 expression, plasma ApoA-I and HDL-c in boy adolescents. International journal of endocrinology and metabolism. 2013;11:76.

389. Ha AS, Ng JY. Rope skipping increases bone mineral density at calcanei of pubertal girls in Hong Kong: A quasi-experimental investigation. Plos one. 2017;12:e0189085.

390. Kemmler W, Engelke K, Lauber D, Weineck J, Hensen J, Kalender WA. Exercise effects on fitness and bone mineral density in early postmenopausal women: 1-year EFOPS results. Medicine and science in sports and exercise. 2002;34:2115–23.

391. Kemmler W, Engelke K, Weineck J, Hensen J, Kalender WA. The Erlangen Fitness Osteoporosis Prevention Study: a controlled exercise trial in early postmenopausal women with low bone density—first-year results. Archives of physical medicine and rehabilitation. 2003;84:673–82.

392. Kemmler W, Lauber D, Weineck J, Hensen J, Kalender W, Engelke K. Benefits of 2 years of intense exercise on bone density, physical fitness, and blood lipids in early postmenopausal osteopenic women: results of the Erlangen Fitness Osteoporosis Prevention Study (EFOPS). Archives of Internal Medicine. 2004;164:1084–91.

393. Kim ES, Im J, Kim KC, Park JH, Suh S, Kang ES, et al. Improved insulin sensitivity and adiponectin level after exercise training in obese Korean youth. Obesity. 2007;15:3023–30.

394. Kim, J., Son, W. M., Headid III, R. J., Pekas, E. J., Noble, J. M., & Park, S. Y. The effects of a 12-week jump rope exercise program on body composition, insulin sensitivity, and academic self-efficacy in obese adolescent girls. Journal of Pediatric Endocrinology and Metabolism. 2020;31:129–37.

395. Kramer A, Poppendieker T, Gruber M. Suitability of jumps as a form of high-intensity interval training: effect of rest duration on oxygen uptake, heart rate and blood lactate. European journal of applied physiology. 2019;119:1149–56.

396. Kusuma, A. I., Setijonob, H., & Mintartoc, E. Effects of jump rope and high jump training with 1:1 intervals on increasing Vo2max and anaerobic threshold. Int J Innov Creativ Change. 2020;12:429–42.

397. Miyaguchi K, Demura S, Omoya M. Relationship between jump rope double unders and sprint performance in elementary schoolchildren. The Journal of Strength & Conditioning Research. 2015;29:3229–33.

398. Mullur KVM, Jyoti D. The impact of jump rope exercises on the body mass index of 12 to 16 years school children. International Journal of Physiology, Nutrition and Physical Education. 2019;4:133–5.

399. da Silva VFN, da Silva Aguiar S, Sousa CV, da Costa Sotero R, Souto Filho JM, Oliveira I, et al. Effects of short-term plyometric training on physical fitness parameters in female futsal athletes. Journal of physical therapy science. 2017;29:783–8.

400. Nogueira RC, Weeks BK, Beck BR. An in-school exercise intervention to enhance bone and reduce fat in girls: The CAPO Kids trial. Bone. 2014;68:92–9.

401. Partavi S. Effects of 7 weeks of rope-jump training on cardiovascular endurance, speed, and agility in middle school student boys. Sport Science. 2013;6:40–3.

402. Pérez-Castilla A, García-Ramos A, Padial P, Morales-Artacho AJ, Feriche B. Effect of different velocity loss thresholds during a power-oriented resistance training program on the mechanical capacities of lower-body muscles. Journal of Sports Sciences. 2018;36:1331–9.

403. PraveenA A, JosephA S, PrasannaA TA, ManoranjithA R. Magnificent Promotion of Muscular Strength and Explosive Power Among College Female Volleyball Players due to the Selected Jump Rope Training.

404. Sandstedt E, Fasth A, Eek MN, Beckung E. Muscle strength, physical fitness and well-being in children and adolescents with juvenile idiopathic arthritis and the effect

of an exercise programme: a randomized controlled trial. Pediatric Rheumatology. 2013;11:1–11.

405. Sankar SB, Thanalakshmi R. Effect of Jump Rope Training on Speed Explosive Power among College Kabaddi Players. Pre-Exercise Nutrition: Carbohydrates and Fluid Requirement for Training and Competition. :50.

406. Seo K. The effects of dance music jump rope exercise on pulmonary function and body mass index after music jump rope exercise in overweight adults in 20's. Journal of physical therapy science. 2017;29:1348–51.

