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TESIS DOCTORAL

Optimización del Rendimiento Muscular en Futbolistas: Rol de la Fatiga, Composición Corporal y Estímulo de Entrenamiento

Felipe Hermosilla Palma

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Optimización del Rendimiento Muscular en Futbolistas: Rol de la Fatiga, Composición Corporal y Estímulo de Entrenamiento

Tesis Doctoral presentada por D/Dª

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(firma)

Las Palmas de Gran Canaria, a 22 de julio de 2025

UNIVERSIDAD DE LAS PALMAS
DE GRAN CANARIA

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INFORMAN:

Que el trabajo de investigación titulado **"**Optimización del Rendimiento Muscular en Futbolistas: Rol de la Fatiga, Composición Corporal y Estímulo de Entrenamiento**"**, ha sido realizado por **Don. Felipe Hermosilla Palma**, en el Departamento de Ciencias Clínicas de la Universidad de Las Palmas de Gran Canaria, bajo su dirección y asesoramiento técnico y científico, y que una vez revisada la presente Memoria, la encuentra apta para su defensa ante tribunal.

Y para que así conste y surta los efectos oportunos, extiende el presente certificado en Las Palmas de Gran Canaria a 22 de julio de 2025

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El Director

Dedicatoria

A mis padres, por su amor incondicional, acá y en el cielo

A mis hermanos y hermana, espero y anhelo se sientan orgullosos

A Paulina, Vicente, Matilde y Lucía, el motivo, la razón y la luz de mis ojos. Son ustedes el amor que me mueve

Agradecimientos.

Los nombres que detallaré a continuación me han formado como profesional y, sobre todo, me han construido como persona. Mencionar su nombre es mi pequeña pero sincera forma de agradecerles, ahora y en los lugares hacia donde me lleve esta hermosa profesión.

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Tabla de contenido

1. INTRODUCCIÓN

La influencia de la fuerza sobre el rendimiento atlético ha sido ampliamente descrita en la literatura. Su importancia en la ejecución de acciones deportivas da cuenta de la importancia de su correcto desarrollo y optimización (Healy et al., 2019; Suchomel et al., 2021). Diversos gestos específicos del deporte dependen en gran medida de la producción de fuerza por unidad de tiempo, siendo esta un factor determinante de éxito deportivo (Suchomel et al., 2016). Aquellos atletas que sean capaces de producir más fuerza en función de una unidad temporal tendrán una ventaja competitiva por sobre el resto (Suchomel & Comfort, 2022). Particularmente en el fútbol, diversos estudios han dado cuenta del rol preponderante que desempeñan este tipo de acciones en el rendimiento del jugador, ya sea en la consecución del gol como en las acciones que previas que lo anteceden (Faude et al., 2012; Haugen et al., 2014).

El rendimiento muscular en los atletas se encuentra influenciado por factores fisiológicos, biomecánicos, antropométricos, estatus de entrenamiento, entre otros. La fatiga acumulada durante el juego y los entrenamientos intensos puede disminuir temporalmente la capacidad de producción de fuerza e influir en la ejecución de movimientos explosivos, cruciales en el fútbol (Silva et al., 2018). Del mismo modo, el nivel competitivo de los jugadores ha demostrado una relación proporcional con el rendimiento físico (Slimani et al., 2019; Slimani & Nikolaidis, 2019). En la misma línea, la composición corporal, especialmente la masa muscular y adiposa, determinan en gran medida el rendimiento físico, dado que una mayor proporción de masa muscular puede mejorar la capacidad de fuerza y potencia, así como el tejido adiposo ir en detrimento de estas (Figueiredo et al., 2020; Radziminski et al., 2020). Por otra parte, las características del estímulo de entrenamiento modulan la respuesta adaptativa, influenciando la capacidad para generar fuerza, velocidad y resistencia (Murphy et al., 2023). En conjunto, estos factores, que conforman el contexto de un futbolista, son determinantes para entender y optimizar las respuestas musculares específicas que impactan el rendimiento.

El fútbol moderno se caracteriza por una alta demanda física, donde los jugadores deben alternar constantemente entre acciones de baja y alta intensidad en un entorno competitivo, dinámico y cambiante (José M. Oliva-Lozano et al., 2023; Schimpchen et al., 2021). Dentro de este contexto, las capacidades musculares —particularmente aquellas asociadas a la fuerza, la velocidad y la potencia— cobran especial relevancia, ya que sustentan las acciones decisivas del juego como el esprint, el salto y el cambio de dirección (França et al., 2024; Hostrup & Bangsbo, 2023; Wing et al., 2020). A su vez, estas capacidades no se desarrollan ni se expresan en el vacío: están moduladas por factores intrínsecos y extrínsecos que componen el entorno del futbolista (Borges et al., 2023; López Cáceres et al., 2019; José M. Oliva-Lozano et al., 2021). Comprender cómo interactúan estas variables resulta fundamental para optimizar el rendimiento deportivo. En consecuencia, surge la necesidad de generar evidencia aplicada que permita analizar con precisión el impacto de distintos componentes contextuales sobre la respuesta muscular, con el fin de mejorar la planificación del entrenamiento y la toma de decisiones técnico-tácticas

La comprensión de estos elementos permite contextualizar el rol de la fuerza en el rendimiento, ya que esta habilidad no solo está influenciada por la fatiga y la composición corporal, sino que también se ve modulada por diversos factores mecánicos, neurales y estructurales que afectan el rendimiento muscular. La fuerza definida como la habilidad ejercer fuerza contra una resistencia externa (Stone, 1993), se encuentra determinada por factores mecánicos, neurales y estructurales (Cormie et al., 2011). En cuanto a los primeros, la capacidad del músculo para generar los mayores niveles de fuerza en un tiempo determinado se considera un factor limitante de rendimiento. En esta línea, diversas expresiones, como el salto, los cambios de dirección y las carreras de velocidad están directamente influenciadas por esta capacidad (Suchomel et al., 2016). Consecuencia de esto, la mejora de aspectos del rendimiento relacionados a estas acciones reviste gran importancia. Es así como la producción de fuerza por unidad de tiempo, velocidad máxima y capacidad de aceleración son determinantes para el éxito deportivo y forman parte esencial de los programas de entrenamiento de la fuerza en diferentes modalidades deportivas (Jimenez-Reyes et al., 2018). Dentro de estas manifestaciones, el desarrollo de la aceleración se convierte en prioridad, por sobre las carreras a máxima velocidad, debido a su predominancia en los deportes de equipo (Morin et al., 2015).

Dentro de los factores limitantes del rendimiento muscular, la fatiga juega un rol preponderante (Marqués-Jiménez et al., 2017). A medida que se incrementa, reduce significativamente la capacidad de generar fuerza, influyendo negativamente en la eficiencia de los movimientos explosivos y la habilidad de realizar esfuerzos repetidos (Girard et al., 2011; Oliver et al., 2008). Dado que limita la recuperación rápida entre acciones intensas, disminuye la capacidad del jugador de mantener altas intensidades de juego durante el juego, comprometiendo la ejecución de acciones clave como el esprint y carreras a altas intensidades (Coutinho et al., 2018). Debido a las características y demandas físicas del fútbol, la capacidad para repetir este tipo de esfuerzos en el transcurso del tiempo es de vital importancia. De este modo la habilidad para repetir esprints (HRS), correspondiente a la capacidad de realizar acciones máximas o casi máximas, de hasta 10” de duración, intercaladas con breves lapsos de recuperación activa o pasiva, corresponde al patrón de esfuerzos clásico en la mayoría de los deportes de equipo (Girard et al., 2011) y se convierte en uno de los propósitos a desarrollar por los entrenadores y cuerpos técnicos.

Del mismo modo, los contenidos magros y adiposos pueden modelar la respuesta física del futbolista (França et al., 2024; Stanković et al., 2023). En este sentido la composición corporal se transforma en uno de los objetivos a tener en cuenta por los entrenadores de la condición física. Mantener una composición corporal adecuada es esencial para un alto desempeño en el fútbol. Investigaciones muestran que los jugadores con menor porcentaje de grasa recorren distancias más largas y a mayor intensidad (Radziminski et al., 2020). Además, Figueiredo et al., (2020) encontraron correlaciones negativas entre masa grasa y altura de salto vertical, y positivas entre masa magra y potencia, así como asociaciones negativas entre masa grasa y rendimiento en esprints repetidos. Asimismo, Campa et al., (2019) destacan la importancia de reducir la grasa y mantener o aumentar la masa magra. Estos resultados subrayan la necesidad de un enfoque integral en el entrenamiento y la nutrición para mejorar la resistencia, la potencia y la capacidad de realizar esfuerzos explosivos repetidos.

Por otro lado, tanto el nivel competitivo de los futbolistas, así como su posición dentro del equipo ha demostrado tener asociación con el rendimiento atlético. De este modo jugadores que compiten en ligas de mayor estatus presentan mayores niveles de condición física que aquellos de ligas menores (Slimani & Nikolaidis, 2017). Asimismo, jugadores de primera división presentan mayores consumos de oxígeno, niveles de fuerza, capacidad de repetir esfuerzos de alta intensidad y acciones explosivas que aquellos de divisiones menores (Sánchez-López et al., 2023; Slimani & Nikolaidis, 2019). En cuanto a los perfiles de rendimiento por posición de juego, estudios previos dan cuenta de diferencias entre puestos para consumo máximo de oxígeno (Metaxas, 2021), fuerza isocinética (Śliwowski et al., 2017), perfiles de aceleración, desaceleración y esprint (Jose M. Oliva-Lozano et al., 2020) y distancias recorridas a alta y muy alta intensidad (Chen et al., 2025).

En cuanto al patrón de esfuerzo, el fútbol alterna entre acciones de alta y baja intensidad, donde la expresión de la fuerza y la potencia son factores clave en el rendimiento de los jugadores. Dentro de las acciones de alta intensidad se encuentran el esprint, aceleración, desaceleración y cambio de dirección (COD) (Dolci et al., 2020; Modric et al., 2019; Stølen et al., 2005; Vigne et al., 2010). En particular, el esprint lineal es decisivo en acciones relacionadas con el gol, con una prevalencia de más del 60% para jugadores que asisten y anotan (Faude et al., 2012). Se ha reportado que el 96% de los sprint en fútbol no sobrepasa los 30 m. y que al menos el 49% de estos son menores a los 10 m (Stølen et al., 2005), lo que hace crucial el desarrollo de la fase de aceleración en la carrera. En cuanto a los COD, estas acciones están entre las más prevalentes en un partido, con aproximadamente 700 esfuerzos por juego y es esencial para evadir a los oponentes y ganar posiciones ventajosas (Dolci et al., 2020). Además, el COD es una habilidad implícita en la agilidad, que incluye situaciones de aceleración, desaceleración y toma de decisiones (Bustamante-Garrido et al., 2023), lo que destaca su importancia para el desarrollo del rendimiento.

Una de las estrategias descritas para maximizar el desarrollo del rendimiento muscular en este tipo de acciones es la carrera de velocidad resistida. Esta consiste en agregar una sobrecarga al atleta al momento de realizar el sprint, el cual puede estar dado por un lastre anexado a un chaleco o a un dispositivo de arrastre (Hrysomallis, 2012). El entrenamiento de velocidad con carreras resistidas ha demostrado tener efectos positivos sobre algunos aspectos del rendimiento físico en futbolistas como por ejemplo el sprint, los cambios de dirección, altura de salto (SJ-CMJ), potencia media, potencia media propulsiva (Gil et al., 2018; McMorrow et al., 2019). En cuanto a la dosificación del estímulo, tradicionalmente se recomiendan cargas de entre el 10 al 12% de la masa corporal. Se argumenta que es la intensidad idónea para no perjudicar la técnica de carrera (Alcaraz et al., 2009). Asimismo, se han reportado mejoras con porcentajes que van desde un 5 a un 20% de la masa corporal en el rendimiento de velocidad para distancias entre 0-40, 20-30 y 20-40 m (Bachero-Mena & González-Badillo, 2014). Recientemente se ha propuesto incrementar estas intensidades a un 80% de la masa corporal e inclusive sobrepasando el 100% de la misma (Morin et al., 2017, 2020). En estos estudios se observó que la dosificación descrita incrementa la potencia máxima y la velocidad para 5 y 30 m así como la optimización del perfil fuerza velocidad horizontal. A pesar de las descripciones anteriores, no existe consenso sobre la influencia de la distancia del sprint resistido en el rendimiento atlético. Ningún estudio ha comparado el efecto de diferentes distancias en el rendimiento muscular dentro del mismo diseño. Este tema es de interés para los entrenadores y los investigadores en ciencias del ejercicio, ya que les permite fundamentar sus prescripciones en evidencia práctica

La presente investigación explica como el contexto modela las respuestas musculares en futbolistas de diversas categorías. Este análisis se agrupa en cuatro áreas (i) Influencia de la fatiga en la respuesta aguda muscular, (ii) Influencia de la composición corporal en la respuesta aguda muscular, (iii) Influencia del nivel competitivo en la respuesta muscular de alta intensidad (iv) Influencia de un protocolo de entrenamiento específico sobre la respuesta crónica muscular. En el punto tres se describen los objetivos que se desprenden de las áreas descritas.

2. JUSTIFICACIÓN.

La toma de decisiones en la programación del entrenamiento requiere respaldo empírico contextualizado. Esta investigación busca generar evidencia aplicada que permita precisar variables clave de dicha programación, facilitando así la adopción de criterios basados en datos por parte de los profesionales del entrenamiento.

El desarrollo de programas de entrenamiento eficaces en fútbol profesional requiere una comprensión detallada de los múltiples factores que influyen en el rendimiento físico-muscular. En este sentido, la investigación aplicada que relacione directamente los componentes contextuales —tales como la fatiga, la composición corporal, el nivel competitivo y la respuesta a estímulos específicos de entrenamiento— con indicadores objetivos de rendimiento se convierte en una herramienta indispensable para la toma de decisiones por parte de los entrenadores y profesionales del rendimiento deportivo.

Se considera que los atletas debe obtener ganancias consistentes y continuas en fuerza, potencia y condición física en general de tal modo que si estas no son adquiridas es posible aseverar que el entrenador ha fallado en su propósito (Hansen, 2014). A partir de lo señalado, se espera obtener información que vaya en directo beneficio de los entrenadores, entregando herramientas que apoyen el proceso de toma de decisiones con sus atletas. En esta línea, la preparación atlética de los deportistas, principalmente en fuerza, se considera un aspecto clave para la consecución del éxito deportivo (Suchomel et al., 2018). Por tanto, contar con información que posibilite fortalecer este aspecto se torna determinante.

En relación con las implicaciones prácticas, las habilidades relacionadas con el sprint y el salto juegan un rol clave en el rendimiento del jugador. Se ha reportado que el 96% de los sprint en fútbol no sobrepasa los 30 m. y que al menos el 49% de estos son menores a los 10 m (Stølen et al., 2005). En esta línea, el desarrollo de los niveles de fuerza máxima predispone favorablemente para mayores expresiones de fuerza por unidad de tiempo (Styles et al., 2016). Por tanto, esta condición se plantea como determinante para el éxito de las habilidades antes mencionadas. De este modo, modalidades de entrenamiento que optimicen esta capacidad posibilitan la adquisición de estrategias que potencialmente puedan maximizar el rendimiento de los deportistas e inclusive ser crucial para aquellas instancias que determinan el resultado del juego.

La utilidad de este estudio, desde el punto de vista de la metodología del entrenamiento, se relaciona con la posibilidad de experimentar con el diseño y operacionalización de las variables que componen la dosis. Este aspecto permite identificar cuáles son las alternativas más adecuadas para favorecer el rendimiento de los futbolistas en esfuerzos de alta intensidad y corta duración, los cuáles son determinantes en el desempeño exitoso de la tarea. De este modo se proyecta aportar a la toma de decisiones fundamentada por parte de los entrenadores, en el contexto de la programación y ajuste de cargas de entrenamiento cuyo propósito sea la optimización del rendimiento.

Diversos estudios han documentado que las acciones explosivas —como el esprint, los cambios de dirección o los saltos— son determinantes para el éxito en las fases decisivas del juego (Faude et al., 2012; Morin et al., 2015). No obstante, existen aún importantes vacíos en cuanto al análisis de las condiciones contextuales que modulan la expresión de estas capacidades, especialmente en condiciones de fatiga, en diferentes etapas del desarrollo deportivo o bajo protocolos de entrenamiento específicos. Comprender cómo estos factores influyen en la capacidad de producir fuerza y potencia de manera eficiente permite personalizar las cargas, reducir el riesgo de lesiones y optimizar los procesos de mejora del rendimiento.

Esta tesis doctoral, desarrollada bajo el formato de compendio por artículos, busca generar evidencia empírica de alta aplicabilidad que contribuya a resolver problemáticas reales del entrenamiento en el fútbol. En particular, se aborda el estudio del rendimiento muscular desde una mirada multifactorial, considerando variables fisiológicas, antropométricas, competitivas y metodológicas. Al abordar esta temática desde cuatro ángulos complementarios —fatiga, composición corporal y maduración, nivel competitivo y volumen de entrenamiento resistido— se ofrece una visión integral del fenómeno, lo cual permite al lector interpretar las respuestas musculares en relación con el contexto específico del futbolista.

Desde el punto de vista práctico, los hallazgos de esta tesis permitirán optimizar el diseño de entrenamientos orientados al desarrollo de habilidades críticas para el fútbol moderno, como la velocidad de reacción, la aceleración y la fuerza explosiva. Además, aportarán criterios basados en evidencia para la dosificación adecuada de la carga y para la evaluación del estado físico en distintas etapas del desarrollo deportivo. Esta integración entre ciencia y práctica se alinea con las necesidades actuales de los cuerpos técnicos, quienes requieren herramientas objetivas, contextualizadas y específicas para maximizar el rendimiento de sus atletas.

Por tanto, esta investigación no solo busca profundizar el conocimiento académico en el campo de las ciencias del ejercicio aplicadas al fútbol, sino que también tiene como propósito ser una guía para la acción profesional, promoviendo intervenciones basadas en datos en lugar de suposiciones. Con ello, se espera aportar a la evolución del entrenamiento deportivo moderno, desde una perspectiva rigurosa, práctica y centrada en el jugador

3. OBJETIVOS.

3.1.Preguntas de investigación:

¿Cómo afectan los esfuerzos repetidos de alta intensidad al rendimiento muscular en futbolistas según su nivel competitivo y grupo etario?

¿Qué relación existe entre la composición corporal, la maduración somática y el rendimiento muscular en futbolistas jóvenes?

¿De qué manera influye el nivel competitivo en la respuesta muscular frente a esfuerzos de alta intensidad en futbolistas profesionales?

¿Cuál es el efecto de un protocolo de esprint resistido con distancias diferenciales sobre las respuestas musculares en futbolistas en etapa de formación?

3.2.Objetivo general:

Explorar la influencia de los componentes contextuales intrínsecos y extrínsecos sobre el rendimiento muscular en futbolistas varones.

3.3.Objetivos específicos (OE):

Analizar el efecto de esfuerzos repetidos de alta intensidad sobre el rendimiento muscular en futbolistas adultos (estudio 1).

Explicar la influencia de la composición corporal, antropometría y maduración somática sobre el rendimiento muscular en futbolistas jóvenes (estudio 2).

Analizar la influencia del nivel competitivo en la respuesta muscular en esfuerzos de alta intensidad en futbolistas profesionales (estudio 3).

Examinar las respuestas musculares a partir de la aplicación de un protocolo de entrenamiento de esprint resistido con distancias diferenciales en futbolistas jóvenes (estudio 4).

A partir de los objetivos propuestos se plantean las siguientes hipótesis de investigación:

3.4. Hipótesis de investigación:

H1: Los esfuerzos repetidos de alta intensidad generan una disminución significativa del rendimiento muscular, siendo esta respuesta modulada por el nivel competitivo del futbolista.

H2: La composición corporal y el grado de maduración somática se correlacionan positivamente con el rendimiento muscular en futbolistas jóvenes.

H3: Los futbolistas profesionales de mayor nivel competitivo presentan respuestas musculares más eficientes (menor fatiga y mayor recuperación) ante esfuerzos de alta intensidad, en comparación con aquellos de menor nivel competitivo.

H4: La aplicación de un protocolo de esprint resistido con distancias diferenciales produce mejoras en las respuestas musculares de futbolistas jóvenes, siendo ésta dependiente de la distancia de esprint.

4. METODOLOGÍA

4.1. Enfoque.

Estudio con enfoque cuantitativo, en donde a través de la medición, utilización de estadística y prueba de hipótesis se propone explorar la influencia de los componentes contextuales intrínsecos y extrínsecos sobre el rendimiento muscular en futbolistas, mediante un proceso secuencial, deductivo y probatorio (Hernández et al., 2016). En una primera etapa se analiza la influencia de factores contextuales, para posteriormente aplicar una intervención de entrenamiento con el propósito de identificar los posibles efectos de esta sobre el rendimiento atlético en futbolistas.

4.2. Alcance.

Estudio de alcance descriptivo, correlacional y explicativo, en donde se especificarán en detalles las propiedades y características de los factores contextuales seleccionados, así como de sus respectivos efectos sobre el rendimiento muscular, con el fin de demostrar con precisión cual es el tipo de manipulación de variables que mayor efecto tiene sobre éste. El alcance correlacional se encuentra determinado por el análisis que explica la influencia de la composición corporal sobre el rendimiento muscular. Además de esto, presenta un alcance explicativo, debido a que se intenta dar respuesta al por qué de los determinados efectos conseguidos y en qué condiciones estos se manifiestan (Hernández et al., 2016).

4.3. Diseño

Estudio de doble diseño. Por una parte, se corresponde con el diseño no experimental, dado que se realizará un análisis de tipo descriptivo de variables que influyen en el rendimiento muscular (OE uno, dos tres; artículos uno, dos y tres). De igual manera, la última parte del estudio (OE cuatro) corresponde a un diseño experimental preprueba/posprueba con grupo control (Hernández et al., 2016), en donde se pretende identificar el efecto de la manipulación de la variable independiente, tipo de entrenamiento, sobre la variable dependiente, rendimiento muscular.

4.4. Población.

Futbolistas profesionales pertenecientes a la primera división del campeonato nacional chileno; Futbolistas en formación pertenecientes a clubes de fútbol profesional chileno

4.5. Muestra

Estudio 1: Diecisiete futbolistas profesionales pertenecientes a primera división del campeonato nacional chileno (edad 23.5±5.0 años; masa corporal 77.1±7.3 kg; talla 1.74±0.03 m)

Estudio 2: Treinta y cuatro futbolistas jóvenes pertenecientes a las categorías formativas de un club de futbol profesional chileno (edad 16.06 ± 0.78 años; talla 1.69 ± 0.06 m; masa corporal 62.39 ± 8.26 kg)

Estudio 3: Ochenta y cuatro futbolistas profesionales participantes de campeonato profesional chileno (edad 23.1 ± 4.97; 74.4 ± 7.39; 1.80 ± 0.06)

Estudio 4: Veinticuatro futbolistas pertenecientes a las categorías formativas de un club de futbol profesional chileno (edad 15.3 ± 0.68 años; masa corporal 61.4 ± 7.08 kg; 1.60 ± 0.06 m)

4.6. Procedimientos.

El levantamiento de datos, así como la aplicación de las pruebas de valoración física se llevaron a cabo en los complejos deportivos de los clubes de futbol que participaron del estudio. Estos se realizaron entre los años 2022 y 2024. Del mismo modo, parte de las pruebas se realizaron en el laboratorio de Ciencias de la Actividad Física de la Universidad Autónoma de Chile, sede Talca.. Todos los procedimientos fueron realizados bajo la normativa ética descrita en la Declaración de Helsinki para estudios en seres Humanos. Los participantes manifestaron voluntariamente su intención de formar parte del proceso, expresando su voluntad mediante un consentimiento informado. Del mismo modo, para los estudios en donde participaron menores de edad, se solicitó la autorización de los padres y/o tutores legales. Los procedimientos contaron con la aprobación del comité de ética de la Universidad Adventista de Chile (resolución 2023-07, acta N°2023-04 y voto 2023-08).

La caracterización de los procedimientos se detalla en los apartados respectivos de los artículos

5. ARTÍCULOS DE INVESTIGACIÓN

5.1. Artículo primero

Título: Changes in the Mechanical Properties of the Horizontal Force-Velocity Profile during a Repeated Sprint Test in Professional Soccer Players / Cambios en las Propiedades Mecánicas del Perfil Fuerza Velocidad Horizontal Durante Esfuerzos Repetidos de Alta Intensidad.

Introducción: El fútbol se caracteriza por un patrón de acciones de intensidad variada. La mayor parte de los esfuerzos se realizan de moderada a baja intensidad. Sin embargo, son los esfuerzos de alta y muy alta intensidad los determinantes en las acciones clave del juego. En este sentido, la capacidad de repetir esfuerzos de alta intensidad (RSA por su sigla en inglés), se convierte en una condición determinante en la construcción de la forma física del futbolista. En línea con esto, el comportamiento en situación de fatiga de las variables mecánicas que explican el esprint lineal puede aportar información para la programación del entrenamiento. De este modo, es posible intervenir de forma individualizada en función del comportamiento de las variables vinculadas con la producción de fuerza y velocidad para este tipo de acciones.

Justificación:
Comprender cómo se modifica el perfil fuerza-velocidad horizontal durante esfuerzos repetidos de alta intensidad permite identificar los efectos de la fatiga sobre la capacidad de esprintar en condiciones similares a las del juego. Esta información resulta clave para individualizar el entrenamiento en función de las demandas reales del fútbol y optimizar el rendimiento en acciones decisivas, donde la producción de fuerza y velocidad es crítica. Además, contribuye a diseñar estrategias de preparación física más precisas, orientadas tanto al desarrollo del rendimiento como a la prevención de lesiones

Objetivo: Analizar los cambios en el perfil fuerza velocidad horizontal durante esfuerzos repetidos de alta intensidad.

Metodología: Enfoque cuantitativo, alcance descriptivo comparativo, diseño transversal con dimensión temporal transeccional. Diecisiete futbolistas profesionales de primera división chilena fueron sometidos a una prueba de esprint repetidos, consistente en ocho repeticiones de 30 metros. Las propiedades mecánicas del perfil fuerza velocidad horizontal fueron analizadas durante cada intento.

Hallazgos principales: La velocidad máxima teórica (V0), potencia máxima y tasa de disminución del ratio de fuerza (DRF) presentan disminuciones durante la realización de la prueba de esprint repetidos ($p<0.05$) con tamaños del efecto (D-Cohen) pequeños a moderados. Por contraparte, la fuerza máxima teórica (F0) y la tasa máxima de desarrollo de la fuerza (RFpeak) no presentan variaciones estadísticamente significativas entre repeticiones de esprint.

Conclusiones: Las variables mecánicas del perfil fuerza velocidad horizontal más sensibles a los efectos de la fatiga son aquellas relacionadas con la producción de fuerza a altas velocidades. Por contraparte, la producción de fuerza al inicio del esprint no se ve afectada por la realización de esprints repetidos de alta intensidad.

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Article

Changes in the Mechanical Properties of the Horizontal Force-Velocity Profile during a Repeated Sprint Test in Professional Soccer Players

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Abstract: The objective was to analyze the changes in the horizontal force-velocity profile (HFVP) during the execution of repeated sprinting. Methods: Seventeen first-division Chilean soccer players completed a repeated sprint protocol consisting of eight sprints of 30 m with 25-s pauses between repetitions. The behavior of HFVP variables in each attempt was recorded from video recordings and analysis in the MySprint® application. Results: Differences ($p < 0.05$) were found between sprints in the following: time (T), starting from sprint 5 ($F = 35.6$; $\eta^2p = 0.69$); theoretical maximum speed (V0), starting from sprint 4 ($F = 29.3$; $\eta^2p = 0.51$); maximum power (PM), starting from sprint 5 ($F = 17$; $\eta^2p = 0.52$); rate of decrease in force index produced at each step (DRF), starting from sprint 1 ($F = 3.20$; $\eta^2p = 0.17$); and RF10, starting from sprint 1 ($F = 15.5$; $\eta^2p = 0.49$). In comparison, F0 and RFpeak did not present any differences ($p > 0.05$). Conclusion: The HFVP variables more sensitive to the effects of fatigue induced by an RSA protocol are those associated with the production of force at high speeds, being V0, DRF, and Pmax, while those that contribute to the generation of force at the beginning of the sprint, F0 and RFpeak, do not present essential variations.

Keywords: fatigue; acceleration; muscle strength; performance

1. Introduction

The ability to perform high-intensity efforts in short periods has been described as one of the main determinants of performance in most sports specialties [1]. In soccer, accelerations, decelerations, changes of direction, and high/very high-intensity runs are most prevalent prior to scoring a goal, becoming determinants of the game's success [2]. Within these sprints, those races performed at a speed range of 19.1 km/h [3] or over 25.2 km/h [4] comply with the described precept. Given soccer's characteristics and physical demands, the ability to repeat this type of effort over time is vital. Thus, the ability to repeat sprints (RSA), corresponding to the ability to perform maximal or near-maximal actions of up to 10″ in duration, interspersed with short periods of active or passive recovery, corresponds to the classic pattern of efforts in most team sports [5]. The RSA and the ability to cover longer distances by sprinting are linked to the outcome of the match in different leagues [6–8], thus becoming one of the fundamental purposes to be developed by coaches and technical teams.

There has been a significant increase in research about the factors/variables affected by fatigue (i.e., repeated-sprint exercise-induced reduction in the maximal power output, force, or speed even though the task can be sustained [5]), during RSA tests, which closely correspond to team-sport activity patterns. For example, Brocherie et al., 2015 [9] showed that a repeated anaerobic sprint test leads to substantial alterations in stride mechanics and leg-spring behavior in professional football players. It is suggested that RSA is also influenced by standard metrics such as step frequency, contact time, and stride time. Besides, whole-body kinematic patterns demonstrate effects on running mechanics that could be determinants for the production/maintenance of repeated sprint performance during an RSA test in team sports athletes [10]. Finally, Van den Tillaar, in 2018 [11], analyzed running kinematics in repeated sprints in training, showing that fatigue induced in repeated 30-m sprints in female soccer players resulted in decreased step frequency and increased contact time. However, the effect of repeated sprints on kinetic variables, such as the horizontal force applied during the sprint, is lacking.

Since maximum speeds are rarely reached in game situations, accelerations assume a preponderant role in the physical performance of athletes [12]. Thus, the analysis of their behavior provides relevant information regarding the components that determine sprinting, for example, the effectiveness of the force applied to the floor and how this allows horizontal displacement, observing that the greater the net force applied horizontally to the floor, the greater the acceleration [13]. Therefore, monitoring and developing variables that determine force production and sprint speed are considered one of the pillars of the training process [14].

An examination of the macroscopic components underlying the force-velocity relationship that explain this performance can be determined using valid and reliable field tests [13,15]. In this sense, the mechanical variables of the horizontal force-velocity profile (HFVP) are as follows: theoretical maximum force (F0), theoretical maximum velocity (V0), maximum power (Pmax), rate of decrease of force produced in each stride (DRF), and maximum value in the force index (RFpeak), which are key to implementing individualized training programs [16], accounting for the mechanical efficiency of the athlete when applying horizontal force, and allow identifying differences depending on the type of sport and the level of sport specialization [17,18]. Likewise, two of its component variables (DRF corresponding to the athlete's ability to maintain high levels of horizontal force production as the speed of displacement increases, and RFpeak, which represents the percentage of the total force generated that is applied horizontally), are strongly correlated with sprint performance [19].

Furthermore, maintaining performance during repeated sprinting by delaying the associated fatigue is of great interest for performance in soccer [20,21]. However, the study of the horizontal force-velocity profile during tests involving sprint repetition or during acute fatigue in soccer has not been sufficiently explored. In this regard, Nagahara 2016 [14] described how fatigue generated during a soccer match produces impairment in velocity (V0) and in the ability to maintain horizontal force levels during a sprint (DRF). Consistent with this, in the context of rugby sevens, research reports the deleterious effects of fatigue on game-specific movement patterns [22], and the prevalence of high-intensity running [23].

Based on the above, describing the influence of fatigue on the mechanical patterns of sprinting to provide background information to generate specific interventions by the technical bodies becomes necessary. Thus, the purpose of the present study was to analyze the changes in HFVP during repeated sprint execution in male professional soccer players. It is hypothesized that all the variables of the HFVP present a detriment in their expression, with those related to force production at high speeds being the most affected.

2. Materials and Methods

2.1. Design

A cross-sectional study design was implemented to examine the changes in the horizontal force-velocity profile using time (s), F0 (N/kg), V0 (m/s), peak power (W/kg), DRF (%), RF 10 m (%), and RFpeak (%) during a repeated-sprint ability (RSA) test.

2.2. Subjects

Seventeen professional soccer players (age 23.5 ± 5.0 years, body mass 77.1 ± 7.3 kg, height 1.74 ± 0.03 m) belonging to the first division of the Chilean national championship participated. According to reports from the club's medical team, all players were in the pre-competitive period and free of musculoskeletal pain or injury. They were also informed about the possible risks and benefits of the study, agreeing to participate by signing a voluntary informed consent. The research was approved by the Chilean Adventist University Ethics Committee No. 2022-34. All procedures followed the principles described in the Declaration of Helsinki for human studies [24].

2.3. Procedures

The evaluations were carried out during the second week of the pre-competitive period, 4 weeks before the start of the competition, at 9:30 a.m. on the third day of the planned microcycle. All participants performed the tests with soccer shoes on a natural grass field. Participants were instructed to arrive at the performance tests rested, fasting for at least 3 h, and adequately hydrated. Light training sessions were scheduled with the technical team 2 days prior to the evaluation.

2.4. Preparation

Prior to the execution of the RSA test, each player completed a 15 min standardized warm-up [25], composed of joint mobility and dynamic stretching, followed by low-intensity aerobic running to conclude with three progressive sprints up to 95% of self-perceived effort, all under the supervision of the team's physical trainer.

2.5. Repeated Sprint Ability (RSA)

After the warm-up, each player performed the RSA test consisting of the execution of eight sprints in a straight line over a distance of 30 m, with a 25 s pause between sprints [26]. According to Girard et al. (2011) [5], the tests that assess this capacity to repeat sprint should be between 10 and 60 s for effort and rest, respectively. The start and finish lines were demarcated on the floor; participants were verbally encouraged to perform each repetition with maximum intensity. Each attempt was recorded by an IPad 8th generation device (Apple, Inc., Cupertino, CA, USA), which was placed perpendicularly 10 m from the surface intended for the race on a tripod at the height of 1.5 m. The analysis of the behavior of the variables of the horizontal velocity force profile were as follows: time (s), F0 (N), V0 (m/s), peak power (W/kg), DRF (%), FV (%), RF 10m (%), and RFpeak (%), which were performed with the MySprint® app, which counts the partial times every 5 m (5 m–10 m–15 m–20 m and 25 m). This app is valid and reliable concerning the reference systems (radar gun and timing photocells) [27].

2.6. Statistical Analysis

Descriptive statistics are presented as mean and standard deviation (SD) because the normality assumption was checked through the Shapiro-Wilk test. The inter-sprint comparison was performed with the repeated measures ANOVA test, and the Greenhouse-Geisser sphericity correction was used when the sphericity assumption was not met. Bonferroni post-hoc tests were performed, and effect sizes are presented as partial eta squared ($\eta^2 p$). The percentage of change was calculated as a practical fatigue index, where the best value was used as a basal reference and the last attempt, since the first attempt is not always the best value [5], resulting in the following equation: (best value-last value)/best value * ±100 [28]. Finally, the effect size between consecutive sprints was calculated using Cohen's d average [29], using the following thresholds for qualitative classification: trivial (<0.2), small (0.21–0.6), moderate (0.6 1–1.2), large (1.21–2), very large (2.1–4) [30]. Sample size (n = 17) allows the detection of an effect size of 0.4 in V0 (m/s) in paired data with an alpha error of 0.05 and a power of 80%. All analyses were performed in SPSS® v.28 software with an alpha of 0.05

3. Results

The descriptive statistics of the mechanical variables in each sprint of the RSA test are shown in Table 1. Differences ($p < 0.05$) between sprints were found in the following: T (F = 35.6; $\eta^2 p = 0.69$; $p = 0.000$), the first sprint presents differences with the remaining seven attempts; V0 (F = 29.3; $\eta^2 p = 0.51$; $p = 0.000$), the first sprint presents differences with the third attempt; PM (F = 17; $\eta^2 p = 0.52$; $p = 0.000$), presents differences with sprint 2, 4, 5, 6, 7, and 8; DRF (F = 3.20; $\eta^2 p = 0.17$; $p = 0.047$), presents differences with sprint 6, 7, and 8; and RF10 (F = 15.5; $\eta^2 p = 0.49$; $p = 0.000$), presents differences with sprint 4, 5, 6, 7, and 8. While for F0 and RFpeak, there were no differences ($p > 0.05$). These differences can be seen in the post-hoc analyses shown in Figure 1.

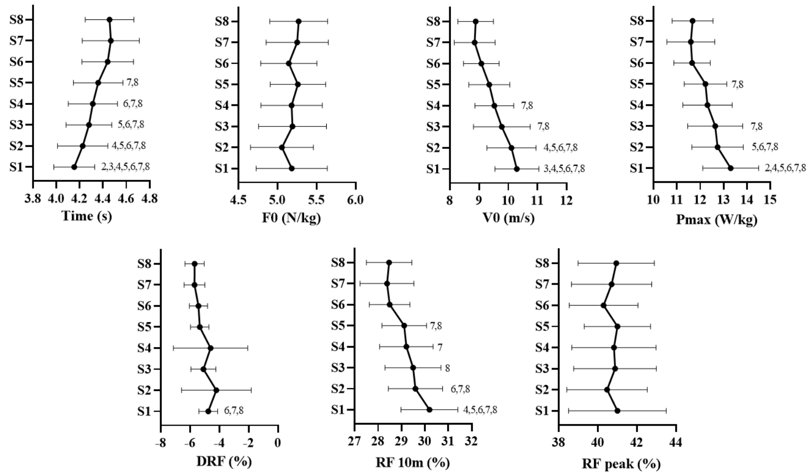

Figure 1. Differences between sprints for the variables of the horizontal force-velocity profile. F0: theoretical maximum force; V0: theoretical maximum speed; Pmax: maximum power; DRF: rate of decrease in force index produced at each step; RF 10 m: force index in the first 10 m; RFpeak: maximum value in force index. 2 = statistically significant difference with sprint number 2; 3 = statistically significant difference with sprint number 3; 4 = statistically significant difference with sprint number 4; 5 = statistically significant difference with sprint number 5; 6 = statistically significant difference with sprint number 6; 7 = statistically significant difference with sprint number 7; 8 = statistically significant difference with sprint number 8.

Table 1. Description and differences for the variables of the horizontal force-velocity profile.

Sprint	T (s)			F0 (N/kg)			V0 (m/s)			PM (w/kg)			DRF (%)			RF 10m (%)			RFpeak (%)		
	M	SD	ES	M	SD	ES	M	SD	ES	M	SD	ES	M	SD	ES	M	SD	ES	M	SD	ES
S1	4.15	0.17	(2) −0.37	5.18	0.46	(2) 0.29	10.29	0.75	(2) −0.23	13.3	1.2	(2) 0.49	−4.77	0.6	(2) −0.37	30.2	1.2	(2) 0.50	41.0	2.5	(2) 0.23
S2	4.23	0.22	(3) −0.26	5.06	0.40	(3) −0.32	10.11	0.84	(3) 0.36	12.7	1.1	(3) 0.09	−4.21	2.4	(3) 0.55	29.6	1.2	(3) 0.09	40.5	2.1	(3) −0.20
S3	4.28	0.20	(4) −0.17	5.19	0.43	(4) 0.03	9.78	0.97	(4) 0.31	12.6	1.2	(4) 0.29	−5.09	0.9	(4) −0.29	29.5	1.2	(4) 0.24	40.9	2.1	(4) 0.03
S4	4.31	0.21	(5) −0.22	5.18	0.39	(5) −0.22	9.52	0.66	(5) 0.25	12.3	1.1	(5) 0.09	−4.61	2.5	(5) 0.47	29.2	1.1	(5) 0.09	40.8	2.2	(5) −0.09
S5	4.36	0.21	(6) −0.38	5.26	0.36	(6) 0.33	9.35	0.70	(6) 0.41	12.2	0.9	(6) 0.68	−5.35	0.6	(6) 0.14	29.1	1.0	(6) 0.69	41.0	1.7	(6) 0.41
S6	4.44	0.22	(7) −0.11	5.14	0.36	(7) −0.28	9.08	0.61	(7) 0.35	11.7	0.8	(7) 0.06	−5.44	0.6	(7) 0.41	28.5	0.9	(7) 0.11	40.3	1.8	(7) −0.22
S7	4.47	0.24	(8) 0.05	5.25	0.40	(8) −0.05	8.85	0.70	(8) −0.05	11.6	1.0	(8) −0.08	−5.71	0.7	(8) −0.02	28.4	1.2	(8) −0.08	40.7	2.1	(8) −0.12
S8	4.46	0.21		5.27	0.37		8.88	0.61		11.7	0.9		−5.69	0.7		28.5	1.0		40.9	2.0	
PC	−7.3			4.23			−13.72			−12.27			−35.2			5.71			0.14		
F	35.62			0.93			29.32			17.02			3.21			15.51			0.45		
p	0.000			0.485			0.000			0.000			0.047			0.000			0.868		
η^2p	0.69			0.06			0.65			0.515			0.17			0.49			0.03		

S: sprint; M: mean; SD: standard deviation; ES: Effect Size; PC: percentage of change; F: F of ANOVA; η2p: partial eta square T: times; F0: theoretical maximum force; V0: theoretical maximum speed; Pmax: maximum power; DRF: rate of decrease of force produced in each stride; RF 10 m: force index in the first 10 m; RFpeak: maximum value in the force index; (2) ES vs. S2; (3) ES vs. S3; (4) ES vs. S4; (5) ES vs. S5; (6) ES vs. S6; (7) ES vs. S7; (8) ES vs. S8.