407. Stengel SV, Kemmler W, Pintag R, Beeskow C, Weineck J, Lauber D, et al. Power training is more effective than strength training for maintaining bone mineral density in postmenopausal women. Journal of applied physiology. 2005;

408. von Stengel S, Kemmler W, Kalender WA, Engelke K, Lauber D. Differential effects of strength versus power training on bone mineral density in postmenopausal women: a 2-year longitudinal study. British journal of sports medicine. 2007;41:649–55.

409. Barrio, E. D., Hernández-García, R., Ramirez-Campillo, R., Garcia-Atutxa, I., Villanueva-Flores, F., & García-de-Alcaraz, A. (2024). Single-Leg Countermovement Jump Compensation Assessment: Content Validity of a Checklist. International Journal of Sports Medicine.

Supplementary Files

Supplementary file 1 Physiotherapy evidence database (PEDro) scale ratings

Ítems	1	2	3	4	5	6	7	8	9	10	11	**Total**
Aggarwal et al. (2010)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	**6**
Bagherian et al. (2019)	Yes	No	No	Yes	No	No	No	Yes	Yes	Yes	Yes	**5**
Bashir et al. (2019)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	**6**
Chuter et al. (2015)	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	No	**6***
Granacher et al. (2013)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	**6**
Junker and Stoggl (2019)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	**6**
Kachanatu et al. (2014)	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	**7**
Kahle and Tevald (2014)	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	**7***
Motealleh et al. (2018)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	**9***
Ozmen and Aydogmus (2016)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	**6**
Ozmen et al. (2020)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	**6**
Park, Hyun and Jee (2016)	Yes	No	No	Yes	No	No	No	Yes	Yes	Yes	Yes	**5**
Sato and Mokha (2009)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	**6**

PEDro scale items number. A detailed explanation for each item: [321]
The total number of points from 0 to 10 scale
* Articles not included in meta-analysis

Supplementary file 2 Physiotherapy evidence database (PEDro) scale ratings

Ítems	1	2	3	4	5	6	7	8	9	10	11	**Total**
Aggarwal, Kumar and Kumar (2010)	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	**7**
Celenay and Kaya (2017) *	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	**7**
Chuter et al. (2015) *	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	**7**
Jamison et al. (2012)	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes	**7**
Junker and Stoggl (2019)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	**6**
Kuhn, Weberrub and Horstmann (2019) *	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	**6**
Lust et al. (2009)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	**5**
Mayer et al. (2014)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	**9**
Mayer et al. (2016)	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	**8**
Ozmen and Aydogmus (2016)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	No	**5**
Sannicandro (2017)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	**6**
Shamsi et al. (2016)	Yes	Yes	No	No	Yes	No	No	Yes	Yes	Yes	Yes	**6**
Stanton, Reaburn and Humpries (2004)	Yes	No	No	No	No	No	No	Yes	Yes	Yes	Yes	**4**
Tse et al. (2005)	Yes	No	No	Yes	No	No	No	No	Yes	Yes	Yes	**4**
Weston, Coleman and Spears (2013) *	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	**6**

PEDro scale items number. A detailed explanation for each item: https://pedro.org.au/english/resources/pedro-scale/

The total number of points from 0 to 10 scale

* articles not included in the meta-analysis

Supplementary material 3: Search strategy (code line) for each database and background of search history.

Date of the search	July, 2017	July, 2019	September, 2021
Databases	PubMed	PubMed, WOS (Core Collection), Scopus	PubMed, WOS (Core Collection[a]), Scopus
Keywords	"plyometric", "training"	"ballistic", "complex", "cycle", "explosive", "force", "plyometric", "shortening", "stretch", "training", "velocity"	"ballistic", "complex", "cycle", "explosive", "force", "jump", "plyometric", "power", "shortening", "stretch", "training", "velocity"
Database fields for the search	All	PubMed: all WOS: all Scopus: title, abstract, keywords	PubMed: all [b] WOS: all [b] Scopus: title, abstract, keywords [b]
Restrictions for the search	None	None	None
Examples of search strategy code line	Pubmed: "plyometric exercise"[MeSH Terms] OR ("plyometric"[All Fields] AND "exercise"[All Fields]) OR "plyometric exercise"[All Fields] OR ("plyometric"[All Fields] AND "training"[All Fields]) OR "plyometric training"[All Fields] WOS: (ALL=(plyometric)) AND ALL=(training) SCOPUS: TITLE-ABS-KEY (plyometric AND training)		
[a]: except for the keywords "jump" and "power" searched in all WOS databases. [b]: except for the keywords "jump" and "power" searched in the database field TITLE.			