4. Discussion

The objective of this study was to analyze the changes in PFVH during repeated sprint execution in male professional soccer players. Therefore, knowing the impact that RSA has on the different strategies used by athletes to maintain the same HFVP power in different actions becomes preponderant for technical and scientific sections of the sport since it allows for improving the prescription of physical exercise, focused on a better understanding the mechanical properties of the neuromuscular system to optimize performance [31].

Our results show that most of the HFVP variables analyzed decrease their performance in the RSA, except for F0, RF 10 m, and RFpeak. These findings are consistent with what was described by Jiménez-Reyes et al. (2019) [25]. They examined the behavior of the HFVP against the application of repeated sprints in rugby sevens players, demonstrating that the variables associated with force production at high speeds, V0 and DRF, decrease because of fatigue inherent to RSA. However, the ability to produce force at low speeds in F0 and peak RF was not compromised. Furthermore, it is possible to infer that the acute effects of fatigue on the mechanical properties of the neuromuscular system mainly affect those aspects related to the maintenance of high levels of force over time, limiting its expression as movement speed increases.

Our study shows no changes in force expression at low speed, arguing that fatigue does not have a counterproductive effect on performance at the beginning of this type of effort. These findings agree with what was described by Nagahara et al. (2016) [14], who deepened studies on the effect of the efforts made in context on these muscular properties in university soccer players. Therefore, a soccer match could alter this ability to produce force at high speeds (V0), impairing horizontal force production. In the same way, the pattern of the effort made during the game is directly proportional to the loss of this effort, with those athletes who covered the greatest distance presenting the most significant loss associated with V0. Also, our findings show an increase in F0, suggesting a possible immunity of this variable to the effects of fatigue. This last aspect can be partially refuted because some modifications in the technical pattern of athletes have been identified to counteract the counterproductive effects. Wdowski et al. (2020) [32] investigated the effect of a specific resistance stimulus on the kinetics of first support during an acceleration run in professional soccer players. Their findings describe that soccer players modify the movement pattern, decreasing the medial-lateral load and increasing the force in the anteroposterior direction, to counteract the effects generated by fatigue. Our results corroborate this, which shows a decrease in performance in the last 20 m of a 30 m sprint.

From what has been described, it is interpreted that the acute effects of fatigue influence HFVP variables related to the lower zone of the F-V curve, negatively impacting V0 and DRF. As mentioned above, the evidence in this regard is limited. The acute effects of an RSA protocol on sprint kinetic and kinematic variables were recently investigated, finding significant decreases for V0 (ES −1.99, large decrease), Pmax (ES −0.65, large decrease), RFpeak (ES −0.94 large decrease), F0 (ES −0.65 moderate decrease), DRF (ES −0.71 moderate decrease), and concluding that the variable mostly affected is power (Pmax), mainly due to a decrease in velocity (V0) [33].

Besides, the long-term effects of stimuli applied during complete soccer seasons on the variables that make up the HFVP have been described [34]. It has been found that the HFVP components that most decrease their performance at the end of the competition compared to the preseason are those that contribute to the generation of force at low speeds, F0 and RFpeak, while those linked to the maintenance of force at high speeds, V0, DRF, and Pmax, increase. Haugen (2018) [35] analyzed the changes in mechanical variables in the sprint and in others associated with the production of force per unit of time in the vertical jump produced before, during, and at the end of a season of training. Thus, F0, V0, and Pmax increase their expression at the end of the season, with greater changes regarding the previous period and during the season. It is essential to mention that, in both cases, no specific training interventions were carried out aimed at improving the components of the HFVP.

The development of fatigue in repeated sprint efforts appears after the first repetition [36], determined by neural factors and metabolite accumulation [5]. Edouard et al. (2018) [37], analyzed kinetic, kinematic, and electromyography variables before, during, and after a repeated sprint protocol of 12 6-s sprints with a 44-s pause between them. They found a decrease in Vmax and Pmax in the first sprint, as in the present study. In addition, they found decreases in horizontal and vertical force, which could be due to two aspects: (a) the method used in the evaluation (treadmill) [38]; and (b) the number of sprints during the protocol, which could have produced performance fatigability [39], inferring that changes in movement strategies possibly occur, affecting the mechanical variables of sprinting. This situation is corroborated by Romero et al. (2022) [33], who report variations in the knee and hip angulations from the performance of a repeated sprint protocol, presenting different responses between individuals (increases or decreases in joint angle), described as protective of movements injuries.

Also, it has been found that speed decreases proportionally to the number of sprints performed [40]. Similarly, speed losses in the competition are around 7.9% during the last 15 min of a match [41]. Based on this characterization, RSA tests should be proposed to simulate such a scenario to provide a valid parameter for comparison. Although our findings are below these values (percentage change for a time in 30 m = 7.3%), they are not unrelated to those described in the literature, where there is a broad spectrum of reported decreases, ranging from 3.2% to 9.5% [42]. Regarding the sprint durations, our results present a mean of 4.3 ± 0.02 s, adjusting to the described conditions.

Some limitations of our study are that the results presented show the mechanical characteristics of the players during a sprint in preparation for the World Cup. However, these variables can be modified based on the training status, quality of training, responsiveness to training, and nutrition, among others [43]. Another limitation in our study is related to equipment and frequency sampling because Stalker radar has 46.9 Hz. However, the literature shows a frequency to high velocity of up to 60 Hz in motion capture systems [44]. Finally, estimates of variables related to the force-velocity profile have been criticized, especially those related to power output. It is proposed that treatment of scalar quantities (e.g., power) as vectors is not appropriate in biomechanics, and vector quantities as impulses could be taken into account as causative factors in performance [45].

5. Conclusions

The HFVP variables most sensitive to the effects of the accumulation of stresses induced by an RSA protocol are those associated with force production at high speeds (i.e., V0, DRF, and Pmax). Conversely, those that contribute to force generation at the beginning of the sprint (F0 and RFpeak) do not present significant variations.

It is recommended to analyze the individual response of the variables obtained by the HFVP in contexts of fatigue, both acutely and chronically. This allows specific interventions depending on the performances that occur at different times. Furthermore, due to the importance of sprinting in the success of decisive actions in soccer, it is necessary to identify the mechanical components that determine its development to manage, reorient, and/or modify the training stimuli accordingly to enhance the individual player's performance.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and was approved by the Scientific Ethical Committee of the Universidad Adventista de Chile No. 2022-34.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are available for research purposes upon request to the corresponding author.

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References

1. Jiménez-Reyes, P.; Contreras, B.; Morin, J.-B. Speed and Acceleration Training. In *Advanced Strength and Conditioning*; Routledge: London, UK, 2018; pp. 310–326. [CrossRef]
2. Faude, O.; Koch, T.; Meyer, T. Straight Sprinting Is the Most Frequent Action in Goal Situations in Professional Football. *J. Sport. Sci.* **2012**, *30*, 625–631. [CrossRef] [PubMed]
3. Brito, Â.; Roriz, P.; Silva, P.; Duarte, R.; Garganta, J. Effects of Pitch Surface and Playing Position on External Load Activity Profiles and Technical Demands of Young Soccer Players in Match Play. *Int. J. Perform. Anal. Sport.* **2017**, *17*, 902–918. [CrossRef]
4. Jones, R.N.; Greig, M.; Mawéné, Y.; Barrow, J.; Page, R.M. The Influence of Short-Term Fixture Congestion on Position Specific Match Running Performance and External Loading Patterns in English Professional Soccer. *J. Sport. Sci.* **2019**, *37*, 1338–1346. [CrossRef]
5. Girard, O.; Mendez-Villanueva, A.; Bishop, D. Repeated-Sprint Ability—Part I. *Sport. Med.* **2011**, *41*, 673–694. [CrossRef] [PubMed]
6. Chmura, P.; Konefał, M.; Chmura, J.; Kowalczuk, E.; Zajac, T.; Rokita, A.; Andrzejewski, M. Match Outcome and Running Performance in Different Intensity Ranges among Elite Soccer Players. *Biol. Sport.* **2018**, *35*, 197–203. [CrossRef] [PubMed]
7. Barrera, J.; Sarmento, H.; Clemente, F.M.; Field, A.; Figueiredo, A.J. The Effect of Contextual Variables on Match Performance across Different Playing Positions in Professional Portuguese Soccer Players. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5175. [CrossRef]
8. Modric, T.; Versic, S.; Sekulic, D.; Liposek, S. Analysis of the Association between Running Performance and Game Performance Indicators in Professional Soccer Players. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4032. [CrossRef] [PubMed]
9. Brocherie, F.; Millet, G.P.; Girard, O. Neuro-Mechanical and Metabolic Adjustments to the Repeated Anaerobic Sprint Test in Professional Football Players. *Eur. J. Appl. Physiol.* **2015**, *115*, 891–903. [CrossRef]
10. De Andrade, V.L.; Palucci Vieira, L.H.; Kalva-Filho, C.A.; Santiago, P.R.P. Critical Points of Performance in Repeated Sprint: A Kinematic Approach. *Sci. Sport.* **2021**, *36*, e141–e150. [CrossRef]
11. Van den Tillaar, R. Comparison of Step-by-Step Kinematics in Repeated 30-m Sprints in Female Soccer Players. *J. Strength Cond. Res.* **2018**, *32*, 1923–1928. [CrossRef]
12. Samozino, P.; Peyrot, N.; Edouard, P.; Nagahara, R.; Jimenez-Reyes, P.; Vanwanseele, B.; Morin, J.B. Optimal Mechanical Force-Velocity Profile for Sprint Acceleration Performance. *Scand. J. Med. Sci. Sport.* **2022**, *32*, 559–575. [CrossRef] [PubMed]
13. Pierre, S.; Rabita, G.; Dorel, S.; Slawinski, J.; Peyrot, N.; Saez de Villarreal, E.; Morin, J.B. A Simple Method for Measuring Power, Force, Velocity Properties, and Mechanical Effectiveness in Sprint Running. *Scand. J. Med. Sci. Sport.* **2015**, *26*, 648–658. [CrossRef]
14. Nagahara, R.; Morin, J.B.; Koido, M. Impairment of Sprint Mechanical Properties in an Actual Soccer Match: A Pilot Study. *Int. J. Sport. Physiol. Perform.* **2016**, *11*, 893–898. [CrossRef]
15. Mendiguchia, J.; Samozino, P.; Martinez-Ruiz, E.; Brughelli, M.; Schmikli, S.; Morin, J.B.; Mendez-Villanueva, A. Progression of Mechanical Properties during On-Field Sprint Running after Returning to Sports from a Hamstring Muscle Injury in Soccer Players. *Int. J. Sports Med.* **2014**, *35*, 690–695. [CrossRef] [PubMed]
16. Morin, J.B.; Samozino, P. Interpreting Power-Force-Velocity Profiles for Individualized and Specific Training. *Int. J. Sport. Physiol. Perform.* **2016**, *11*, 267–272. [CrossRef] [PubMed]
17. Jiménez-Reyes, P.; García-Ramos, A.; Cuadrado-Peñafiel, V.; Párraga-Montilla, J.A.; Morcillo-Losa, J.A.; Samozino, P.; Morin, J.B. Differences in Sprint Mechanical Force–Velocity Profile between Trained Soccer and Futsal Players. *Int. J. Sport. Physiol. Perform.* **2019**, *14*, 478–485. [CrossRef] [PubMed]
18. Jiménez-Reyes, P.; Samozino, P.; García-Ramos, A.; Cuadrado-Peñafiel, V.; Brughelli, M.; Morin, J.B. Relationship between Vertical and Horizontal Force-Velocity-Power Profiles in Various Sports and Levels of Practice. *PeerJ* **2018**, *2018*, e5937. [CrossRef]
19. Morin, J.B.; Edouard, P.; Samozino, P. Technical Ability of Force Application as a Determinant Factor of Sprint Performance. *Med. Sci. Sport. Exerc.* **2011**, *43*, 1680–1688. [CrossRef]
20. Rampinini, E.; Bishop, D.; Marcora, S.M.; Ferrari Bravo, D.; Sassi, R.; Impellizzeri, F.M. Validity of Simple Field Tests as Indicators of Match-Related Physical Performance in Top-Level Professional Soccer Players. *Int. J. Sport. Med.* **2007**, *28*, 228–235. [CrossRef]
21. Ruscello, B.; Tozzo, N.; Briotti, G.; Padua, E.; Ponzetti, F.; Stefano, D. Influence of the Number of Trials and the Exercise to Rest Ratio in Repeated Sprint Ability, With Changes of Direction and Orientation. *J. Strength Cond. Res.* **2013**, *27*, 1904–1919. [CrossRef]
22. Ross, A.; Gill, N.; Cronin, J. The Match Demands of International Rugby Sevens. *J. Sport. Sci.* **2015**, *33*, 1035–1041. [CrossRef] [PubMed]
23. Higham, D.G.; Pyne, D.B.; Anson, J.M.; Eddy, A. Movement Patterns in Rugby Sevens: Effects of Tournament Level, Fatigue and Substitute Players. *J. Sci. Med. Sport.* **2012**, *15*, 277–282. [CrossRef] [PubMed]

24. World Medical Association. World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. *JAMA* **2013**, *310*, 2191–2194. [CrossRef] [PubMed]
25. Jiménez-Reyes, P.; Cross, M.; Ross, A.; Samozino, P.; Brughelli, M.; Gill, N.; Morin, J.B. Changes in Mechanical Properties of Sprinting during Repeated Sprint in Elite Rugby Sevens Athletes. *Eur. J. Sport. Sci.* **2019**, *19*, 585–594. [CrossRef]
26. Rodríguez-Fernández, A.; Sanchez-Sanchez, J.; Ramirez-Campillo, R.; Nakamura, F.Y.; Rodríguez-Marroyo, J.A.; Villa-Vicente, J.G. Relationship Between Repeated Sprint Ability, Aerobic Capacity, Intermittent Endurance, and Heart Rate Recovery in Youth Soccer Players. *J. Strength Cond. Res.* **2019**, *33*, 3406–3413. [CrossRef]
27. Romero-Franco, N.; Jiménez-Reyes, P.; Castaño-Zambudio, A.; Capelo-Ramírez, F.; Rodríguez-Juan, J.J.; González-Hernández, J.; Toscano-Bendala, F.J.; Cuadrado-Peñafiel, V.; Balsalobre-Fernández, C. Sprint Performance and Mechanical Outputs Computed with an IPhone App: Comparison with Existing Reference Methods. *Eur. J. Sport. Sci.* **2017**, *17*, 386–392. [CrossRef]
28. Merino-Muñoz, P.; Pérez-Contreras, J.; Aedo-Muñoz, E. The Percentage Change and Differences in Sport: A Practical Easy Tool to Calculate. *Sport Perform. Sci. Rep.* **2020**, *118*, 446–450. [CrossRef]
29. Lakens, D. Calculating and Reporting Effect Sizes to Facilitate Cumulative Science: A Practical Primer for t-Tests and ANOVAs. *Front. Psychol.* **2013**, *4*, 863. [CrossRef]
30. Hopkins, W.G.; Marshall, S.W.; Batterham, A.M.; Hanin, J. Progressive Statistics for Studies in Sports Medicine and Exercise Science. *Med. Sci. Sport. Exerc.* **2009**, *41*, 3–12. [CrossRef]
31. Samozino, P.; Rejc, E.; di Prampero, P.E.; Belli, A.; Morin, J.B. Optimal Force-Velocity Profile in Ballistic Movements-Altius: Citius or Fortius? *Med. Sci. Sport. Exerc.* **2012**, *44*, 313–322. [CrossRef]
32. Wdowski, M.M.; Clarke, N.; Eyre, E.L.J.; Morris, R.; Noon, M.; Eustace, S.J.; Hankey, J.; Raymond, L.M.; Richardson, D.L. The Effect of Fatigue on First Stance Phase Kinetics During Acceleration Sprint Running in Professional Football Players. *Sci. Med. Footb.* **2020**, *5*, 90–96. [CrossRef] [PubMed]
33. Romero, V.; Lahti, J.; Castaño Zambudio, A.; Mendiguchia, J.; Jimenez-Reyes, P.; Morin, J.-B. Effects of Fatigue Induced by Repeated Sprints on Sprint Biomechanics in Football Players: Should We Look at the Group or the Individual ? *Int. J. Environ. Res. Public Health* **2022**, *19*, 4643. [CrossRef] [PubMed]
34. Jiménez-Reyes, P.; Garcia-Ramos, A.; Párraga-Montilla, J.A.; Morcillo-Losa, J.A.; Cuadrado-Peñafiel, V.; Castaño-Zambudio, A.; Samozino, P.; Morin, J.-B. Seasonal Changes in the Sprint Acceleration Force-Velocity Profile of Elite Male Soccer Players. *J. Os Strength Cond. Res.* **2020**, *3*, 70–74. [CrossRef] [PubMed]
35. Haugen, T.A. Soccer Seasonal Variations in Sprint Mechanical Properties and Vertical Jump Performance. *Kinesiology* **2018**, *50*, 102–108.
36. Mendez-Villanueva, A.; Hamer, P.; Bishop, D. Fatigue in Repeated-Sprint Exercise Is Related to Muscle Power Factors and Reduced Neuromuscular Activity. *Eur. J. Appl. Physiol.* **2008**, *103*, 411–419. [CrossRef] [PubMed]
37. Edouard, P.; Mendiguchia, J.; Lahti, J.; Arnal, P.J.; Gimenez, P.; Jiménez-Reyes, P.; Brughelli, M.; Samozino, P.; Morin, J.B. Sprint Acceleration Mechanics in Fatigue Conditions: Compensatory Role of Gluteal Muscles in Horizontal Force Production and Potential Protection of Hamstring Muscles. *Front. Physiol.* **2018**, *9*, 1706. [CrossRef] [PubMed]
38. Morin, J.B.; Samozino, P.; Bonnefoy, R.; Edouard, P.; Belli, A. Direct Measurement of Power during One Single Sprint on Treadmill. *J. Biomech.* **2010**, *43*, 1970–1975. [CrossRef]
39. Enoka, R.M.; Duchateau, J. Translating Fatigue to Human Performance. *Med. Sci. Sport. Exerc.* **2016**, *48*, 2228–2238. [CrossRef]
40. Thomas Little; Williams, A.G. Effects of Sprint Duration and Exercise: Rest Ratio on Repeated Sprint Performance and Physiological Responses in Professional Soccer Players. *J. Strength Cond. Res.* **2007**, *21*, 646–648. [CrossRef]
41. Abt, G.; Reaburn, P.; Holmes, M.; Gear, T. Changes in Peak Sprint Speed during Prolonged High-Intensity Intermittent Exercise That Simu- Lates Team Sport Play. *J. Sport. Sci.* **2003**, *21*, 256–257. [CrossRef]
42. Charron, J.; Garcia, J.E.V.; Roy, P.; Ferland, P.-M.; Comtois, A.S. Physiological Responses to Repeated Running Sprint Ability Tests: A Systematic Review. *Int. J. Exerc. Sci.* **2020**, *13*, 1190–1205.
43. Haugen, T.; Seiler, S.; Sandbakk, Ø.; Tønnessen, E. The Training and Development of Elite Sprint Performance: An Integration of Scientific and Best Practice Literature. *Sport. Med. Open* **2019**, *5*, 44. [CrossRef]
44. Miranda, D.L.; Rainbow, M.J.; Crisco, J.J.; Fleming, B.C. Kinematic Differences between Optical Motion Capture and Biplanar Videoradiography during a Jump-Cut Maneuver. *Bone* **2013**, *46*, 567–573. [CrossRef]
45. Knudson, D. Letter to the Editor Regarding 'the Correlation of Force-Velocity-Power Relationship of a Whole-Body Movement with 20 m and 60 m Sprint'. *Sports Biomech.* **2021**, *23*, 1–5. [CrossRef]

5.2. Artículo segundo

Título: Predicción del rendimiento físico en futbolistas jóvenes a través de características antropométricas, composición corporal y estados de maduración somática.