Supplementary material 4. Exclusion reasons for studies included in the preliminary qualitative synthesis.

Study	Reason
Aminaie et al. (2017) [322]	Exercise interventions perform different numbers of total jumps (e.g., 972 vs 135) and combined with different types of training (e.g., no resistance training vs resistance training)
Arazi et al. (2012) [323]	Exercise interventions compared two types of surfaces (e.g., mat vs aquatic).
Blazevich et al. (2003) [324]	Exercise interventions combined with other different types of training and was impossible to determine why improvements occur (e.g., squat + sprint vs forward hack squat + sprint vs sprint).
Carlson et al. (2009) [325]	The study presents methodological limitations, and the subjects' characteristics are poorly described, was impossible to determine why improvements occur.
Chakshuraksha and Apanukul [326]	Exercise interventions used the same type of jump (e.g., CMJ) and combined with other different types of training (e.g., resistance training complex vs resistance training complex with accentuated eccentric loading).
Chaouachi et al. (2014) [327]	Exercise interventions combined with other types of training, and it was impossible to determine why improvements occur (e.g., none vs balance training).
Chmielewski et al. (2016) [328]	Anterior cruciate ligament reconstruction patients were the sample of the study. Exercise interventions used the same type of jumps and varied training intensity (e.g., low vs high).
Ciacci and Bartolomei (2018) [329]	Exercise interventions combined with other types of training made it impossible to determine why improvements occurred (e.g., hang-clean vs half squat).
Coratella et al. (2018) [330]	Exercise interventions perform a different number of total jumps (e.g., 800vs 656)
Elias et al. (2018) [331]	Exercise interventions variables were too different to compare the type of jumps: number of total jumps (e.g., 1600 vs 3080), intensity (e.g., max vs decrease during tapering) and progressive overload (e.g., volume + technique vs volume + technique + intensity)
Escobar et al. (2020) [332]	Exercise interventions used the same type of jump (e.g., squat jumps, CMJs and single-leg CMJs) and combined with other different types of training (e.g., squat + deadlifts + leg press vs squat + leg press).
Escobar et al. (2022) [333]	Exercise interventions used the same type of jumps and perform a different number of total jumps (e.g., 2160 vs 540)
Escriva-Selles and Gonzalez-Badillo [334]	Several differences between groups to make comparison (e.g., number of total jumps, intensity, progressive overload, combined one group with RT etc.)
Fathi et al. (2019) [335]	No clearly reported type of jump training, additionally, exercise interventions combined with other types of training, and it was impossible to determine why improvements occur (e.g., resistance training vs none).
Fatourus et al. (2000) [336]	Exercise interventions combined with other types of training, and it was impossible to determine why improvements occur (e.g., resistance training vs none).
Fowler et al. (1995) [337]	Several differences between groups to make the comparison (e.g., number of total jumps, 222 loaded jump squats vs 105 loaded jump squats + 399 pendulum jumps, intensity, progressive overload, combined with RT and other with RT and feedback, etc.)
Gauffin et al. (1989) [338]	Exercise interventions perform a different number of total jumps (e.g., 1440 vs 1320)
Gonzalo Skok et al. (2017) [339]	Exercise interventions involving jump training programs representing less than 50% of the total training load when delivered in conjunction with other training interventions (e.g., backward lunges, defensive-like shuffling steps, side-step, crossover cutting, lateral crossover cutting and lateral squat).
Hammami et al. (2019) [340]	Several differences between experimental groups make comparisons difficult (e.g., number of total jumps, combined training, tapering, etc.). Additionally, the statistical presentation of the information was poorly reported.
Helland et al. (2017) [341]	Comparison between exercise groups in the number of total jumps was too different (e.g., 635 vs 760) and combined training was different (e.g., RT + feedback vs RT).
Hortobagyi et al. (1991) [342]	Comparison between exercise groups in the number of total jumps was too different (e.g., 2280 vs 820). (PDF not found)
Huang et al. (2021) [343]	Exercise interventions combined with other types of training, and it was impossible to determine why improvements occur (e.g., none vs balance training). Consequently, the number of total jumps between groups was different (e.g., 2652 vs 1776).
Huang et al. (2014) [344]	Exercise interventions combined with other types of training, and it was impossible to determine why improvements occur (e.g., none vs balance training). Consequently, the number of total jumps between groups was different (e.g., 2736 vs 1776).

Huang and Lin (2010) [345]	Exercise interventions combined with other types of training, and it was impossible to determine why improvements occur (e.g., none vs balance training).
Jafari et al. (2013) [346]	All exercise interventions participated in the same training program. In general, type of training is poorly described.
Jiménez-Reyes et al. (2019) [62]	Impossible to make comparisons due to the highly individualized training program regarding training variable moderators.
Jiménez-Reyes et al. (2017) [347]	Not clearly reported the type of jump training along the exercise intervention groups.
Kamalakkannan et al. (2011) [348]	Both exercise intervention groups perform the same type of jump training. Comparison of this study is with or without resistance aquatic plyometric training.
Kamandulis et al. (2012) [349]	Only one exercise intervention group, impossible to make comparisons.
Kamandulis et al. (2012) [350]	Both exercise intervention groups perform the same type of jump training. Several differences between groups to make comparison (e.g., number of total jumps, intensity, training duration, etc.)
Kasmi et al. (2021) [351]	This study compared a group that performed jump training with other that performed jump training + eccentric training. Groups performed different number of total jumps (e.g., 1040 vs 384)
Katsikari et al. (2020) [352]	Only one exercise intervention group, impossible to make comparisons.
Keller et al. (2020) [353]	Several differences between groups to make the comparison (e.g., number of total jumps, 640-1120 vs 608-740, progressive overload, combined with COD and other no combined, etc.)
Kukric et al. (2012) [354]	This study compared a group that performed jump training with other that performed jump training + resistance training. Groups performed different number of total jumps (e.g., 1920 vs 4200)
Lievens et al. (2021) [355]	Exercise intervention groups perform the same type of jump training, except for one group that performed only 4 of 8 drills of the other groups. Several differences between groups to make comparison (e.g., number of total jumps, intensity, progressive overload, etc.)
Lindberg et al. (2021) [356]	This study compared a group that performed jump training + balance strength training with other that performed jump training + velocity training. Groups performed different number of total jumps (e.g., 1700 vs 2000).
Lloyd et al. (2016) [357]	This study compared a group that performed jump training with other that performed jump training + resistance training. Groups performed different number of total jumps (e.g., 958 vs 486)
Lyttle et al. (1996) [358]	Several differences between groups to make the comparison (e.g., number of total jumps, 496- vs 31, progressive overload, combined with RT and other upper body plyometrics, etc.)
Mero et al. (2021) [359]	Effects of jump training cannot be isolated, as the lack of detailed information about jump training.
Myklebust et al. (2003) [360]	Mix a lot of type of trainings and jump training is not clearly reported, impossible to make comparisons.
Ogiso and Miki (2020) [361]	Effects of jump training cannot be isolated, one group performed electromyostimulation + RT probably vs no adittional training.
Pamuk et al. (2022) [362]	The number of total jumps was too different (e.g., 2424 vs 1944)
Radnor et al. (2017) [363]	This study compared a group that performed jump training with other that performed jump training + resistance training. Groups performed different number of total jumps (e.g., 958 vs 486)
Ramirez-Campillo et al. (2018) [364]	Differences in combined training: RT unilateral vs RT bilateral.
Rhea et al. (2008) [365]	Several differences between experimental groups make comparisons difficult (e.g., number of total jumps, combined training, frequency, load, intensity, etc.). Methodological approach has many confusions.
Rhea et al. (2008) [366]	Several differences between experimental groups make comparisons difficult (e.g., number of total jumps, combined training, frequency, load, intensity, etc.). Methodological approach has many confusions.
Saez de Villareal et al. 2015 [367]	Authors applied 3 training interventions with different nature and characteristics (different volumes; exercises; environments such as water versus land, etc...), this make difficult to compare training outcomes.
Saez de Villareal et al. 2013 [368]	Authors applied 3 training interventions with different volumes (e.g., 936 vs 321 vs 615), this make difficult to compare training outcomes (e.g., loaded vs unloaded and cyclic vs acyclic).
Saez de Villareal et al. 2011 [369]	Authors applied 3 training interventions with different volumes (e.g., 936 vs 321 vs 615), this make difficult to compare training outcomes (e.g., loaded vs unloaded and cyclic vs acyclic).
Sanchez-Sanchez et al. 2021 [370]	Both exercise intervention groups perform the same type of jump training. One performed during 3 weeks and the other performed during 6 weeks.