Introducción: Dentro de los factores que determinan el rendimiento atlético, la composición y las medidas corporales han demostrado ser aspectos claves para su óptimo desarrollo. Es así como la masa magra corresponde al componente cuyo desarrollo se asocia con una mayor expresión de rendimiento, debido a su rol en la producción de fuerza. Por contraparte, el exceso de tejido adiposo actúa como una carga inerte que compromete la eficiencia del sistema neuromuscular, disminuyendo la relación fuerza-peso y, en consecuencia, el rendimiento en acciones explosivas como el salto y el esprint Del mismo modo, las respuestas adaptativas en atletas jóvenes se encuentran moduladas por el estado madurativo. De este modo es posible observar que para iguales edades cronológicas el estado de maduración biológica es dispar. En este sentido, el estudio de la sinergia entre estas variables podría aportar información valiosa para los entrenadores de la condición física en futbolistas jóvenes.

Justificación: La integración de variables como la composición corporal, la antropometría y la maduración biológica permite una comprensión más precisa del rendimiento físico en futbolistas jóvenes. Dado que estos factores interactúan de manera compleja durante el desarrollo, su análisis conjunto puede orientar intervenciones más efectivas y personalizadas en los procesos de entrenamiento, optimizando tanto la expresión de fuerza y velocidad como el desarrollo atlético a largo plazo.

Objetivo: Analizar el impacto de la masa grasa, la masa magra, las medidas antropométricas y el estado de maduración en el rendimiento físico de jóvenes futbolistas.

Metodología: Enfoque cuantitativo, alcance descriptivo-correlacional, diseño no experimental con una dimensión temporal transeccional. Treinta y cuatro futbolistas en formación fueron sometidos a valoraciones de composición corporal, maduración somática y rendimiento físico. Se analizaron las asociaciones entre las variables mediante regresión múltiple y los tamaños del efecto mediante D-Cohen.

Hallazgos principales: La composición corporal explica en un 68% el rendimiento en cambio de dirección. En cuanto a la producción estática de fuerza, la composición corporal explica las variaciones de la Fuerza Máxima Isométrica y el Impulso en un 78 y un 50%, respectivamente. En cuanto a la expresión dinámica de la fuerza, la composición corporal explica las variaciones de Altura de Salto en un 39%, Pico Concéntrico de Fuerza en un 64% y Potencia Pico en un 64% e Impulso Concéntrico en un 75%.

Conclusiones: La masa libre de grasa así como las circunferencias de muslo y pierna son predictores para la fuerza máxima y potencia. Del mismo modo, la masa grasa presenta asociaciones negativas con el rendimiento en fuerza explosiva. Estos resultados destacan la relevancia de la composición corporal sobre el rendimiento físico en futbolistas en formación

2024, Retos, 61, 1199-1206

Prediction of physical performance in young soccer players through anthropometric characteristics, body composition, and somatic maturation states

Predicción del rendimiento físico en futbolistas jóvenes a través de características antropométricas, composición corporal y estados de maduración somática

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Abstract. Introduction: Physical performance in young soccer players may be influenced by body composition, anthropometric measures, and maturation status. This study examines how these variables affect isometric strength, vertical jump, and change of direction. Objective: To analyze the impact of fat mass, lean mass, anthropometric measures, and maturation status on physical performance in young soccer players. Methodology: A correlational study was conducted with players from a Chilean soccer team ((N=34; 16.06 ± 0.78 y; 1.69 ± 0.06 m; 62.39 ± 8.26 kg), using a DEXA scanner to assess body composition and physical tests (Change of direction; Isometric Midthigh Pull and Countermovement Jump) to measure performance. A LASSO regression model was employed to identify significant predictors. Results: The anthropometric variables, body composition, and PHV explain the percentage of variance in the model to varying degrees (R^2 0.05 to 0.78) with medium and large effect sizes (Cohen's f^2 0.6 to 3.0). Conclusion: Body composition and maturation status are crucial for optimizing performance in young soccer players.
Keywords: Body Composition, Young Soccer Players, Maturation, Physical Performance

Resumen. Introducción: El rendimiento físico en jóvenes futbolistas puede estar influenciado por la composición corporal, las medidas antropométricas y el estado de maduración. Este estudio examina cómo estas variables afectan la fuerza isométrica, el salto vertical y el cambio de dirección. Objetivo: Analizar el impacto de la masa grasa, la masa magra, las medidas antropométricas y el estado de maduración en el rendimiento físico de jóvenes futbolistas. Metodología: Se realizó un estudio correlacional con jugadores de un equipo de fútbol chileno (N=34; 16.06 ± 0.78 años; 1.69 ± 0.06 m; 62.39 ± 8.26 kg), utilizando un escáner DEXA para evaluar la composición corporal y pruebas físicas (cambio de dirección; tirón isométrico de muslo medio y salto con contramovimiento) para medir el rendimiento. Se empleó un modelo de regresión LASSO para identificar predictores significativos. Resultados: Las variables antropométricas, la composición corporal y el APHV explican el porcentaje de varianza en el modelo en diferentes magnitudes (R^2 0.05 a 0.78) con tamaños del efecto medios y grandes (f^2 de Cohen 0.6 a 3.0). Conclusión: La composición corporal y el estado de maduración son cruciales para optimizar el rendimiento en jóvenes futbolistas.
Palabras clave: Composición Corporal, Jóvenes Futbolistas, Maduración, Rendimiento Físico.

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Introduction

Soccer is, an intermittent and acyclic sport that involves actions performed at varying intensities (Dolci et al., 2020). Moreover, soccer performance is influenced by a combination of technical, tactical, physiological, biomechanical, and psychological factors (Stølen et al., 2005), highlighting the relevance of maintaining all these variables at reasonable levels. According to global positioning system (GPS) technology analyses, most activities occur at moderate to low intensities (Andrzejewski et al., 2019). However, the actions that determine the game´s outcome are those performed at high intensity. Accordingly, Faude et al. (2012) describes that the sequences leading up to a goal involve linear sprints, accelerations, and changes of direction (COD). Thus, the ability to generate high muscle tension quickly becomes fundamental, as an optimal level of physical fitness is crucial for achieving high performance. This is way researchers often look for factors that can be manipulated to improve physical performance (Pérez et al., 2021)

Maintaining an appropriate body composition and weight is essential for high performance in soccer. Research shows that players with lower body fat percentages cover longer distances and at higher intensities (Radziminski et al., 2020). Additionally, Figueiredo et al. (2020) found negative correlations between fat mass and vertical jump height, and positive correlations between lean mass and power. Negative associations were also observed between fat mass and performance in repeated sprints. Campa et al. (2019) emphasize the importance of reducing fat and maintaining or increasing lean mass. These findings highlight the need for a comprehensive approach to training and nutrition to improve endurance, power, and the ability to perform repeated explosive efforts.

Additionally, França et al. (2024) found that greater lean mass and lower fat mass are associated with better performance in direction changes among young soccer players. Concentric strength, dependent on muscle mass, is crucial for re-acceleration, but excessive lean mass can negatively affect

2024, Retos, 61, 1199-1206

performance (Stanković et al., 2023). Therefore, while increased muscle mass improves explosive strength and acceleration, it can also limit agility if not optimized for soccer-specific movements. Balancing body composition to maximize performance in direction changes without compromising movement efficiency is essential.

Among the methods for analyzing body composition, dual-energy X-ray absorptiometry (DEXA) is considered the gold standard due to its high precision in measuring lean and fat mass (Shepherd et al., 2017). Although anthropometry and bioelectrical impedance are also used (Moreira et al., 2015), DEXA offers detailed and accurate measurements, which are crucial for adjusting training and improving performance in soccer players (Figueiredo et al., 2020; Radziminski et al., 2020). Additionally, DEXA allows monitoring body mass changes over time, as evidenced by studies showing significant variations in lean mass during different training stages (Staśkiewicz-Bartecka et al., 2023).

Biological maturation, which can be assessed through four indicators—sexual, skeletal, dental, and somatic—significantly affects athletic performance (Albaladejo-Saura et al., 2021; Gómez-Campos et al., 2013; Malina et al., 2004). Somatic maturation states can be assessed by calculating the Age at Peak Height Velocity (APHV), which estimates the point at which an individual reaches their highest growth rate. This indicator, along with the assessment of bone and sexual maturation, provides valuable information on how physical development influences athletic capacities such as strength and agility (Mirwald et al., 2002; Peña-González et al., 2022).

In young soccer players, APHV is crucial for adjusting training programs and optimizing performance. Players at advanced stages of maturation may have an advantage in muscle strength (Eskandarifard et al., 2022). In contrast, those at earlier stages of maturation may have greater future development potential (de la Rubia et al., 2024).

To date, there is a limited number of studies exploring the influence of body composition assessed by DEXA on physical performance in young soccer players. Moreover, this study is notable for its focus on the relationship between age at peak growth and physical performance, which has received scant attention in existing literature. In this context, the research aims to analyze how body composition and maturation states affect the physical performance of young soccer players.

Methods

Design and participants

Quantitative study with a descriptive scope, non-experimental type, and a crossectional temporal dimension. The study was conducted with young soccer players (N=34; 16.06 ± 0.78 y; 1.69 ± 0.06 m; 62.39 ± 8.26 kg) from a Chilean professional soccer team, all of whom had at least 2 years of experience in the sport. These players trained five times a week and participated in one official competition match per week.

Procedures

Data collection occurred over two weeks during the competitive period. Body composition measurement were taken in the first week, while physical performance tests were conducted in the second week. Body composition measurements were performed at the Universidad Autónoma de Chile using a DEXA scanner (Lunar Prodigy, GE Medical Systems, Madison, Wisconsin, USA). Relative and absolute values of fat, lean, and bone mass were analyzed.

The study followed ethical standards for research involving human subjects, following the Helsinki Declaration. Approval was obtained from the relevant ethics committee before the study began (Adventist University of Chile, resolution 2023-07, Acta No. 2023-04, and vote No. 2023-08). Informed consent and assent from their parents or guardians were obtained from the participants. Participation was entirely voluntary, and confidentiality of the data was ensured. Participants were provided detailed information about the study's objectives, procedures, and potential risks.

Anthropometry

Anthropometric measurements were conducted to complement the assessment of body composition. Skinfolds evaluated included the thigh and calf, using a Rosscraft SLIGUI Body Fat Caliper® (Beta Technology, Richmond, Canada). Body circumferences (thigh and calf) were measured with a metal anthropometric tape from Rosscraft to ensure precision and consistency in each measurement. Body mass was recorded using a calibrated digital scale (SECA 803), while height was measured with a portable stadiometer (SECA 213).

Body Composition

The participants' body composition was assessed using dual-energy X-ray absorptiometry (DEXA) (Lunar Prodigy, GE Medical Systems, Madison, Wisconsin, USA). The analysis's measurements included total body mass, total fat mass, lower limb lean mass, total lean mass, lower limb bone mineral content, and total bone mineral content. A specialized technician performed all scans and standardized them to ensure data accuracy.

Somatic Maturation

Somatic maturation was assessed following the methodology proposed by Mirwald et al. (2002). The following variables were used: total height, sitting height, body mass, and decimal age of the participants.

Height: The participant's total height was measured with a stadiometer (SECA 213, Basel, Switzerland) in a bipedal position, ensuring they were barefoot and had their head aligned in the Frankfurt plane. The measurement was recorded in centimeters.

Sitting Height: This was recorded with the same stadiometer but with the participant sitting on a flat surface of known height (40 cm). It ensured the trunk was upright and the legs flexed at a 90-degree angle.

Body Mass: Evaluated using a digital scale (SECA 803, Basel, Switzerland), with the weight recorded in kilograms, while the participant was barefoot and wearing light clothing.

Decimal Age: Calculated from the difference between birth and assessment date, expressed in years and fractions.

Once these data were collected, they were entered into the model proposed by Mirwald. This model estimates somatic maturation based on the participant's proximity to peak height velocity (PHV). Previous studies have extensively validated this model, demonstrating its accuracy in estimating biological maturation in young populations.

Performance Tests

Isometric Mid-Thigh Pull (IMTP)

The IMTP test was conducted on day 1 of week 1. The procedure followed the methodologies described by Comfort et al. (2019). Specific activation involved three IMTP attempts at 50%, 75%, and 90% of perceived effort, with one minute of rest between them. Subsequently, three maximum attempts were performed, starting with the instruction: "Push with your feet against the ground as fast and hard as you can." Each attempt lasted of 8 seconds, with 3 seconds dedicated to preparation and 5 seconds to effort. The rest between attempts was 2 minutes. Data were recorded using force plates (PASPORT force plate, PS-2141, PASCO Scientific, California) with SPARKvue software (version 4.6.1, USA), exported to an Excel spreadsheet (version 16, Microsoft, USA), and processed in Matlab (version 9.6, USA). Absolute peak force (PFI), as well as impulse at 100 ms (I100), were analyzed. The start of the tests was estimated based on a change of 5 standard deviations in the force-time curve (McMahon et al., 2018).

Countermovement Jump (CMJ)

The CMJ test was conducted on day 1 of week 1. Following a specific activation of 5 submaximal jumps, players performed 3 maximum CMJ attempts, with a 2-minute pause between attempts. The depth of the descent was self-determined according to the player's comfort. Players were instructed to jump "as fast and high as possible" (Lockie, 2018). Data were recorded with force plates (PASPORT force plate, PS-2141, PASCO Scientific, California) using SPARKvue software (version 4.6.1, USA), exported to an Excel spreadsheet (version 16, Microsoft, USA), and processed in Matlab (version 9.6, USA). The following variables were analyzed: jump height (JH), obtained through impulse-momentum (Xu et al., 2023), peak force (PFC), peak power (PP), braking impulse (BI), and concentric impulse (CI).

Change of Direction

The modified 505 test (m505) (Taylor et al., 2019) was applied during the second shift of the second session of week 1. A practice attempt was conducted to familiarize players with the exercise dynamics. Two photoelectric barriers (Chronojump software, version 2.3.0-79, Barcelona, Spain) and a marker on the ground 0.5 m from them were set up. Players were instructed to run as fast as possible for 5 m, turn 180°, and return to the starting point. Three attempts were made, changing direction with the right leg (Dos'Santos et al., 2020). The best recorded time was used for analysis.

Statistical Analysis

The normality of the variables was assessed using the Shapiro-Wilk test, and the normality assumption was met ($p > 0.05$). All descriptive statistics for anthropometric variables and physical performance will be expressed as means and standard deviations. A LASSO (Least Absolute Shrinkage and Selection Operator) regression was performed due to its robustness against multicollinearity and its ability to select and eliminate redundant variables, which enhances the precision and interpretability of the models (Kipp & Warmenhoven, 2022). All variables were scaled before entering the model (centered [mean zero] and standardized [standard deviation 1]). The data were split into 70% for the training set and 30% for the test set. A 5-fold cross-validation was used with 100 values of "lambda" ranging from 0.001 to 100. The root mean square error (RMSE) metric was employed to select the lambda that minimized this metric. The model was then evaluated on the test set, and the results will describe the RMSE and the coefficient of determination (R^2). Cohen's f^2 is appropriate for calculating the effect size (ES) within a multiple regression model in which the independent variable of interest and the dependent variable are both continuous. Cohen's f^2 was calculated as previously described (Selya et al ., 2012) . The following threshold values for ES reported as f^2 were employed: ≥0.02 as small, ≥0.15 as medium, and ≥0.35 as large. All statistical analyses were conducted using RStudio, with the following libraries: *rsample* for partitioning the training and test sets; *glmnet* and *caret* for performing the LASSO regression.

Results

Regarding anthropometric variables, the average age of the players was 16.06 ± 0.78 years, with an average height of 1.69 ± 0.06 meters. The Age Peak Height Velocity (APHV) averaged 1.05 ± 0.65, suggesting that participants have already passed through the pubertal growth spurt. Skinfolds measured at the thigh and calf (SkT and SkC) had means of 8.41 ± 2.86 mm and 5.31 ± 2.63 mm, respectively. The thigh circumference (CcT) averaged 47.7 ± 3.38 cm, while the calf circumference (CcC) averaged 35.3 ± 2.07 cm. Body mass averaged 58.3 ± 8.04 kg, with an average fat mass of 8.99 ± 3.05 kg and a fat-free mass (FFM) of 47.07 ± 5.70 kg. Average values for bone mineral content in the lower limbs (BMCLL) and total bone mineral content (BMC) were 1091 ± 141 g and 2239 ± 323 g, respectively (table 1).

For physical performance variables, results showed an average time of 2.58 ± 0.11 seconds for the change of direction (COD) and 1640 ± 258 N for peak isometric force (PFI). The impulse at 100 ms (I100) was 91.2 ± 15.22 N·s, while jump height (JH) averaged 0.33 ± 0.04 meters. The concentric peak force (PFC) averaged 1469 ± 201 N, and peak power (PP) reached 3248 ± 531 W. For braking impulse (BI), the average was 68.0 ± 22.19 N, and the average concentric impulse (CI) was 155 ± 30.7 N·s (table 2).

Table 1.
Descriptive Statistics of Anthropometric and Physical Performance Variables

Anthropometric variables			PP variables		
	M	±SD		M	±SD
Age (y)	16.06	0.78	COD	2.58	0.11
Height (m)	1.69	0.06	PFI (N)	1640	258
APHV	1.05	0.65	I100 (N*s)	91.2	15.22
SkT (mm)	8.41	2.86	JH (m)	0.33	0.04
SkC (mm)	5.31	2.63	PFC (N)	1469	201
CcT (cm)	47.7	3.38	PP (W)	3248	531
CcC (cm)	35.3	2.07	BI (N*s)	68.0	22.19
BM (kg)	58.3	8.04	CI (N*s)	155	30.7
FM (kg)	8.99	3.05			
FFMLL (kg)	17.36	2.29			
FFM (kg)	47.07	5.70			
BMCLL (gr)	1091	141			
BMC (gr)	2239	323			

Abbreviations: PP: physical performance; APHV: age peak height velocity; SkT: thigh skinfold; SkC: calf skinfold; CcT: thigh circumference; CcC: calf circumference; BM: body mass; FM: fat mass; FFMLL: lower limb free fat mass; FFM: total body free fat mass; BMCLL: lower limb bone mineral content; BMC: total bone mineral content; COD: change of direction; PFI: peak force IMTP; I100: impulse 100ms; JH: jump height CMJ; PFC: peak force CMJ; PP: peak power CMJ; BI: braking impulse CMJ; CI: concentric impulse CMJ.

Table 2.
LASSO Regression Model for Predicting Physical Performance Variables Based on Anthropometric and Body Composition Variables

	COD	PFI	I100	JH	PFC	PP	BI	CI
R^2	0.68	0.78	0.50	0.39	0.64	0.64	0.05	0.75
f^2	2.1**	3.5**	1.0**	0.6**	1.8**	1.8**	0.1*	3.0**
RMSE	0.055	173	14.8	0.036	99	399	21	21
Variables	β	β	β	β	β	β	β	β
Intercept	2.58	1612	90.1	0.34	1471	3357	66.1	160
Age (y)	-0.01		1.97	-0.0002		-89.8		
Height (m)		20.2	1.09					
APHV		0.19				36.8		
SkT (mm)			-1.21	0.003		-19.2		
SkC (mm)		-14.7	-0.66	-0.01				
CcT (cm)		59.0	3.23	0.01		23.8	6.28	8.83
CcC (cm)			-0.72		6.28	186	6.16	
BM (kg)					89.6			
FM (kg)	0.03			-0.02		-204		
FFMLL (kg)				0.01		265		0.01
FFM (kg)		80.0			43.5	118	1.42	
BMCLL (gr)			1.57					13.1
BMC (gr)		0.77	2.99					

Abbreviations: R^2 coefficient of determination; RMSE root mean square error; β beta coefficient; f^2 Cohen's effect size; APHV age peak height velocity; SkT thigh skinfold; SkC calf skinfold; CcT thigh circumference; CcC calf circumference; BM body mass; FM fat mass; FFMLL lower limb free fat mass; FFM total body free fat mass; BMCLL lower limb bone mineral content; BMC total bone mineral content; COD change of direction; PFI peak force IMTP; I100 impulse 100 ms IMTP; JH jump height CMJ; PFC peak force CMJ; PP peak power CMJ; BI braking impulse CMJ; CI concentric impulse CMJ. ES *medium; **ES large.

The results of the LASSO regression model show the significant predictor variables for various physical performance tests of young soccer players, evaluated through different measurements of strength, power, and change of direction ability.

For COD capacity, the model explains 68% of the variability in performance (R^2 = 0.68), with a root mean square error (RMSE) of 0.055. Among the predictor variables, the CcC stands out with a beta coefficient (β) of 59.0, indicating that larger calf circumferences are associated with improved change of direction ability. Conversely, the SkT has a negative coefficient (β = -1.21), suggesting that a greater skinfold thickness is related to poorer performance in this test.

Regarding the PFI, the model has an R^2 of 0.78 and an RMSE of 173. Height is a significant variable with a β of 20.2, indicating that greater height is associated with a higher peak force. Additionally, FFM showed a strong positive influence (β = 80.0), confirming the importance of muscle mass in developing maximum strength.

For I100, the model explains 50% of the variability (R^2 = 0.50). The SkT and SkC stand out with negative beta coefficients (β -1.21 and β=-0.66, respectively). This result indicates the negative effect of skinfold thickness on maximum force production. On the other hand, the beta coefficients for CcT (β=3.23), BMCLL (β=1.57), and BMC (β=2.99) indicate a positive influence on the performance of this variable. This finding underscores the importance of muscular and bone structure in the early phases of force production.

Regarding JH, the model explains 39% of the variability (R^2 = 0.39), with an RMSE of 0.036. The SkC and FM have a negative effect on jump height (β = -0.01; β = -0.02, respectively), while CcC and FFMLL show a positive effect (β = 0.01). These results highlight the significant influence of muscular dimensions and fat mass on jump performance, suggesting the need to consider them in training and assessment programs.

The PFC also showed a high predictive capability with an R^2 of 0.64, with BM being the most influential variable (β = 89.6), followed by FFM (β = 43.5). This reinforces the idea that greater body mass and muscular dimensions contribute to higher force production.

Regarding PP, the model explains 64% of the variability, highlighting the positive influence of the PHV (β = 36.8), CcT (β = 23.8), CcC (β = 186), FFMLL (β = 265), and FFM (β = 118). Meanwhile, FM and SkT present a significant negative effect (β = -19.2; β = -204), indicating that body fat accumulation negatively impacts the ability to generate power. Finally, both BI and CI are positively influenced to varying degrees by variables related to total and regional fat-free mass. Thus, together, the findings demonstrate the influence of muscular and bone structure as well as fat accumulation on static and dynamic strength production.

Discussion

The aim of the study was to analyze the impact of body composition, anthropometric variables, and maturation states on physical performance in young football players. Our findings highlight the varied influence of independent variables as predictors of physical performance in young footballers.

In football, high-intensity horizontal movements play a crucial role in the success of actions (Faude et al., 2012). It has been described that these movements are influenced by the anthropometric and body composition characteristics of the players (Atakan et al., 2017). Furthermore, the use of this information has been proposed as part of the talent selection process (Toselli et al., 2024). In this context, the COD (change of direction) ability may be influenced by lean mass and fat mass indices. An interesting consideration is the proportion of lean mass that enhances performance. In this regard, Stanković et al. (2023) hypothesize that high levels of muscle mass could affect actions involving changes in direction. However, most of the studies consulted conclude that higher lean mass indices favor these types of actions. Our findings are contradictory in this respect. While it is true that performance in COD is explained by anthropometric and body composition variables to 68% with a large effect size (f^2 2.1), lean mass seems to have no implication in this result, with fat mass showing a greater effect ($\beta = 0.03$). Lean mass total, and particularly lean mass of the lower limb, does not influence this association.

In the present study, a significant relationship was observed between body composition and anthropometric variables with force production in isometric tests. The analyses revealed a coefficient of determination (R^2) of 0.78 for peak force with a large effect size (f^2 2.1), indicating that a high percentage of the variability in maximum strength can be explained by these variables. In contrast, the R^2 of 0.50 for the 100 ms impulse suggests a moderate influence. However, a large effect size (f^2 1.0), suggests that the predictor variables have a considerable relationship with performance on this measure. This discrepancy highlights the need to interpret both indices together to obtain a more complete picture of the impact of the variables on physical performance The beta coefficients (β) of individual variables highlight their differential impact on isometric strength: the calf skinfold had a β of -14.7, suggesting a negative relationship, indicating that higher skinfolds are associated with lower levels of strength. On the other hand, the thigh perimeter showed a β of 59.0, and lean mass a β of 80.0, both indicating a positive and significant relationship, where greater measurements in these variables are associated with a higher peak force. Bone mineral content, with a β of 0.77, also showed a positive association, although less pronounced. These findings underscore the importance of lean mass and thigh perimeter in optimizing isometric strength, while reducing subcutaneous fat may be crucial for improving performance.

Recent studies underscore the significant influence of body composition on power tests, especially in dynamic efforts requiring explosive strength production. In this context, lower limb muscle mass has proven to be a key factor, facilitating a higher generation of power relative to total body mass (Toselli et al., 2022). This finding suggests that soccer players with a higher proportion of lean mass have a competitive advantage in terms of strength production. However, scientific literature still presents discrepancies. For instance, Ishida et al. (2021) reported significant correlations between lean mass percentage and strength generation ability ($r=0.50$, $p<0.05$), while fat mass showed an inverse correlation ($r=-0.37$). These results reinforce the notion that fat mass acts as an additional load that does not contribute to power production, which has been confirmed in studies demonstrating its negative impact on vertical jump height, in contrast to the positive influence of lean mass (Esco et al., 2018).

Our study's results align with this description. Significant relationships are observed between body composition and anthropometric variables with different measures of strength and power. For peak concentric strength, the coefficient of determination R^2 of 0.64 and there is a large effect size (f^2 1.8), suggests that the analyzed variables explain a considerable proportion of the variability in this measure. Beta coefficients indicate that leg circumference ($\beta = 6.28$), total body mass ($\beta = 89.6$), and lean mass ($\beta = 43.5$) have a significant positive influence on peak concentric strength, highlighting the importance of lean mass and muscle size in strength generation.

Regarding peak power, also with an R^2 of 0.64 and there is a large effect size (*f^2 1.8*), the results show varied influences of the variables. Negative coefficients for thigh skinfold ($\beta = -19.2$) and fat mass ($\beta = -204$) suggest that greater subcutaneous fat thickness and higher fat mass are associated with lower power. In contrast, thigh circumference ($\beta = 23.8$), leg circumference ($\beta = 186$), and measures of lean mass both in the lower limb ($\beta = 265$) and total body ($\beta = 118$) have a positive association, indicating that larger muscle dimensions and lean mass may enhance explosive capacity.

Finally, concentric impulse showed an R^2 of 0.75 and there is a large effect size (f^2 3.0), indicating a high predictive capacity of the considered variables. Thigh circumference ($\beta = 8.83$), lean mass in the lower limb ($\beta = 0.01$), and bone mineral content in the lower limb ($\beta = 13.1$) have a positive influence on concentric impulse, suggesting that greater muscle mass and adequate bone mineralization significantly contribute to impulse generation.

In summary, these findings highlight the importance of lean mass and muscle size in strength and power production, while reducing subcutaneous fat and ensuring adequate bone mineralization can enhance performance in measures of isometric strength and power.

Our findings show that the APHV has a notable influence on physical performance, evidenced by a beta coefficient (β) of 0.19 for the isometric peak force (IMTP) and 36.8 for the peak power (CMJ). These relationships, with R^2 values of 0.78 and 0.64 respectively with a large effect size (and there is a large effect size (f^2 1.0 and 1.8, respectively), highlight how APHV contributes to performance in these tests.

Comparing these results with existing literature reveals an interesting contrast. The literature suggests that APHV can significantly impact strength and power development due to hormonal changes and body composition shifts occurring during the pubertal growth spurt. For example, studies such as those by Malina et al. (2004) and Till et al. (2017) have noted that peak height velocity is associated with improvements in strength and power, but often report a more pronounced effect during or immediately after APHV, which could be related to rapid neuromuscular adaptation and changes in muscle mass. In contrast, the beta coefficient of 0.19 for IMTP in our study suggests a relatively moderate influence of APHV on isometric strength, which might indicate that other factors, such as muscle maturation and training experience, play a more significant role in this measure. On the other hand, the β of 36.8 for CMJ suggests a more significant influence of APHV on explosive power, which is consistent with previous findings suggesting a greater sensitivity of power performance to hormonal and growth changes during adolescence (Albaladejo-Saura et al., 2021).

In summary, while our findings confirm that APHV impacts physical performance, the magnitude of this influence varies according to the performance measure and may be moderated by additional factors such as muscle maturation and training adaptation. This variability in the effects of APHV highlights the need to consider multiple aspects of physical development and maturation when evaluating performance in different physical tests.

Conclusion

The results of this study highlight the complexity of the interaction between body composition, anthropometric variables, and maturational states in the physical performance of young soccer players. While fat-free mass and anthropometric measures such as thigh and leg circumference proved to be key predictors of peak force and power, body fat was negatively associated with the ability to generate explosive force. Additionally, APHV showed a variable impact on performance, with a more pronounced influence on peak power than on isometric strength. These findings underscore the importance of considering both body composition and biological development to optimize physical performance in young soccer players, suggesting that personalized training and talent selection should account for these individual differences. However, the moderate influence of biological maturation on certain measures suggests that other factors, such as training experience, could play a critical role. Future research could focus on identifying how these variables interact throughout athletic development to maximize long-term performance.

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Referencias

Albaladejo-Saura, M., Vaquero-Cristóbal, R., González-Gálvez, N., & Esparza-Ros, F. (2021). Relationship between biological maturation, physical fitness, and kinanthropometric variables of young athletes: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, *18*(1), 1–20. https://doi.org/10.3390/ijerph18010328

Andrzejewski, M., Pluta, B., Konefał, M., Konarski, J., Chmura, J., & Chmura, P. (2019). Activity profile in elite Polish soccer players. *Research in Sports Medicine*, *27*(4), 473–484. https://doi.org/10.1080/15438627.2018.1545648

Atakan, M. M., Unver, E., Demirci, N., Cinemre, A., Bulut, S., & Turnagol, H. H. (2017). Effect of body composition on fitness performance in young male football players. *Turkish Journal of Sport and Exercise*, *19*(1), 54–59.

Campa, F., Semprini, G., Júdice, P. B., Messina, G., & Toselli, S. (2019). Anthropometry, Physical and Movement Features, and Repeated-sprint Ability in Soccer Players. *International Journal of Sports Medicine*, *40*(2), 100–109. https://doi.org/10.1055/a-0781-2473

Comfort, P., Dos'Santos, T., Beckham, G. K., Stone, M. H., Guppy, S. N., & Haff, G. G. (2019). Standardization and methodological considerations for the isometric midthigh pull. *Strength and Conditioning Journal*, *41*(2), 57–79. https://doi.org/10.1519/SSC.0000000000000433

de la Rubia, A., Kelly, A. L., García-González, J., Lorenzo, J., Mon-López, D., & Maroto-Izquierdo, S. (2024). Biological maturity vs. relative age: Independent impact on physical performance in male and female youth handball players. *Biology of Sport*, *41*(3), 3–13. https://doi.org/10.5114/biolsport.2024.132999

Dolci, F., Hart, N. H., Kilding, A. E., Chivers, P., Piggott, B., & Spiteri, T. (2020). Physical and Energetic Demand of Soccer: A Brief Review. *Strength and Conditioning*

Journal, *42*(3), 70–77. https://doi.org/10.1519/SSC.0000000000000533

Dos'Santos, T., Mcburnie, A., Thomas, C., Comfort, P., & Jones, P. A. (2020). Biomechanical Determinants of the Modified and Traditional 505 Change of Direction Speed Test. *Journal of Strength and Conditioning Research*, *34*(5), 1285–1296. https://doi.org/10.1519/JSC.0000000000003439

Esco, M. R., Fedewa, M. V., Cicone, Z. S., Sinelnikov, O. A., Sekulic, D., & Holmes, C. J. (2018). Field-based performance tests are related to body fat percentage and fat-free mass, but not body mass index, in youth soccer players. *Sports*, *6*(4). https://doi.org/10.3390/sports6040105

Eskandarifard, E., Nobari, H., Sogut, M., Clemente, F. M., & Figueiredo, A. J. (2022). Exploring interactions between maturity status and playing time with fluctuations in physical fitness and hormonal markers in youth soccer players. *Scientific Reports*, *12*(1), 1–8. https://doi.org/10.1038/s41598-022-08567-5

Faude, O., Koch, T., & Meyer, T. (2012). Straight sprinting is the most frequent action in goal situations in professional football. *Journal of Sports Sciences*, *30*(7), 625–631. https://doi.org/10.1080/02640414.2012.665940

Figueiredo, D. H., Dourado, A. C., Stanganelli, L. C. R., & Gonçalves, H. R. (2020). Evaluation of body composition and its relationship with physical fitness in professional soccer players at the beginning of pre-season. Retos, 2041(40), 117–125. https://doi.org/10.47197/retos.v1i40.82863

França, C., Gouveia, É. R., Martins, F., Ihle, A., Henriques, R., Marques, A., Sarmento, H., Przednowek, K., & Lopes, H. (2024). Performance among Youth Soccer Players. *Sports (Basel)*, *12*, 1–9.

Gómez-Campos, R., Arruda de, M., Hobold, E., Abella, C. ., Carmago, C., Martinez, C., & Cossio-Bolaños, M. . (2013). Valoración de la maduración biológica: usos y aplicaciones en el ámbito escolar. Revista Andaluza de Medicina Del Deporte, 6(4), 151–160

Ishida, A., Travis, S. K., & Stone, M. H. (2021). Associations of body composition, maximum strength, power characteristics with sprinting, jumping, and intermittent endurance performance in male intercollegiate soccer players. *Journal of Functional Morphology and Kinesiology*, 6(1), 0–7. https://doi.org/10.3390/jfmk6010007

Kipp, K., & Warmenhoven, J. (2022). Applications of regularized regression models in sports biomechanics research. *Sports Biomechanics*, *00*(00), 1–19. https://doi.org/10.1080/14763141.2022.2151932

Lockie, R. G. (2018). Sprint Testing. In P. Comfort, P. A. Jones, & J. J. McMahon (Eds.), *Performance Assessment in Strength and Conditioning* (First, p. 198). Routledge. https://doi.org/10.4324/9781315222813

Peña-Gónzalez, I., Javaloyes, A., & Moya-Ramón, M. (2022). The effect of the maturity status on strength performance in young elite basketball players. Retos, 45, 858–863. https://doi.org/10.47197/retos.v44i0.91616

Malina, R. M., Eisenmann, J. C., Cumming, S. P., Ribeiro, B., & Aroso, J. (2004). Maturity-associated variation in the growth and functional capacities of youth football (soccer) players 13-15 years. *European Journal of Applied Physiology*, *91*(5–6), 555–562. https://doi.org/10.1007/s00421-003-0995-z

McMahon, J. J., Suchomel, T. J., Lake, J. P., & Comfort, P. (2018). Understanding the Key Phases of the Countermovement Jump Force-Time Curve. *Strength & Conditioning Journal*, *40*(4).

Mirwald, R. L., Baxter-Jones, A. D. G., Bailey, D. A., & Beunen, G. P. (2002). An assessment of maturity from anthropometric measurements. *Medicine and Science in Sports and Exercise*, *34*(4), 689–694. https://doi.org/10.1249/00005768-200204000-00020

Moreira, O. C., Alonso-Aubin, D. A., De Oliveira, C. E. P., Candia-Luján, R., & De Paz, J. A. (2015). Métodos de evaluación de la composición corporal: Una revisión actualizada de descripción, aplicación, ventajas y desventajas. *Archivos de Medicina Del Deporte*, *32*(6), 387–394.

Pérez-Contreras, J., Merino-Muñoz, P., & Aedo-Muñoz, E. (2021). Link between body composition, sprint and vertical jump in young elite soccer players from Chile. *MHSalud*, *18*(2), 0–13. https://doi.org/10.15359/MHS.18-2.5

Radziminski, L., Szwarc, A., Padrón-Cabo, A., & Jastrzebski, Z. (2020). Correlations between body composition, aerobic capacity, speed and distance covered among professional soccer players during official matches. *Journal of Sports Medicine and Physical Fitness*, *60*(2), 257–262. https://doi.org/10.23736/S0022-4707.19.09979-1

Selya, A. S., Rose, J. S., Dierker, L. C., Hedeker, D., & Mermelstein, R. J. (2012). A practical guide to calculating Cohen's f 2, a measure of local effect size, from PROC MIXED. Frontiers in Psychology, 3(APR), 1–6. https://doi.org/10.3389/fpsyg.2012.00111

Shepherd, J. A., Ng, B. K., Sommer, M. J., & Heymsfield, S. B. (2017). Body composition by DXA. *Bone*, *104*, 101–105. https://doi.org/10.1016/j.bone.2017.06.010

Stanković, M., Čaprić, I., Đorđević, D., Đorđević, S., Preljević, A., Koničanin, A., Maljanović, D., Nailović, H., Muković, I., Jelaska, I., & Sporiš, G. (2023). Relationship between Body Composition and Specific Motor Abilities According to Position in Elite Female Soccer Players. *International Journal of Environmental Research and Public Health*, *20*(2). https://doi.org/10.3390/ijerph20021327

Staśkiewicz-Bartecka, W., Grochowska-Niedworok, E., Zydek, G., Grajek, M., Kiciak, A., Białek-Dratwa, A., Niewiadomska, E., Kowalski, O., & Kardas, M. (2023). Anthropometric Profiling and Changes in Segmental Body Composition of Professional Football Players in Relation to Age over the Training Macrocycle. *Sports*, *11*(9). https://doi.org/10.3390/sports11090172

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of Soccer An Update. *Sports Medicine*, *35*(6), 501–536. https://doi.org/10.2165/00007256-200535060-00004

Taylor, J. M., Cunningham, L., Hood, P., Thorne, B., Irvin, G., & Weston, M. (2019). The reliability of a modified 505 test and change-of-direction deficit time in elite youth football players. *Science and Medicine in Football*, *3*(2), 157–162. https://doi.org/10.1080/24733938.2018.1526402

Till, K., Scantlebury, S., & Jones, B. (2017). Anthropometric and Physical Qualities of Elite Male Youth Rugby League Players. *Sports Medicine*, *47*(11), 2171–2186. https://doi.org/10.1007/s40279-017-0745-8

Toselli, S., Grigoletto, A., & Mauro, M. (2024). Anthropometric, body composition and physical performance of elite young Italian football players and differences between selected and unselected talents. *Heliyon*, *10*(16), e35992. https://doi.org/10.1016/j.heliyon.2024.e35992

Toselli, S., Mauro, M., Grigoletto, A., Cataldi, S., Benedetti, L., Nanni, G., Di Miceli, R., Aiello, P., Gallamini, D., Fischetti, F., & Greco, G. (2022). Assessment of Body Composition and Physical Performance of Young Soccer Players: Differences According to the Competitive Level. *Biology*, *11*(6). https://doi.org/10.3390/biology11060823

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5.3. Artículo tercero

Título: Diferencias en el rendimiento de la prueba 30-15 IFT entre posiciones de juego y categorías en futbolistas profesionales adultos

Introducción: Debido a las características de las acciones que determinan el éxito en acciones decisivas del fútbol, se resalta la capacidad de los jugadores para realizar esfuerzos de alta intensidad. Del mismo modo, acceder a pruebas valoren la aptitud aeróbica en deportes intermitentes permite analizar rendimientos individuales con el fin de identificar debilidades en este aspecto de la condición física. La prueba intermitente 30-15 se ha propuesto como una estrategia confiable y sensible para determinar cambios en la aptitud aeróbica, así como para prescribir cargas de entrenamiento.

Justificación: Comparar el desempeño en la prueba intermitente 30-15 entre divisiones y posiciones de juego permite objetivar las diferencias de aptitud aeróbica que sustentan la capacidad de repetir esfuerzos de alta intensidad —clave en las acciones decisivas del fútbol profesional. Al identificar los perfiles fisiológicos propios de cada nivel competitivo y rol táctico, los preparadores físicos pueden ajustar las cargas de entrenamiento de forma específica, detectar carencias individuales y optimizar la planificación para maximizar el rendimiento colectivo.

Objetivo: Evaluar el rendimiento de equipos de fútbol profesional de diferentes divisiones y posiciones de juego.

Metodología: Enfoque cuantitativo, alcance descriptivo-comparativo, diseño no experimental con una dimensión temporal transeccional. Ochenta y cuatro futbolistas profesionales pertenecientes a primera división A (1A; n=21), primera división B (1B; n=42) y segunda división (2a; n=21) del campeonato chileno participaron del estudio. El rendimiento aeróbico fue evaluado a partir de la velocidad final alcanzada (VIFT) en la prueba 30-15 Intermittent Fitness Test. Se realizaron comparaciones por división y entre posiciones mediante la prueba Anova de dos factores. Del mismo modo se calcularon los tamaños del efecto de dichas comparaciones, mediante Eta Parcial al Cuadrado (n2p).

Hallazgos principales: Se encontraron diferencias entre las divisiones 1A, 1B y 2a en VIFT, con tamaños del efecto grandes ($p=0,002$, $\eta^2p=0,166$). El análisis post-hoc reveló valores significativamente más altos con efectos moderados para 1A en comparación con 1B y 2a ($p<0,05$). Se observaron efectos de interacción moderados, aunque no alcanzaron significación ($p=0,2$, $\eta^2p=0,115$)

Conclusiones: Los jugadores pertenecientes a 1A presentan un mayor rendimiento aeróbico. En cuanto a las posiciones, los mediocampistas laterales son quienes presentan un mayor rendimiento. Es posible afirmar que tanto el nivel competitivo como el rol táctico son factores que podrían influenciar el rendimiento físico en jugadores de fútbol profesional.