Sánchez-Sixto et al. (2021) [371]	This study compared a group that performed jump training with other that performed jump training + resistance training. Groups performed different number of total jumps (e.g., 330 vs 512)
Simpson et al. (2001) [372]	This study compared an individualized vs non-individualized intensity with the same type of jumps. Groups performed different number of total jumps (e.g., 720 or less vs 216)
Siti et al. (2014) [373]	Groups performed different number of total jumps (e.g., 2520 vs 2808 vs 4140) and makes impossible comparison.
Smilios et al. (2013) [374]	Groups performed different number of total jumps (e.g., 360 repeated jumps + 300 loaded jumps vs 360 repeated jumps + 480 loaded jumps vs 360 repeated jumps) and makes impossible comparison.
Zaras et al. (2014) [292]	This study showed different types of tapering but used the same type of jump training with differences between total number jumps (e.g., 300 vs 540).

Supplementary file 5. Physiotherapy evidence database (PEDro) scale ratings.

Item	Gómez-Molina et al. (2018)[291]	Andrade et al. (2018)[289]	Turner, Owings and Schwane (2003)[294]	Bonacci et al., (2011)[275]	Spurrs, Murphy and Watsford (2003)[276]	Pellegrino, Ruby and Dumke (2016)[290]	Berryman, Maurel and Bosquet (2010)[375]	Ache-Dias et al. (2018)[293]	Barnes et al. (2013) [283]	Saunders et al., (2006)[283]	Lundstrom et al. (2017)[76]	Paavolainen et al. (1999) [284]	Taipale et al. (2010)[285]	Taipale et al. (2013)[282]	Sedano et al. (2013)[376]	Li et al. (2019)[274]	Giovanelli et al. (2017)[279]	Blagrove et al. (2018)[302]
Item 1 a	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Item 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes
Item 3	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Item 4	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Item 5	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Item 6	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Item 7	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Item 8	Yes	No	Yes	No	Yes	Yes	No	No	No	Yes	No	No	Yes	No	Yes	Yes	Yes	No
Item 9	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Item 10	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Item 11	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total (maximum = 10)	5	5	5	5	5	5	5	5	3	6	5	4	4	4	6	4	6	5

Note. Item 1: Eligibility criteria specified (not included in final rating). Item 2: Random group allocation. Item 3: Concealed allocation. Item 4: Similar groups at baseline. Item 5: Blinding of subjects. Item 6: Blinding of coaches. Item 7: Blinding of assessors. Item 8: 85% of subjects received one key measurement. Item 9: Intention to treat. Item 10: Statistical significance reported for one key outcome. Item 11: Effect sizes and measures of variability.

Supplementary file 6: Search strategy (code line) for each database and background of search history.

Date of the search	July, 2017	July, 2019	September, 2021
Databases	PubMed	PubMed, WOS (Core Collection), Scopus	PubMed, WOS (Core Collection[a]), Scopus
Keywords	"plyometric", "training"	"ballistic", "complex", "cycle", "explosive", "force", "plyometric", "shortening", "stretch", "training", "velocity"	"ballistic", "complex", "cycle", "explosive", "force", "jump", "plyometric", "power", "shortening", "stretch", "training", "velocity"
Database fields for the search	All	PubMed: all WOS: all Scopus: title, abstract, keywords	PubMed: all [b] WOS: all [b] Scopus: title, abstract, keywords [b]
Restrictions for the search	None	None	None
Examples of search strategy code line	Pubmed: "plyometric exercise"[MeSH Terms] OR ("plyometric"[All Fields] AND "exercise"[All Fields]) OR "plyometric exercise"[All Fields] OR ("plyometric"[All Fields] AND "training"[All Fields]) OR "plyometric training"[All Fields] WOS: (ALL=(plyometric)) AND ALL=(training) SCOPUS: TITLE-ABS-KEY (plyometric AND training)		
[a]: except for the keywords "jump" and "power" searched in all WOS databases. [b]: except for the keywords "jump" and "power" searched in the database field TITLE.			

Supplementary material 7: Exclusion reasons for studies included in preliminary qualitative synthesis.

Study	Reason
[303]	Exercise interventions not involving jump rope training (e.g., intermittent bouts of 30 s of maximal continuous jumps; i.e., no rope was used).
[79]	Only one experimental rope jump training group.
[377]	Compared jump rope training with traditional running group.
[378]	Only one experimental rope jump training group.
[379]	Only one experimental rope jump training group.
[318]	Exercise interventions not involving jump rope training (i.e., rope jumps represented less than 50% of the total training load, when delivered in conjunction with other drills, such as lateral barrier hop, box hopping, countermovement jump, countermovement jump to box, cycled split squat jump, push-ups with and without clapping hands, etc.).
[380]	Not included two experimental jumping groups.
[381]	Only one experimental rope jump training group.
[80]	Only one experimental rope jump training group.
[328]	Only one experimental rope jump training group.
[382]	Compared two different training protocols (hang clean+ jump rope vs half squat + speed ladder).
[383]	Only one experimental rope jump training group.
[384]	Only one experimental rope jump training group.
[385]	Only one experimental rope jump training group.
[386]	Only one experimental rope jump training group.
[387]	Only one experimental rope jump training group.
[78]	Only one exercise intervention involved jump rope training (compared sport specific training vs balance, speed, agility, quickness and jump rope training)
[388]	Not included two experimental jumping groups.
[389]	Only one experimental rope jump training group.
[85]	Only one experimental rope jump training group.
[390]	Only one experimental rope jump training group.
[391]	Only one experimental rope jump training group.
[392]	Only one experimental rope jump training group.
[393]	Only one experimental rope jump training group.
[394]	Only one experimental rope jump training group.
[395]	Only one experimental rope jump training group.
[396]	Only one experimental rope jump training group.
[224]	Compared jump rope training with high jump experimental group.
[397]	Compared jump rope training with countermovement abalakov experimental group.
[398]	Only one experimental rope jump training group.
[399]	Only one experimental rope jump training group.
[400]	Only one experimental rope jump training group.
[401]	Only one experimental rope jump training group.
[402]	Only one experimental rope jump training group.
[403]	Exercise interventions involving jump rope training programs representing less than 50% of the total training load when delivered in conjunction with other training interventions (e.g., jumping jack, vertical drop jump, horizontal drop jump, countermovement jump, abdominal crunch, Romanian deadlift, etc.).

[311] Only one experimental rope jump training group.

[404] Exercise interventions involving jump rope training programs representing less than 50% of the total training load when delivered in conjunction with other type of jumps (e.g., skipping, lateral cone jumps, bounding, box jumps and acelerations)

[405] Only one experimental rope jump training group.

[304] Only one experimental rope jump training group.

[406] Doubtful quality or peer-review process unclear from the journal.

[314] Doubtful quality or peer-review process unclear from the journal.

[86] Only one experimental rope jump training group.

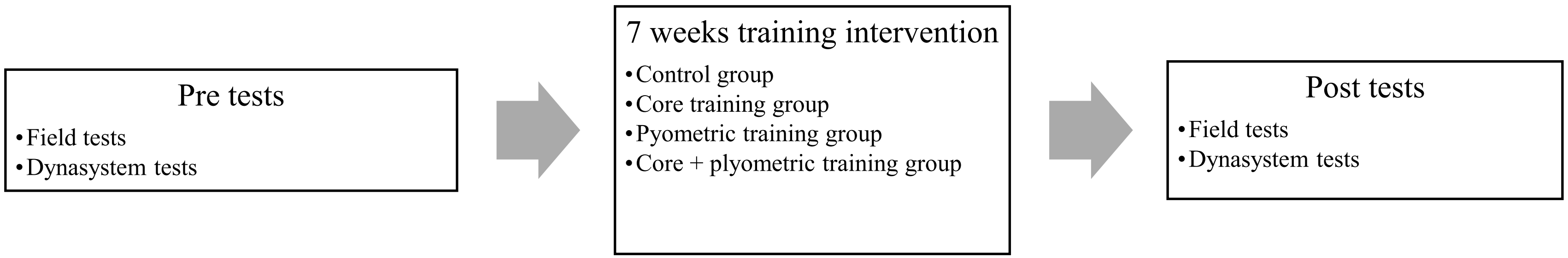
[407] Only one experimental rope jump training group.

[408] Exercise interventions involving jump rope training programs representing less than 50% of the total training load when delivered in conjunction with other training interventions (e.g., weightlifting session, gymnasium session consisting of coordination, strength, endurance, and range of motion training).

[408] Exercise interventions involving jump rope training programs representing less than 50% of the total training load when delivered in conjunction with other training interventions (e.g., weightlifting session, gymnasium session consisting of coordination, strength, endurance, and range of motion training).