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Differences in 30-15 IFT test performance across playing positions and categories among adult professional soccer players

Diferencias en el rendimiento de la prueba 30-15 IFT entre posiciones de juego y categorías en futbolistas profesionales adultos

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Abstract. Objective: This study aims to assess the performance of professional soccer teams from different divisions and playing positions using the 30-15 intermittent fitness test (30-15 IFT). Methods: The sample comprised 84 male soccer players from first division teams A (1A) (n=21; mean age 23.5±5.2 years), first division B (1B) (n=42; mean age 23.0±5.0), and second professional division (2nd) (n=21; mean age 22.9±4.7 years). Performance was evaluated based on the final speed achieved in the 30-15 IFT (VIFT). Results: Significant differences were observed between 1A and both 1B and 2nd in VIFT (p=0.002, n2p=0.115). Additionally, differences were found between defenders and full-backs in VIFT (p=0.002, n2p=0.197). Conclusion: Performance in the 30-15 IFT varies across divisions, with 1A achieving the highest values. Moreover, full-backs demonstrated superior performance compared to defenders. These findings provide valuable insights for coaches, physical trainers, and sports scientists for optimizing training programs.
Keywords: soccer, exercise test, physical fitness, athletic performance

Resumen. Objetivo: Este estudio tiene como objetivo evaluar el rendimiento de equipos de fútbol profesional de diferentes divisiones y posiciones de juego utilizando la prueba intermitente de fitness 30-15 (30-15 IFT). Métodos: La muestra comprendió 84 futbolistas masculinos de equipos de primera división A (1A) (n=21; edad media 23.5±5.2 años), primera división B (1B) (n=42; edad media 23.0±5.0), y segunda división profesional (2ª) (n=21; edad media 22.9±4.7 años). El rendimiento se evaluó según la velocidad final alcanzada en la 30-15 IFT (VIFT). Resultados: Se observaron diferencias significativas entre 1A y tanto 1B como 2ª en VIFT (p=0.002, n2p=0.115). Además, se encontraron diferencias entre defensores y laterales en VIFT (p=0.002, n2p=0.197). Conclusión: El rendimiento en la 30-15 IFT varía entre divisiones, con 1A logrando los valores más altos. Además, los laterales demostraron un rendimiento superior en comparación con los defensores. Estos hallazgos proporcionan información valiosa para entrenadores, preparadores físicos y científicos del deporte en la optimización de programas de entrenamiento
Palabras clave: Fútbol, pruebas de esfuerzo, acondicionamiento físico, rendimiento atlético

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Introduction

Soccer is a sport with a sustained and intense pattern of intermittent actions. During the game, soccer players travel an average of 10 km at an intensity of 70% of maximum oxygen consumption (VO2max.) (Bangsbo et al., 2006). Likewise, sprints, accelerations, changes of direction, jumps, and shoots determine the success of the actions and are discriminatory between elite players and lower categories (Faude et al., 2012). The decreased effectiveness of technical actions typical of soccer has been reported after repeated high-intensity sequences (Ferraz et al., 2019; Kellis et al., 2006). Due to this, aerobic metabolism becomes a determining factor due to its influence on recovery between efforts (Bishop et al., 2011). Previous research has described differences in performance, both in aerobic and anaerobic actions, in players of different competitive levels (Slimani & Nikolaidis, 2017; Toselli et al., 2022) as well as between playing positions (Modric et al., 2020; Pérez-Contreras et al., 2022; Tereso et al., 2024; Velásquez-González et al., 2023).

Gas analysis is the gold standard for assessing VO2max. However, its accessibility is limited to laboratories and research centers (Bennett et al., 2016; Cherouveim et al., 2022). Furthermore, VO2max alone does not reflect the endurance of the soccer player but rather is the ability to maintain high running intensities (Buchheit et al., 2013). For this reason, field tests have a comparative advantage due to their low cost and implementation. Likewise, they provide running speeds associated with VO2max, which primarily reflect specific performance in the game (Bok & Foster, 2021). Regarding efforts that request the anaerobic pathway, speed tests, direction changes, and dynamic and static strength are widely used. Its use is related to controlling fitness and prescribing training loads (Dugdale et al., 2019; Hulse et al., 2013).

There is an association between competitive status and physical performance in soccer players. There are differences in VO2max between high-level professional soccer players and those from less competitive leagues and between positions within the team (Modric et al., 2019, 2020; Slimani & Nikolaidis, 2017). Similarly, the number of sprints, accelerations, and direction changes is greater in world-class players (Di Salvo et al., 2010, 2013; Slimani & Nikolaidis, 2017). Thus, the assessment of performance profiles becomes one of the purposes to be developed by coaches and technical bodies since it allows them to discriminate between competitive levels and playing positions.

Given the demands of the competition calendar, applying tests that reflect both profiles separately becomes difficult (Scott et al., 2017). Due to this, those that incorporate running, changes of direction, and accelerations are appropriate strategies to assess the aerobic/anaerobic component of the soccer player (Bok & Foster, 2021). In this context, round-trip tests become relevant due to their specific race pattern, which incorporates the actions above. In particular, the use of the 30-15 Intermittent fitness test (30-15 IFT) has increased over time, and this is possibly due to its excellent reliability (intraclass correlation coefficient ≥0.80 and coefficient of variation ≤6%) (Grgic et al., 2021). Besides, VIFT explains performance in anaerobic tests in both the horizontal and vertical planes (Scott et al., 2017; Silva et al., 2022).

The performance in this test allows us to discriminate between positions and categories, providing information to identify weaknesses and design strategies that optimize performance. In this way, comparing performance between categories could guide technical teams on the physical differences between divisions and provide reference values. The objective of this study is to analyze the performance in the 30-15 IFT test in teams belonging to the first division A (1A), first division B (1B), second professional division (2nd) and between positions of the game. A proportional relationship between test performance and competitive level is hypothesized. As a complementary hypothesis, it is stated that midfielders are the ones who will present the greatest performance over defenders, full-backs, and forwards.

Methods

Sample

Eighty-four male professional soccer players belonging to a first division A (1A) (n=21; age 23.5±5.2 years; height 1.74±0.03 m; mass 77.1±7.3 kg), first division B (1B) (n=42; age 23.0±5.0; height 1.76±7.0 m; mass 74.1±7.6 kg) and second professional division (2nd) (n=21; age 22.9±4.7 years; height 1.75±3.4 m; mass 74.6±7.3 kg) participated in the study. To be included in the study, they had to meet the following criteria: a) Have participated in all training sessions since the beginning of the season; b) Do not present muscle injuries until three weeks before the evaluation. Before the start of the tests, the aim of the research and the procedures were verbally explained. All soccer players signed an informed consent form. The tests were part of the evaluations programmed by the respective teams, therefore the approval of the ethics committee was not necessary (Winter & Maughan, 2009). The study was carried out following the ethical guidelines of the Declaration of Helsinki.

Procedures

The evaluations were carried out within the preparation period before the start of their respective competitions: the second microcycle for 1A, the third microcycle for 1B, and the fifth microcycle for the second. All were conducted at 10:00 a.m., with ambient temperatures between 20°C and 23°C. The session began with a 10-minute warm-up by the physical trainers of each campus, consisting of joint mobility and dynamic stretching. For the 1A and 1B teams, the test was carried out on a natural grass surface with soccer shoes, while for the 2a team, it was on synthetic grass with jogging shoes.

30-15 intermittent fitness test (30-15 IFT)

The tests were performed using the protocol described by Buchheit, (2008). Players ran for 30 s, interspersed with 15 s passive recovery, between two lines 40 m apart at a pace determined by an audible signal. The test begins with a speed of 8.0 km/h with increments of 0.5 km/h every 30 s. Players were verbally encouraged to complete as many stages as possible. The test concluded when the player could not maintain the running pace or could not be in the 3 m zones arranged at the ends and center of the course for three consecutive times. The velocity achieved in the last completed stage was recorded as the VIFT.

Perception of effort

The rating of perceived effort was evaluated using the RPE scale (Borg CR-10 scale) proposed by Foster et al., (2001) immediately after the player's participation in the test. The trainers of the three teams regularly used this internal load control modality in their training sessions. Therefore, the athletes were familiar with the procedure.

Statistical Analysis

The data was checked for normality using the Shapiro-Wilk test. The homogeneity of the variables was analyzed using Levene's test. The mean and standard deviation were used to present the descriptive values. The differences between the factors' division and playing position were analyzed using a two-factor ANOVA test to see the interaction effects between factors. If main and interaction effects were found, Bonferroni post-hoc tests were performed. Effect sizes were expressed as partial eta squared (n^2_p). All statistical analyses were conducted using SPSS version 29 software, with an alpha level of 5% established.

The normality of the variables was assessed by analyzing the standardized residuals through the Kolmogorov-Smirnov test (p>0.05) and Q-Q plots, where the assumption of normality was met. Therefore, descriptive statistics will be presented as mean and standard deviation. Equality of variances was assessed using Levene's test, where the assumption of homogeneity was met (p>0.05). A two-way ANOVA was employed to examine differences between the division and playing position factors and to assess interaction effects between factors. Bonferroni post-hoc tests were conducted in case of significant main or interaction effects. Effect sizes were expressed as partial eta squared (η^2p) and interpreted categorically using the following thresholds: trivial <0.01; small 0.011 to 0.06; moderate 0.061 to 0.14; and large >0.141(Lakens, 2013). For post-hoc comparisons, effect size was calculated as Cohen's d, and the following thresholds were used for categorization: trivial 0 to 0.2; small 0.21 to 0.6; moderate 0.61 to 1.2; large 1.21 to 2; and very large >2 (Hopkins et al., 2009). All statistical analyses were performed using SPSS version 29, with an alpha level of 5% established. Figures were created using JASP software (version 0.17.2.0) and GraphPad (GraphPad Prism version 10.0.0 for Windows, GraphPad Software, Boston, Massachusetts USA).

Results

Table 1 displays the descriptive statistics for VIFT across divisions. Large differences were found between the 1st, 1b, and 2nd divisions in VIFT (p=0.002, η^2p=0.166). Post-hoc analysis revealed significantly higher values with moderate effects for 1a compared to 1b and 2a (p<0.05) (Figure 1). Moderate interaction effects were observed, although they did not reach significance (p=0.2, η^2p=0.115). Figure 1 illustrates the effect sizes along with their 95% confidence intervals.

Table 1.
Descriptive and inferences statistical for divisions.

Variables	1A M (SD)	1B M (SD)	2nd M (SD)	Divisions F	Divisions p	Divisions n^2_p	Interaction F	Interaction p	Interaction n^2_p
VIFT (km/h)	22.2[a,b] (1.37)	21.1 (0.88)	21.2 (0.93)	6.789	0.002	0.166	1.474	0.200	0.115

[a] difference with 1B; [b] differences with 2nd; Medium M; SD standard deviation; F for ANOVA; n^2_p eta partial squared.

Table 2.
Descriptive and inference statistics for positions.

Variables	Defenders M (SD)	Forwards M (SD)	Full-backs M (SD)	Midfielders M (SD)	Divisions F	Divisions p	Divisions n^2_p
VIFT (km/h)	20.8[f] (0.89)	21.5 (1.25)	21.9 (1.07)	21.6 (1.03)	5.549	0.002	0.197

[f] differences with full-back p<0.05; M differences with midfielder p<0.05; Medium M; SD standard deviation; F for ANOVA; n^2_p partial eta squared.

Table 2 presents the descriptive statistics for VIFT across playing positions. Significant differences were observed among positions in VIFT (p=0.002, η^2p=0.197). Post-hoc analysis revealed moderate to large differences between defense and both lateral and midfielder positions (p<0.05) (Figure 2). Figure 2 displays the effect sizes along with their 95% confidence intervals.

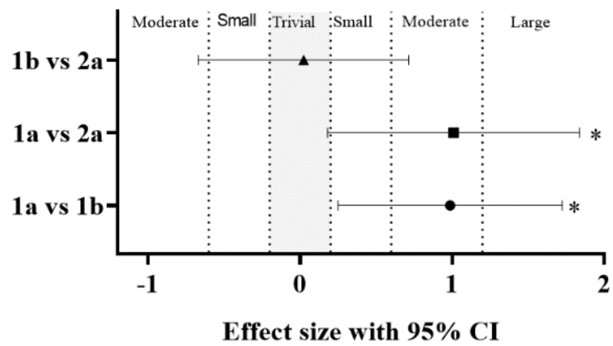

Figure 1. The effect sizes, along with their 95% confidence intervals, between categories.

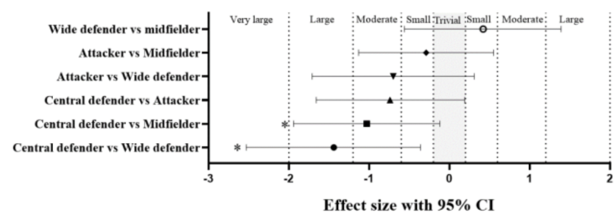

Figure 2. The effect sizes, along with their 95% confidence intervals, between playing positions

Discussión

The purpose of this study was to compare performance in the 30-15 IFT test in teams belonging to 1A, 1B, and 2nd of the Chilean professional soccer league. In the same way, there is a comparison between playing positions. The results suggest that performance is proportional to the competitive level and is affected by position on the playing field.

Endurance is crucial in soccer player performance, especially in recovery between high-intensity efforts, being a key component of physical fitness (Bishop et al., 2011; Stølen et al., 2005). For this reason, analyzing the physical profile according to the competitive level becomes interesting when designing training strategies according to the requirements. Along these lines, various studies have described the differences in resistance capacity between competitive levels, these being directly proportional (Slimani et al., 2019; Slimani & Nikolaidis, 2017; Tønnessen et al., 2013). In agreement, our findings account for this, given that 1A players present higher performances compared to 1B and 2nd. Regarding anaerobic efforts, a relationship has been observed between repeated sprints, changes of direction, and anaerobic reserve speed with performance in the 30-15 IFT test (Ingebrigtsen et al., 2014; Scott et al., 2017; Silva et al., 2022). First-division soccer players present greater covered distances, number of high-intensity runs, and explosive efforts in general (Di Salvo et al., 2013; Krustrup et al., 2003), an aspect that could explain our results.

Concerning Regarding the comparison by playing position, the defenses, full-backs, and midfielders are the ones who present the highest performance in the test. Guerrero-Calderón et al., (2022) recently analyzed loads in first-division soccer players and found that midfielders lead in medium-high and very high-intensity races, according to other authors (Dolci et al., 2020; Modric et al., 2019). However, a particular finding is associated with the greater performance presented by the full-backs. It is proposed that some contextual factors, such as the quality of the opponent, the tactical disposition, and the momentary result of the match, influence running performance (Bok & Foster, 2021; Konefał et al., 2023; Tierney et al., 2016). Due to the 30-15 IFT running pattern, the test performance could be related to match distance and the ability to repeat sprints between other anaerobic actions. It has been described that, due to their tactical role, the external players (defenders and midfielders) cover greater distances by sprinting (Alonso-Callejo et al., 2022; Di Salvo et al., 2010). Our results indicate that the full-back and defenders present the highest VIFT. However, these are significant only concerning the defenders.

The present study has some limitations. The evaluations were carried out at different times of each macrocycle, so the accumulated loads of each team and the different surfaces may have influenced the results. Therefore, the results may not reflect the maximum performance of the footballers. Future studies should incorporate other physical fitness tests to perform a more in-depth analysis of the physical performance profile according to categories.

Conclusion

From the results obtained, it is concluded that there are differences in the performance of the IFT 30-15 test between categories, with players belonging to the first division being those with a higher VIFT. From the point of view of the playing position, the full-back position presents greater performance within the team, with the category not influencing this difference. This background information is useful for coaches, physical trainers, and sports scientists for better training load programming. However, other studies should cover soccer players from other continents and female players.

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Declaration of interest

The authors declare that there are no conflicts of interest and no funding or research grants were received during study, research, or assembly of the manuscript.

Availability of data and materials

Datasets and materials used are available from the corresponding author upon request.

References

Alonso-Callejo, A., García-Unanue, J., Perez-Guerra, A., Gomez, D., Sánchez-Sánchez, J., Gallardo, L., Oliva-Lozano, J. M., & Felipe, J. L. (2022). Effect of playing position and microcycle days on the acceleration speed profile of elite football players. *Scientific Reports*, *12*(1), 1–9. https://doi.org/10.1038/s41598-022-23790-w

Bangsbo, J., Mohr, M., & Krustrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. *Journal of Sports Sciences*, *24*(7), 665–674. https://doi.org/10.1080/02640410500482529

Bennett, H., Parfitt, G., Davison, K., & Eston, R. (2016). Validity of Submaximal Step Tests to Estimate Maximal Oxygen Uptake in Healthy Adults. *Sports Medicine*, *46*(5), 737–750. https://doi.org/10.1007/s40279-015-0445-1

Bishop, D., Girard, O., & Mendez-Villanueva, A. (2011). Repeated-sprint ability part II: Recommendations for training. *Sports Medicine*, *41*(9), 741–756. https://doi.org/10.2165/11590560-000000000-00000

Bok, D., & Foster, C. (2021). Applicability of field aerobic fitness tests in soccer: Which one to choose? *Journal of Functional Morphology and Kinesiology*, *6*(3). https://doi.org/10.3390/jfmk6030069

Buchheit, M. (2008). THE 30-15 INTERMITTENT FITNESS TEST: ACCURACY FOR INDIVIDUALIZING INTERVAL TRAINING OF YOUNG INTERMITTENT SPORT PLAYERS. *Journal of Strength and Conditioning Research*, *22*(2), 365–374.

Buchheit, M., Simpson, B. M., & Mendez-Villanueva, A. (2013). Repeated high-speed activities during youth soccer games in relation to changes in maximal sprinting and aerobic speeds. *International Journal of Sports Medicine*, *34*(1), 40–48. https://doi.org/10.1055/s-0032-1316363

Cherouveim, E. D., Methenitis, S. K., Simeonidis, T., Georginis, P., Tsekouras, Y. E., Biskitzi, C., Tsolakis, C., & Koulouvaris, P. (2022). Validity and Reliability of New Equations for the Prediction of Maximal Oxygen Uptake in Male and Female Elite Adolescent Rowers. *Journal of Human Kinetics*, *83*(1), 77–86. https://doi.org/10.2478/hukin-2022-0053

Di Salvo, V., Baron, R., González-Haro, C., Gormasz, C., Pigozzi, F., & Bachl, N. (2010). Sprinting analysis of elite soccer players during European Champions League and UEFA Cup matches. *Journal of Sports Sciences*, *28*(14), 1489–1494. https://doi.org/10.1080/02640414.2010.521166

Di Salvo, V., Pigozzi, F., González-Haro, C., Laughlin, M. S., & De Witt, J. K. (2013). Match performance comparison in top English soccer leagues. *International Journal of Sports Medicine*, *34*(6), 526–532. https://doi.org/10.1055/s-0032-1327660

Dolci, F., Hart, N. H., Kilding, A. E., Chivers, P., Piggott, B., & Spiteri, T. (2020). Physical and Energetic Demand of Soccer: A Brief Review. *Strength and Conditioning Journal*, *42*(3), 70–77. https://doi.org/10.1519/SSC.0000000000000533

Dugdale, J. H., Arthur, C. A., Sanders, D., & Hunter, A. M. (2019). Reliability and validity of field-based fitness tests in youth soccer players. *European Journal of Sport Science*, *19*(6), 745–756. https://doi.org/10.1080/17461391.2018.1556739

Faude, O., Koch, T., & Meyer, T. (2012). Straight sprinting is the most frequent action in goal situations in professional football. *Journal of Sports Sciences*, *30*(7), 625–631. https://doi.org/10.1080/02640414.2012.665940

Ferraz, R. M. P., van den Tillaar, R., Pereira, A., & Marques, M. C. (2019). The effect of fatigue and duration knowledge of exercise on kicking performance in soccer players. *Journal of Sport and Health Science*, *8*(6), 567–573. https://doi.org/10.1016/j.jshs.2016.02.001

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., Doleshal, P., & Dodge, C. (2001). A New Approach to Monitoring Exercise Training. *Journal of Strength and Conditioning Research*, *15*(1), 109–115. https://doi.org/10.1519/1533-4287(2001)015<0109:ANATME>2.0.CO;2

Grgic, J., Lazinica, B., & Pedisic, Z. (2021). Test–retest reliability of the 30–15 Intermittent Fitness Test: A systematic review. *Journal of Sport and Health Science*, *10*(4), 413–418. https://doi.org/10.1016/j.jshs.2020.04.010

Guerrero-Calderón, B., Alfonso Morcillo, J., Chena, M., & Castillo-Rodríguez, A. (2022). Comparison of training and match load between metabolic and running speed metrics of professional Spanish soccer players by playing position. *Biology of Sport*, 933–941. https://doi.org/10.5114/biolsport.2022.110884

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3–12. https://doi.org/10.1249/MSS.0b013e31818cb278