Anexos

Anexo 1. Propuesta futura línea de investigación



Core training group

Exercise	*Exercise description*	*Sets*	*Seconds/reps*	*Rest/secs*	*Video example*
Abdominal bracing squat position	Activate the abdominal muscles maximally without hollowing the abdomen	3	10 secs	20 secs	
Supine lying dynamic arm-leg	Mantain isometric trunk from supine-lying position and alternate arm and leg raises	3	10 reps	30 secs	
Quadruped dynamic arm-leg	Mantain isometric trunk from quadruped position and alternate arm and leg raises	3	10 reps	30 secs	
1-leg dynamic glute bridge	Supine-lying with 1 knee flexed and foot on the floor trust hip maximum as possible	2	15 reps	30 secs/between legs	https://drive.google.com/drive/u/0/folders/1tLz1Lo4IwiHG1uKaEtb8Bxzql95y11RC
Squat medball side to side	From squat position push the medball to floor side to side as fast as possible	3	10 reps	60 secs	
1-leg medball front to front	With only 1 leg on the floor push the medball to floor as fast as possible	2	15 reps	60 secs/between legs	
1-leg band anti rotation	With only 1 leg on the floor push the band attached from lateral to your grip without trunk rotation	2	15 reps	30 secs/between legs	
Estimate total work time	11 min				
Estimate total rest time	15 min				
Estimate total session time	26 min				

Plyometric training group

Exercise	*Exercise description*	*Sets*	*Seconds/reps*	*Rest/secs*	*Video example*
Ankle jumps 2-2	Jump as fast as possible using only ankle joint	2	10 jumps	120 secs	
Symetric medball fall down	Fall down from box 60 cm	2	5 jumps	120 secs	
Assymetric fall down	Fall down from box 60 cm without symetric legs	2	5 jumps	120 secs	
Stopped jump squat 2-1	Jump from ground squat position and land with 1 leg	2	5 jumps each leg jumps	120 secs	https://drive.google.com/drive/u/0/folders/1tLz1Lo4IwiHG1uKaEtb8Bxzql95y11RC
Stopped jump lunge 2-1	Jump from ground lunge position and land with 1 leg	2	5 jumps each leg jumps	120 secs	
Side jumps	Jump side to side and land with different leg	2	10 jumps	120 secs	
Drop jump 2-2	Fall down from 60 cm box and jump as fast as possible	2	5 jumps	120 secs	

Total work	100 jumps
Estimate total rest time	28 min
Estimate total session time	40 min
Intensity	Maximal of each jump

Core + plyometric training group

Day 1

	Week 1		Week 2			Week 3		Week 4			Week 5		Week 6		Week 7	
Draw-ing lying down	2	10 sec	3	10 sec	Draw-ing lying quadruped	2	10 sec	3	10 sec	Draw-ing lying squat position	2	10 sec	3	10 sec	1	10 sec
Quadruped dynamic leg	3	10	3	10	Quadruped dynamic arm-leg	3	10	3	10	Quadruped dynamic arm-leg rotation	3	10	3	10	2	10
Fall down	3	10	3	12	Medball fall down	3	10	3	12	1 leg fall down	3	10	3	12	2	10
Isometric glute bridge	3	20 sec	3	20 sec	Dynamic glute bridge	3	20 sec	3	20 sec	1-leg glute bridge	3	20 sec	3	20 sec	2	20 sec
Ankle jumps 2-2	2	20	3	20	Pike jumps	2	20	3	20	Ankle jumps 1 leg	2	20	3	20	1	20
CMJs 2-2	3	10	3	10	CMJs 2-1	3	10	3	10	CMJs 1-1	3	10	3	10	2	10

Day 2

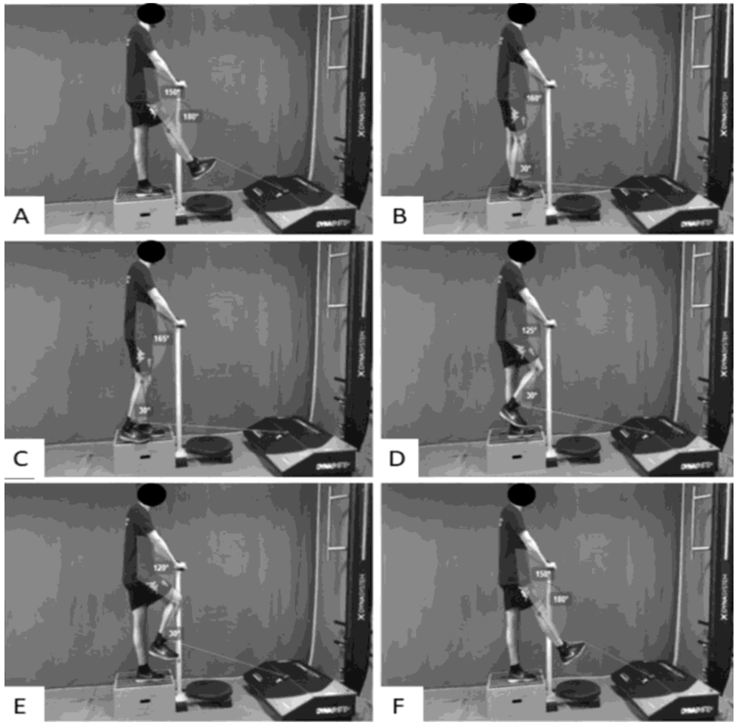
	Week 1		Week 2			Week 3		Week 4			Week 5		Week 6		Week 7	
Hollowing lying down	2	10 sec	3	10 sec	Hollowing quadruped	2	10 sec	3	10 sec	Hollowing squat position	2	10 sec	3	10 sec	1	10 sec
Isometric bacing dynamic arm	3	10	3	10	Isometric bacing dynamic leg	3	10	3	10	Isometric bacing dynamic leg-arm	3	10	3	10	2	10
Stopped squat 2-2	3	10	3	12	Stopped squat 2-1	3	10	3	12	Stopped squat 1-1	3	10	3	12	2	10
Kneeling antirotation	3	10	3	10	Squat antirotation	3	10	3	10	1 leg squat antirotation	3	10	3	10	2	20 sec
Lunge jump 2-2	2	10 each leg	3	10 each leg	Lunge jump 2-1	2	10 each leg	3	10 each leg	Lunge jump 1-1	2	10 each leg	3	10 each leg	1	20
Drop jump	3	10	3	10	Drop jump 2-1	3	10	3	10	Drop jump 1-1	3	10	3	10	2	10
Total jumps/week	200		252			200		252			200		252		120	
Total core sets/week	16		18			16		18			16		18		10	
72h rest between sessions	120sec rest between plyometric exercises				60sec rest between core exercises					Maximum effort in all series						

Field tests

Evaluation	*Tests*		*Measurement*	*Material*	*Trial attemps*	*Measure attemps*
Dynamic stability	Y-balance test	Anterior	cm	Meter	6	3
		Postrolateral	cm	Meter	6	3
		Posteromedial	cm	Meter	6	3
Static stability	1 leg eyes open	right	sec	Stopwatch	6	3
		left	sec	Stopwatch	6	3
	1 leg eyes closed	right	sec	Stopwatch	6	3
		left	sec	Stopwatch	6	3
Vertical performance	CMJ		height	My jump app	6	3
Agility	T-test		sec	Stopwatch	6	3

Dynasystem tests

Evaluation	*Tests*	*Measurement*	*Material*	*Trial attemps*	*Measure attemps*	*Pasos previos*
Trunk flexion strength	Trunk flexion strength	Newtons	Dynasystem	4 sets - 5 reps (2 reps submáximas y 3 máximas)	6 sets - 4 reps (máximas)	Medir ROM entre trocanter y acromion (100% del ROM)
				0.15 m/s 25% ROM	0.15 m/s 25% ROM	Sentados en banco plano y pies en el suelo, posición de tronco 90º
				0.15 m/s 50%ROM	0.30 m/s 25% ROM	2 sesiones de familiarización
				0.45m/s 25% ROM	0.45 m/s 25% ROM	5 min trote < 130ppm
				0.45m/s 50% ROM	0.15 m/s 50%ROM	5 min movilidad
				3 min rest cada set	0.30 m/s 50%ROM	3 sets 15 secs de plancha y puente de glúteo
					0.45 m/s 50%ROM	
					0 m/s 90º isometric 5 secs	

Hamstring sterngth	Swing excentric hamstring test	Averge and maximum load (N)	Dynas ystem	1 set - 5 reps	3 sets 5 reps	Medir pie de apoyo a la Dynasystem
				20 cm/s	20 cm/s	Medir ROM pierna dominante (la del test): paralelo a la pierna estática y 30º de fexion de rodilla
					40 cm/s	5 min cicloergómetro 100 W 70-80r/min
					60 cm/s	Hip extension 10 reps cada pierna
						Unilateral bridge 10 reps cada pierna
						Swing phase of running with elastic band