Hulse, M. A., Morris, J. G., Hawkins, R. D., Hodson, A., Nevill, A. M., & Nevill, M. E. (2013). A field-test battery for elite, young soccer players. *International Journal of Sports Medicine*, *34*(4), 302–311. https://doi.org/10.1055/s-0032-1312603

Ingebrigtsen, J., Brochmann, M., Castagna, C., Bradley, P. S., Ade, J., Krustrup, P., & Holtermann, A. (2014). *Relationships Between Field Performance Tests in High-Level Soccer Players*. *28*(4), 942–949. https://doi.org/10.1519/JSC.0b013e3182a1f861

Kellis, E., Katis, A., & Vrabas, I. S. (2006). Effects of an intermittent exercise fatigue protocol on biomechanics of soccer kick performance. *Scandinavian Journal of Medicine and Science in Sports*, *16*(5), 334–344. https://doi.org/10.1111/j.1600-0838.2005.00496.x

Konefał, M., Radzimiński, Ł., Chmura, J., Modrić, T., Zacharko, M., Padrón-Cabo, A., Sekulic, D., Versic, S., & Chmura, P. (2023). The seven phases of match status differentiate the running performance of soccer players in UEFA Champions League. *Scientific Reports*, *13*(1), 1–8. https://doi.org/10.1038/s41598-023-33910-9

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., Pedersen, P. K., & Bangsbo, J. (2003). The Yo-Yo intermittent recovery test: Physiological response, reliability, and validity. *Medicine and Science in Sports and Exercise*, *35*(4), 697–705. https://doi.org/10.1249/01.MSS.0000058441.94520.32

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. *Frontiers in Psychology*, *4*(NOV), 1–12. https://doi.org/10.3389/fpsyg.2013.00863

Modric, T., Versic, S., & Sekulic, D. (2020). Aerobic fitness and game performance indicators in professional football players; playing position specifics and associations. *Heliyon*, *6*(11). https://doi.org/10.1016/j.heliyon.2020.e05427

Modric, T., Versic, S., Sekulic, D., & Liposek, S. (2019). Analysis of the association between running performance and game performance indicators in professional soccer players. *International Journal of Environmental Research and Public Health*, *16*(20). https://doi.org/10.3390/ijerph16204032

Pérez-Contreras, J., Villaseca-Vicuña, R., Zapata-Huenullán, C., Benavides-Roca, L., Merino-Muñoz, P., & Vidal-Maturana, F. (2022). Condición física de futbolistas adultos y jóvenes de un equipo profesional de Nicaragua. *Revista Ciencias de La Actividad Física*, *23*(2), 1–14. https://doi.org/10.29035/rcaf.23.2.4

Scott, B. R., Hodson, J. A., Govus, A. D., & Dascombe, B. J. (2017). The 30-15 intermittent fitness test: Can it predict outcomes in field tests of anaerobic performance? *Journal of Strength and Conditioning Research*, *31*(8), 2825–2831. https://doi.org/10.1519/JSC.0000000000001563

Silva, A. F., Alvurdu, S., Akyildiz, Z., & Clemente, F. M. (2022). Relationships of Final Velocity at 30-15 Intermittent Fitness Test and Anaerobic Speed Reserve with Body Composition, Sprinting, Change-of-Direction and Vertical Jumping Performances: A Cross-Sectional Study in Youth Soccer Players. *Biology*, *11*(2). https://doi.org/10.3390/biology11020197

Slimani, M., & Nikolaidis, P. T. (2017). Anthropometric and physiological characteristics of male Soccer players according to their competitive level, playing position and age group: a systematic review. *The Journal of Sports Medicine and Physical Fitness*, *November*. https://doi.org/10.23736/S0022-4707.17.07950-6

Slimani, M., Znazen, H., Miarka, B., & Bragazzi, N. L. (2019). Maximum Oxygen Uptake of Male Soccer Players According to their Competitive Level, Playing Position and Age Group: Implication from a Network Meta-Analysis. *Journal of Human Kinetics*, *66*(1), 233–245. https://doi.org/10.2478/hukin-2018-0060

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of Soccer An Update. *Sports Medicine*, *35*(6), 501–536. https://doi.org/10.2165/00007256-200535060-00004

Tereso, D., Gamonales, J. M., Petrica, J., Ibáñez, S. J., & Paulo, R. (2024). Avaliação da composição corporal, da potência de membros inferiores e da potência anaeróbia de jogadores de futebol: diferenças consoante a posição em campo. *Retos-Nuevas Tendencias En Educacion Fisica Deporte Y Recreacion*, *59*, 1034–1045.

Tierney, P. J., Young, A., Clarke, N. D., & Duncan, M. J. (2016). Match play demands of 11 versus 11 professional football using Global Positioning System tracking: Variations across common playing formations. *Human Movement Science*, *49*, 1–8. https://doi.org/10.1016/j.humov.2016.05.007

Tønnessen, E., Hem, E., Leirstein, S., Haugen, T., & Seiler, S. (2013). Maximal aerobic power characteristics of male professional soccer players, 1989-2012. *International Journal of Sports Physiology and Performance*, *8*(3), 323–329. https://doi.org/10.1123/ijspp.8.3.323

Toselli, S., Mauro, M., Grigoletto, A., Cataldi, S., Benedetti, L., Nanni, G., Di Miceli, R., Aiello, P., Gallamini, D., Fischetti, F., & Greco, G. (2022). Assessment of Body Composition and Physical Performance of Young Soccer Players: Differences According to the Competitive Level. *Biology*, *11*(6). https://doi.org/10.3390/biology11060823

Velásquez-González, H., Peña-Troncoso, S., Hernández-Mosqueira, C., Pavez-Adasme, G., Gómez-Álvarez, N., & Sáez de Villarreal, E. (2023). Perfil de esfuerzos de alta velocidad considerando la posición de juego de futbolistas profesionales chile-nos, registrados por un dispositivo GPS: un estudio piloto (Profile of high-speed efforts considering the playing position of Chilean professional soccer players, rec-orded by a GPS device: A Pilot Study). *Retos*, *48*, 590–597. https://doi.org/10.47197/retos.v48.97014

Winter, E. M., & Maughan, R. J. (2009). Requirements for ethics approvals. *Journal of Sports Sciences*, *27*(10), 985–985. https://doi.org/10.1080/02640410903178344

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5.4 Artículo cuarto

Título: Optimizing Muscle Performance in Young Soccer Players: Exploring the Impact of Resisted Sprint Training and Its Relationship with Distance Covered

Introducción: Las acciones explosivas son caracterizadas como determinantes en el éxito de las fases decisivas en el fútbol. De este modo, la búsqueda de estrategias de entrenamiento que optimicen esta capacidad se torna una necesidad. Diversos métodos han demostrado ser efectivos para este propósito, sin embargo, existen aspectos de la dosis que no han sido descritos en la literatura especializada. En este sentido, las carreras lastradas son un método de entrenamiento que mejora la respuesta neuromuscular en futbolistas, sin embargo, los aspectos de la dosis tradicionalmente manipulaos por los investigadores se asocian a la intensidad. Por esta razón se propone indagar en la manipulación de los volúmenes de entrenamiento, operacionalizados en la distancia recorrida, sobre la respuesta adaptativa en futbolistas jóvenes.

Justificación: Explorar el impacto de la distancia recorrida en esprints resistidos permite avanzar en la comprensión de cómo el volumen de entrenamiento, más allá de la intensidad, influye en las adaptaciones neuromusculares de futbolistas jóvenes. Esta información es clave para optimizar la dosificación del entrenamiento, personalizar las cargas según el nivel de desarrollo y maximizar los beneficios sobre el rendimiento explosivo, especialmente en etapas formativas donde las respuestas al estímulo pueden variar ampliamente.

Objetivo: Analizar la influencia de la distancia de esprint en carreras resistidas sobre el rendimiento muscular en futbolistas jóvenes

Metodología: Enfoque cuantitativo, alcance descriptivo-comparativo, diseño experimental con una dimensión temporal longitudinal. Veinticuatro futbolistas jóvenes fueron aleatorizados en 3 grupos con distancias diferenciales (10m-20m-30m) y sometidos a 12 sesiones de entrenamiento de esprint resistido durante 6 semanas. El volumen se homogeneizó entre los grupos, estableciéndose una distancia total de 120 m por sesión para cada uno. El rendimiento muscular fue evaluado antes y después del protocolo de entrenamiento, mediante pruebas de fuerza estática (IMTP), dinámica (CMJ) así como con esprint lineal y cambio de dirección. Las comparaciones entre grupos y tiempo se realizaron mediante la prueba ANOVA de dos factores. Los tamaños del efecto fueron calculados mediante Eta Parcial al Cuadrado (η^2p)

Hallazgos principales: El rendimiento en las variables correspondientes a las pruebas de fuerza estática y dinámica mejoraron en función del tiempo, en los tres grupos experimentales, con tamaños del efecto pequeños a moderados sin diferencias entre grupos. Mismos resultados se presentaron en esprint lineal y con cambio de dirección, con cambios en función del tiempo (pre/post) y tamaños del efecto triviales a pequeños.

Conclusiones: Los incrementos de rendimiento para salto vertical, fuerza isométrica, esprint y cambios de dirección se presentan independientemente de la distancia recorrida en el entrenamiento con esprint resistidos, no existiendo diferencias en función de la distancia de esprint. Distancias entre 10 y 30 m con cargas individualizadas podrían ser adecuadas para mejorar el rendimiento muscular en futbolistas jóvenes

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Article

Optimizing Muscle Performance in Young Soccer Players: Exploring the Impact of Resisted Sprint Training and Its Relationship with Distance Covered

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Abstract: Background: Speed training with resisted sprints has been shown to positively affect neuromuscular performance in soccer players. Various loads, ranging from 10% to 120% of body mass, have demonstrated performance improvements across the spectrum. However, the impact of sprint distance with optimal load on these adaptive responses has yet to be thoroughly described. Objective. To analyze the influence of sprint distance in resisted sprints on muscle performance in young soccer players. Methods. This quantitative study utilized a pre-post experimental design. The sample consisted of 24 young soccer players (15.3 ± 0.68 years; 61.4 ± 7.08 kg; 1.60 ± 0.06 m) randomized into three groups (10, 20, and 30 m) and subjected to 12 sessions of resisted sprint training over six weeks. The volume was homogenized across groups, with a total distance of 120 m for each. The intervention's effect was analyzed through performance in the isometric mid-thigh pull (IMTP), countermovement jump (CMJ), modified 505 agility test (505 m), and linear sprint tests. Differences were analyzed using a mixed ANOVA, incorporating a between-subjects factor (training group) and a within-subjects factor (pre- and post-intervention). Results. Time-dependent differences were observed in all groups for peak force (PF) ($p < 0.001$; $\eta^2p = 0.62$), time to PF (TPF) ($p < 0.001$; $\eta^2p = 0.53$), impulse at 50 ($p < 0.001$; $\eta^2p = 0.57$), 100 ($p < 0.001$; $\eta^2p = 0.60$), and 200 ms ($p < 0.001$; $\eta^2p = 0.67$) in IMTP; jump height by impulse-momentum ($p < 0.001$; $\eta^2p = 0.64$), rate of force development ($p = 0.04$; $\eta^2p = 0.14$), yielding impulse ($p < 0.001$; $\eta^2p = 0.49$), and concentric impulse ($p = 0.01$; $\eta^2p = 0.19$) in CMJ; time ($p < 0.001$; $\eta^2p = 0.46$) in 505 m; and average speed in linear sprint ($p = 0.003$; $\eta^2p = 0.36$), with moderate to large effect sizes, regardless of the distance covered. No differences were observed for the interaction between the time* and group or between groups. Conclusion. Performance improvements were independent of the sprint distance, with no differences between training groups. Distances between 10 and 30 m may enhance muscle performance in young soccer players.

Keywords: resistance training; muscle strength; football; physical fitness; puberty players

1. Introduction

Soccer alternates between high- and low-intensity actions, where strength and power expression are key factors in high-intensity player performance. High-intensity actions, such as sprints, accelerations, decelerations, and changes of direction (COD) [1–4], play a key role in goal-related situations, with linear sprinting being decisive in over 60% of assists and goals scored by players [5]. Most sprints in soccer occur over short distances (0 to 30 m) [6,7], making acceleration development crucial. Regarding COD, these actions are among the most prevalent in a match, with approximately 700 efforts per game [1]. Accordingly, COD is essential for evading opponents and gaining advantageous positions. Additionally, COD is an implicit skill in agility, including acceleration, deceleration, and decision-making situations [8], highlighting its importance for performance development.

Concerning the methods to develop this quality, they can be divided into three subgroups according to task specificity [9]: (a) Primary methods, which are based on sprint-specific actions; (b) Secondary methods, which also focus on sprint patterns but incorporate overload or underload conditions; and (c) Tertiary methods, characterized by the inclusion of non-sprint-specific actions, such as plyometrics or resistance training. Speed training with resisted running (secondary methods) has proven effective for soccer players of different ages and genders [10–12]. Various devices and force vectors have been experimented with in this context [13], with sled running being an effective method for increasing acceleration capacity [14,15]. This type of intervention also reports improvements in a wide range of related actions, such as changes of direction, jump height (SJ-CMJ), average power, and propulsive average power [11,16,17]. It is important to highlight that these capacities undergo accelerated development in tandem with the processes of biological maturation [3]. Moreover, manipulating the external training load's variables is crucial for achieving performance improvements [18].

The dosing of resisted sprint loads ranges from 10% to 120% of body mass. Performance improvements have been reported across the spectrum [17,19–21]. These studies have shown that this dosing increases maximal power and speed over 5 and 30 m. It also optimizes the horizontal force-velocity profile. Theoretically, training with a resisted-sled load that induces a ~50% decrement in maximum velocity (i.e., optimal load) increases the ability to produce maximal power output. It also leads to a practical increase in the ability to transfer force throughout the sprinting phases. This results in an increase in both force and velocity capacities [22]. Runs of up to 30 m are key for promoting acceleration development, as this phase predominantly occurs within that distance [23]. Finally, factors such as the athletes' training status and the manipulation of the training load can influence the achievement of optimal adaptations [14].

Heavy loads, ranging from 75–112% of body weight (BW), improve the expression of the mechanical components of sprinting (force, velocity, and maximal power). These results persist residually, lasting even after four weeks without specific intervention [17]. However, there is evidence pointing to the detrimental effect of loads that reduce maximal sprint speed by more than 30%, as they can negatively impact running technique [9]. This is an important consideration for physical conditioning coaches. Similarly, both heavy and light loads enhance performance in early and late acceleration phases [24]. These improvements are evident in within-group comparisons. However, their effectiveness over sprint training without resistance remains inconclusive [25,26].

Regarding the effects on other explosive actions, it has been shown that resisted sprints with 30% body weight loads do not improve change-of-direction performance, nor vertical jump height [27]. It has been proposed that the inclusion of combined strength stimuli in both the vertical and horizontal planes would be more suitable for improving this expression of performance [28]. Methodological guidelines suggest that programming based on velocity loss percentages may be more suitable for improving acceleration [24].

Despite these findings, no studies have incorporated the manipulation of sprint distance as an independent variable to verify its influence on neuromuscular performance improvements. Therefore, the present study aims to analyze the influence of different resisted sprint distances on neuromuscular performance in young soccer players. The research hypothesis proposes that certain distances maximize muscular adaptations during high-intensity efforts.

2. Materials and Methods

2.1. Experimental Approach to the Problem

The study was conducted with young male soccer players from a professional Chilean club. The training program was executed over nine weeks (see Figure 1) between March and June during the competitive season. Week 1 was dedicated to familiarization, during which two sessions of sled drags with loads of 10% and 20% of body mass were performed. During this period, mass and height were evaluated using a scale (SECA model 803) and a stadiometer (SECA model 213) with an accuracy of 0.1 kg and 0.1 m, respectively. Subsequently, assessments were conducted before and after (weeks two and nine) the 12 sessions of resisted sprint training. The evaluations were performed over two days, with 48 h between them: Day 1 included (a) measurements of height and mass, (b) an isometric mid-thigh pull, and (c) a countermovement vertical jump; Day 2 included (a) a 30 m linear sprint and (b) a change of direction (m505). After the initial assessments, subjects were randomized into three groups, each with different sprint distances: G10m (10 m—n = 8), G20m (20 m—n = 7), and G30m (30 m—n = 9), using Excel's RAND() function for random assignment. Between weeks 3 and 8, 12 sessions of resisted sprints with differential distances and optimal load were applied. The optimal load is defined as reducing maximum speed by 50%. This load magnitude maximizes horizontal power production [29]. The sessions were supervised by the study's principal investigator and the team coaches. All procedures were conducted at the club's outdoor facilities, with a temperature range of 17° to 20 °C.

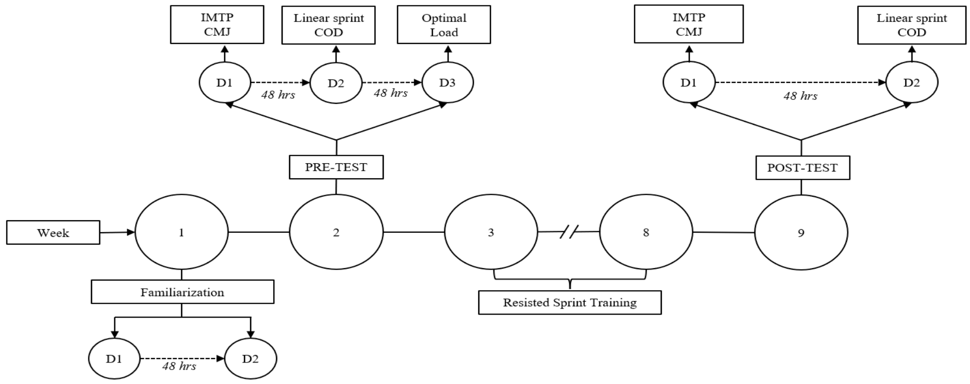

Figure 1. Experimental design. Temporal sequence of resisted sprint training protocol. Total volume: nine weeks (Week 1 = familiarization; Week 2 and 9 = pre- and post-test, respectively; Week 3 to 8 = resisted sprint training). IMTP: Isometric mid-thigh pull; CMJ: Countermovement jump; COD: Change of direction; D: Day.

2.2. Participants

Twenty-four young male soccer players (15.9 ± 0.69 years; 61.4 ± 7.08 kg; 1.69 ± 0.06 m) from the S15 and S16 categories of a professional Chilean soccer club voluntarily participated in the study. Participants were selected through convenience sampling. All players had a weekly training frequency of six sessions, including the official competition. At the start of the intervention, they were informed about the benefits and potential risks of the research. They expressed their willingness to participate by signing informed assent and consent forms, signed by their parents or legal guardians. The study was conducted according to the ethical standards for research involving humans, as stated in the Declaration of Helsinki. It was approved by the Ethics Committee of Adventist University of Chile, Chillán, Chile (resolution 2023-07, Acta No. 2023-04, and vote No. 2023-08).

2.3. Procedures

2.3.1. Performance Tests

Isometric Mid-Thigh Pull (IMTP)

The IMTP test was conducted on day one of weeks two and nine (see Figure 1). The procedure for the test execution aligns with previously described methods [30]. Specific activation included three attempts of IMTP at 50%, 75%, and 90% of perceived effort, with a one-minute rest between them. Following this, three maximal attempts were performed with the instruction, "Push your feet into the ground as quickly and forcefully as possible." Each attempt lasted eight seconds, with the first three seconds for preparation and the remaining five seconds for effort. The rest period between attempts was two minutes. Data were recorded using force plates (PASPORT force plate, PS-2141, PASCO Scientific, Roseville, CA, USA) via SPARKvue software (version 4.6.1, Roseville, CA, USA), then exported to an Excel spreadsheet (version 16, Microsoft, Redmond, WA, USA) and finally processed in Matlab (version 9.6, Natick, MA, USA). The onset of both tests was estimated using a five-standard-deviation change in the force-time curve [31]. Analyzed variables included absolute peak force (IPF) and impulse at 50, 100, and 200 ms.

Countermovement Vertical Jump (CMJ)

The CMJ test was conducted on day one of weeks two and nine (see Figure 1). After a specific activation of five submaximal jumps, players performed three maximal CMJ attempts with a two-minute rest between them. The depth of the descent was self-selected for comfort. Players were instructed to jump "as quickly and as high as possible" [32]. The jumps were performed with hands fixed on the hips. Data were recorded using force plates

(PASPORT force plate, PS-2141, PASCO Scientific, Roseville, CA, USA) via SPARKvue software (version 4.6.1, Roseville, CA, USA), then exported to an Excel spreadsheet (version 16, Microsoft, Redmond, WA, USA) and finally processed in Matlab (version 9.6, Natick, MA, USA). Analyzed variables included jump height (JH) calculated through impulse momentum, rate of power development (RDP), yielding impulse (IY), braking impulse (IB), and concentric impulse (IC).

Linear Sprint

Speed tests were conducted on day two of weeks two and nine (see Figure 1). Warm-up was supervised by the club's physical trainer, consisting of joint mobility and dynamic stretches, followed by low-intensity aerobic running and three progressive sprints performed at up to 95% of perceived effort. Players performed two 30 m sprints with a three-minute recovery between attempts. Verbal encouragement was given to ensure maximal voluntary effort. The average speed of the best attempt was recorded using photoelectric cells (Chronojump software, version 2.3.0-79, Barcelona, Spain).

Change of Direction (COD)

The modified 505 test (505 m) [33] was conducted during the second session of weeks two and nine. One trial was performed to familiarize individuals with the execution dynamics. Two photoelectric barriers (Chronojump software, version 2.3.0-79, Barcelona, Spain) were placed, with a marker on the floor half a meter away from them. From this point, participants were instructed to run as quickly as possible for 5 m, turn 180°, and return to the start. Three attempts were performed, with participants changing direction with the right leg [34]. The best recorded time was used for analysis.

Optimal Load

Optimal load determination for sled dragging was conducted on the third day of the familiarization week (see Figure 1). To individualize the load magnitude, participants performed sprints with progressive loads (0%, 25%, 50%, and 75% of body mass) over 30 m for each attempt. The optimal load reduces speed by 50% compared to an unloaded sprint [35]. Calculations followed the procedure described by Romero-Franco et al. (2017) [36] using the MySprint® application (version 2.1.0). Video recordings were made with an 8th generation iPad (Apple, Inc., Cupertino, CA, USA) placed perpendicular to the running surface, 10 m away, on a tripod at a height of 1.5 m. Six markers were placed at 5, 10, 15, 20, 25, and 30 m, with necessary parallelism corrections. Participants were encouraged to run as fast as the load allowed.

Training Protocol

Before each session, the team's physical trainer conducted a standardized 10-min general warm-up. This included moderate-intensity linear running and changes of direction, bodyweight strength exercises such as squats and lunges, and dynamic flexibility drills. Players in the G10m, G20m, and G30m groups completed an equalized volume of 120 m of sled dragging with optimal load in each session. The repetition dosing was as follows: G10m: 12 repetitions, G20m: six repetitions, G30m, four repetitions. A two-minute recovery period was provided between attempts (see Figure 2).

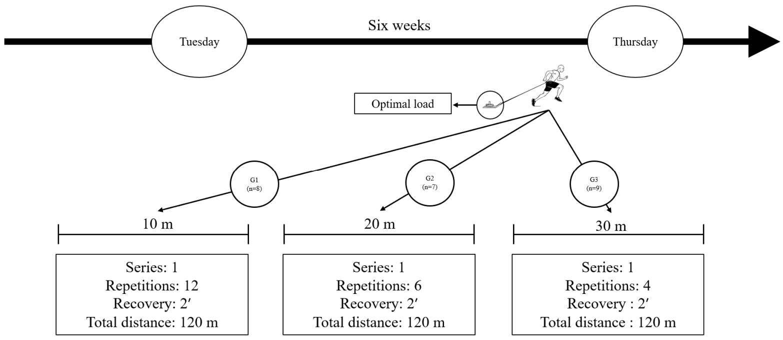

Figure 2. Design protocol resisted sprints, typical week. Duration: six weeks, weekly frequency: two sessions. G1: Experimental group 10 m; G2: Experimental group 20 m; G3: Experimental group 30 m.

Statistical Analysis

Data normality was assessed using the Shapiro-Wilk test, and variance homogeneity was checked using the Levene test. Differences were analyzed with a mixed ANOVA, incorporating a between-subjects factor (training group) and a within-subjects factor (pre- and post-intervention). Partial eta squared (η^2p) was calculated to determine the effect sizes, providing a measure of the proportion of variance explained by each factor and their interaction. Effect sizes and percentage changes were also calculated. For effect sizes, Cohen's d was used, with the following qualitative thresholds: trivial (<0.2), small (0.21–0.6), moderate (0.61–1.2), large (1.21–2), and very large (2.1–4) [37]. Percentage changes were calculated as described by Merino-Muñoz et al. (2020) [38]. Analyses were conducted using Microsoft Excel and IBM SPSS Statistics for Windows, version 29.0. Armonk, NY, USA: IBM Corp.

3. Results

3.1. Isometric Strength

The results for peak force (PF), time to peak force (TPF), impulse at 50 ms (I50), impulse at 100 ms (I100), and impulse at 200 ms (I200) are presented. All variables showed changes over time, irrespective of the training group (Table 1). No significant differences were found between groups when comparing pre- and post-intervention data (Table 1). However, differences were observed between groups for PF ($p = 0.03$; $\eta^2p = 0.26$). Effect sizes for PF ranged from trivial to small, while TPF showed moderate effect sizes, and I50, I100, and I200 had small effect sizes. All groups demonstrated percentage changes associated with improved performance.

Table 1. Pre- and post-test scores (Mean [SD]), Effect Size, and Percentage of Change in Isometric Mid-thigh Pull Performance.

		Pre		Post		ES	PC (%)	Time		Time and Group		Group	
	Group	Mean	SD	Mean	SD			p	η^2p	p	η^2p	p	η^2p
PF (N)	10 m	1660	310	1713	325	0.17	3.19	<0.001	0.62	0.30	0.12	0.03	0.26
	20 m	1441	185	1472	177	0.18	2.20						
	30 m	1836	121	1888	133	0.42	2.89						
TPF (ms)	10 m	2.85	1.32	1.77	0.84	0.97	−37.75	<0.001	0.53	0.81	0.03	0.48	0.08
	20 m	2.49	1.17	1.68	1.37	0.64	−32.53						
	30 m	2.06	1.13	1.38	1.07	0.62	−32.83						
Impulse 50 ms (N·kg)	10 m	40.81	8.77	43.8	11.2	0.30	7.44	<0.001	0.57	0.58	0.07	0.17	0.16
	20 m	34.67	5.51	36.2	5.80	0.27	4.44						
	30 m	42.25	5.14	44.6	5.98	0.42	5.49						
Impulse 100 ms (N·kg)	10 m	89.32	20.30	98.1	27.3	0.37	9.87	<0.001	0.60	0.30	0.12	0.15	0.16
	20 m	74.74	11.70	78.9	12.1	0.35	5.60						
	30 m	92.87	13.38	99.7	15.1	0.47	7.29						
Impulse 200 ms (N·kg)	10 m	209	50.38	227.5	61.5	0.34	9.19	<0.001	0.67	0.21	0.14	0.11	0.19
	20 m	171	27.23	182	25.3	0.40	6.15						
	30 m	217	35.80	235	36.9	0.49	8.17						

PF: Peak force; TPF: Time of peak force; ES: Effect size; PC: Percent of change.

3.2. Vertical Jump

The results for jump height (JH), rate of force development (RFD), impulse at take-off (ID), yielding impulse (IY), braking impulse (IB), and concentric impulse (IC) are presented. All variables exhibited changes over time, regardless of the training group (Table 2). No significant differences were found between groups when comparing pre- and post-intervention data (Table 2). Similarly, there were no differences between groups. Effect sizes varied from trivial to moderate for JH, trivial to small for RFD, small to moderate for ID, trivial to moderate for IY, and trivial to small for IB and IC. All groups demonstrated percentage changes associated with improved performance, except for the 10 m group in IB (−0.84%) and the 20 m group in IC (−0.42%).

Table 2. Pre- and post-test scores (Mean [SD]), Effect Size, and Percentage of Change in Vertical Jump Performance.

		Pre		Post		ES	PC (%)	Time		Time and Group		Group	
	Group	Mean	SD	Mean	SD			*p*	$\eta^2 p$	*p*	$\eta^2 p$	*p*	$\eta^2 p$
JH (m)	10 m	0.33	0.03	0.36	0.05	0.69	9.09	<0.001	0.64	0.17	0.16	0.92	0.01
	20 m	0.32	0.05	0.33	0.06	0.2	3.13						
	30 m	0.33	0.05	0.35	0.06	0.41	6.06						
RPD (W/s)	10 m	307	104.8	312	93.6	0.04	1.38	0.041	0.137	0.659	0.053	0.292	0.119
	20 m	292	94.2	324	131.7	0.28	11.02						
	30 m	248	41.9	266	32.4	0.48	7.27						
ID (N·kg)	10 m	39.4	11.7	43.4	13.6	0.31	10.16	0.003	0.27	0.791	0.035	0.253	0.129
	20 m	32.1	5.4	39.3	11.0	0.82	22.22						
	30 m	42.0	8.2	48.4	10.7	0.67	15.34						
IY (N·kg)	10 m	36.4	10.8	48.3	12.6	1.01	32.65	<0.001	0.492	0.009	0.327	0.184	0.151
	20 m	39.3	12.3	40.0	10.7	0.06	1.82						
	30 m	45.7	8.4	50.3	10.7	0.48	10.22						
IB (N·kg)	10 m	74.3	18.1	73.6	13.7	0.04	−0.84	0.235	0.048	0.792	0.035	0.067	0.215
	20 m	57.9	12.8	63.9	26.7	0.29	10.37						
	30 m	79.3	21.6	89.9	16.7	0.55	13.31						
IC (N·kg)	10 m	155	23.9	161	21.6	0.24	3.46	0.014	0.19	0.443	0.087	0.04	0.246
	20 m	135	17.1	134	16.5	0.03	−0.42						
	30 m	160	13.9	165	12.5	0.39	3.19						

JH: Jump height; RPD: Rate power development; ID: Impulse discharge; IY: Yielding impulse; IB: Braking impulse; IC: Concentric impulse; ES: Effect size; PC: Percent of change.

3.3. Change of Direction

Performance in the change of direction (COD) test showed improvements over time ($p < 0.001$, $\eta^2 p = 0.46$), regardless of the training group ($p = 0.36$, $\eta^2 p = 0.10$). No significant differences were found between groups when comparing pre- and post-intervention data (Table 3). Effect sizes ranged from small to moderate (ES = 0.44 to 0.90) across the groups. All groups demonstrated percentage changes associated with improved performance.

Table 3. Pre- and post-test scores (Mean [SD]), Effect Size, and Percentage of Change in COD Performance.

		Pre		Post		ES	PC (%)	Time		Time and Group		Group	
	Group	Mean	SD	Mean	SD			*p*	$\eta^2 p$	*p*	$\eta^2 p$	*p*	$\eta^2 p$
Time (s)	10 m	2.58	0.12	2.47	0.16	0.75	−4.16	<0.001	0.46	0.36	0.1	0.54	0.07
	20 m	2.54	0.10	2.41	0.17	0.9	−5.00						
	30 m	2.57	0.11	2.52	0.10	0.44	−1.84						

ES: Effect size; PC: Percent of change.

3.4. Linear Sprint

Average speed improved over time ($p = 0.003$, $\eta^2 p = 0.36$), regardless of the training group ($p = 0.89$, $\eta^2 p = 0.01$). No significant differences were observed between groups when comparing pre- and post-intervention data ($p = 0.57$, $\eta^2 p = 0.05$). Effect sizes ranged from small to moderate (ES = 0.37 to 0.62) across the groups (Table 4). All groups showed percentage changes indicative of performance improvement.

Table 4. Pre- and post-test scores (Mean [SD]), Effect Size, and Percentage of Change in Sprint Performance.

		Pre		Post		ES	PC (%)	Time		Time and Group		Group	
	Group	Mean	SD	Mean	SD			*p*	η^2p	*p*	η^2p	*p*	η^2p
Mean Speed (m/s)	10 m	6.07	0.27	6.17	0.24	0.37	1.61	0.003	0.36	0.89	0.01	0.57	0.05
	20 m	6.08	0.23	6.22	0.21	0.62	2.30						
	30 m	5.97	0.15	6.10	0.25	0.58	2.08						

ES: Effect size; PC: Percent of change.

4. Discussion

Resisted sprint training has emerged as an effective method for enhancing the acceleration phase of sprinting [14,15]. Previous studies have reported improvements in soccer-specific actions such as linear sprints [39], change of direction (COD) [10], and accelerations [24]. Despite the general agreement on the benefits of this training method, the influence of sprint distance on adaptive responses remains to be determined. This study aimed to analyze the impact of different resisted sprint distances on muscular performance in young soccer players. It was hypothesized that distance would significantly influence muscular adaptation in high-intensity efforts. The results indicate that adaptations occurred regardless of the resisted sprint distance, albeit with varying magnitudes.

Our findings indicate an improvement in change of direction (COD) performance for all sprint distances. These results are consistent with previous research. Gil et al. (2018) [11] implemented a resisted and unloaded sprint training protocol with adult soccer players over six weeks, using a load that reduced maximum speed by 10%. They observed a 6.1% improvement in COD performance time, although there were no significant differences compared to the unloaded group. Their protocol also included overloaded jumps (60% BM), which makes it difficult to attribute the improvements solely to resisted training. Additionally, they used a device that did not allow for sprints at distances suitable for the development of acceleration and maximum speed (7 m linear sprint), limiting the ability to evaluate the influence of sprint distance on performance. In our case, the strength stimulus was limited exclusively to sled drags, with no other specific strength exercises included, and only the technical-tactical sessions corresponding to the planned training for those days were added. Similarly, Pareja-Blanco et al. (2019) [40] designed a protocol with five training groups, based on resisted sprints with high and low loads (LST—12.5% BM and HST—80% BM, respectively), as well as resisted sprints with high and low loads combined with vertical jumps with overload (LST + SQ and HST + SQ, respectively), and a group performing jumps with overload (SQ). Their findings showed that only LST + SQ, HST + SQ, and LST improved COD performance. Consistent with our results, improvements in COD were observed without the need to add an extra stimulus, with the caveat that the sled load was on average higher than the one described in Gil et al.'s study. A possible explanation for this phenomenon could be found in the lower level of expertise of the study subjects, which increases the responsiveness regardless of the magnitude of the stimulus.

Recently, Loturco et al. (2024) [27] have questioned the effectiveness of resisted sprints as a strategy to optimize high-intensity actions in young soccer players. In their study, two training protocols were designed: one based on squat jumps and another on resisted runs with a load equivalent to 30% of body mass. The results indicated significant improvements in vertical jump height only in the group that performed squat jumps, while the resisted running group showed no relevant progress in the performance variables assessed. These findings led the authors to suggest that the inclusion of resisted sprints at the beginning of the season may be questionable due to the lack of positive effects on sprint and jump performance.

One of the key observations by Loturco et al. (2024) [27] concerns the timing of the season when these training strategies are implemented. Previous studies have reported performance improvements using resisted sprints, but these interventions were conducted during the competitive period, suggesting a possible interaction with the specific demands of that stage. In line with this background, our findings show that applying the training protocol during the competitive period could explain the observed increases in change of direction (COD) performance. Therefore, it is plausible that the improvements obtained are influenced by the synergy between the implemented protocol and the demands of competition.

In this regard, Mainer-Pardos et al. (2024) [28] point out that although resisted sprint training contributes to improving COD performance, its effects are enhanced when combined with stimuli performed in the vertical plane. However, it is not possible to attribute the effectiveness of this strategy exclusively to resisted sprints, as the studies reviewed did not include comparisons with a non-resisted control group; instead, only within-group comparisons were conducted. Regarding our findings, they could be explained by the level of expertise of the players included in the sample. Since the participants had limited prior exposure to this type of training and, therefore, had a greater adaptation reserve, a relatively low training dose was sufficient to generate improvements in their performance.

The impact of resisted sprint training on linear sprint performance has been well-documented in the literature [16,21,28]. However, the influence of sprint distance on these adaptations still needs to be conclusive. Rodríguez-Rosell et al. (2022) [41] implemented a resisted sprint protocol with five different load magnitudes, ranging from 0 to 80% BM, over a fixed distance of 20 m. All groups showed speed improvements, ranging from 0.8% for 80% BM to 1.5% for 40% BM. Similarly, Bachero-Mena & González-Badillo (2014) [20] conducted 14 sessions of resisted sprints with differential loads (5 [LL]–12.5 [ML]–20 [HL] % BM) over distances between 20 and 35 m over seven weeks with physically active students. Results demonstrated improved times over 30 m for all groups, with significant improvements ($p < 0.001$) observed in the HL group. The authors noted that high loads primarily affect the initial meters of the sprint, specifically during the acceleration phase. Our findings support this assertion, as the G20 group experienced the most significant improvement (ES = 0.62; Δ 3.2%). Comparable results were reported by West et al. (2013) [42], who conducted 12 sessions of resisted sprints (12.5% BM) with professional rugby players (n = 20). The largest effect sizes for performance over 10 and 30 m were observed in the resisted sprint group compared to the unloaded sprint group, with a sprint distance of 20 m, consistent with our findings.

Our findings on the effects of resisted sprints on vertical jump kinematics indicate improvements in force production per unit of time and vertical jump height. Previous research supports these results, with similar protocols showing enhanced performance in these variables. For instance, Sinclair et al. (2021) [43] demonstrated significant improvements in vertical jump height following 16 sessions over eight weeks of resisted sprint training with professional rugby players. Specifically, 20-m sprints with a load of 25.0–26.9% BM and a total volume of 180 m per session resulted in a 6.5% increase in vertical jump height (from 40.43 $\pm$ 3.87 cm to 43.07 $\pm$ 4.55 cm). Conversely, results for metrics derived from the force-time curve are less consistent. Harrison & Bourke (2009) [44] conducted 12 sessions of resisted sprints over 20 m (~13% BM, 120 m per session), analyzing possible effects on force-time relationships through vertical jumps without countermovement (SJ). Their results showed no improvements in the rate of force development (RFD) or the time to reach the maximum rate of force development (p values of 0.502 and 0.296 for time; 0.738 and 0.245 for time x group, respectively). The absence of a stretch-shortening cycle in the selected jump gesture may have limited the expression of the adaptation. This could explain the lack of improvements in force production per unit of time. However, this assertion might be challenged by the results of Alcaraz et al. (2012) [45], who also found no improvements in RFD for countermovement jumps.

Kinetic variables derived from the isometric mid-thigh pull (IMTP) test also showed improvements across all three experimental groups. According to our literature review, there is a lack of evidence regarding the effects of resisted sprint training on these metrics. However, peak force (PF) measured through static strength tests has demonstrated moderate to high correlations with various performance expressions. Comfort et al. (2019) [30] reported moderate to high correlations between PF, as assessed by the IMTP, and performance in change of direction (COD), 20-m sprints, and countermovement jumps (r = −0.57 to 0.79, $p < 0.05$; r = −0.69, $p < 0.05$; r = 0.59 to 0.82, $p < 0.05$, respectively). Given the observed improvements in these performance variables, it is plausible to infer that the increases in PF observed across all three groups could be attributed to these overall enhancements in muscular performance.

To our knowledge, no original studies have specifically examined the influence of sprint distance on physical performance in any population. From this perspective, our study is pioneering in its approach, as it evaluates different sprint distances with homogenized volume and individualized load within the same design. Rumpf et al. (2016) [46] reviewed the effects of various speed training methods on sprint performance over different distances. Their conclusions highlighted that resisted sprint training was most effective for improving performance over distances of 20 m, with greater effectiveness observed as the drag load increased (over 10% body mass or 10% velocity decrement). An important aspect to consider is the influence of load magnitude on running mechanics. In this regard, Zabaloy et al. (2023) [9] warn that loads causing a velocity loss greater than 30% negatively impact running technique, effectively transforming the sprint into a heavy-loaded march. From this perspective, such a method could be considered a tertiary approach to sprint development, akin to strength training with loads close to 1RM. This aspect should be taken into account by physical conditioning coaches.

One limitation of our study is that we did not control for split times during the 30-m sprint. This omission prevents us from providing insights into how sprint distance might influence the acceleration phase of sprinting. Similarly, the limited experience of the selected sample in high-intensity strength training may have contributed to the observed adaptations. The literature strongly emphasizes this point, particularly the inverse relationship between the magnitude of changes and the athletes' level of expertise. Finally, the inclusion of internal load markers (e.g., lactate, heart rate, muscle soreness) could contribute to the better understanding of adaptive responses in young soccer players [47–49].

Overall, our study strengthens the body of evidence supporting the benefits of specific training strategies for enhancing performance in team sports. In particular, our design introduces new elements that had not been previously explored: (i) Individualization of the load based on optimal/high load parameters in developing soccer players, (ii) Comparison of different sprint distances within the same design, and (iii) Examination of the effects of resisted sprints on metrics of the force-time curve in both static and dynamic tests.

5. Conclusions

Our findings have significant implications for coaches and trainers working with young soccer players. We observed performance improvements in vertical jump, isometric strength, sprinting, and change of direction, regardless of the sprint distance used in resisted sprint training. No significant differences were found based on the sprint distance. Therefore, our study suggests that sprint distances ranging from 10 to 30 m, with individualized loads, could be equally effective for enhancing muscular performance in young soccer players.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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References

1. Dolci, F.; Hart, N.H.; Kilding, A.E.; Chivers, P.; Piggott, B.; Spiteri, T. Physical and Energetic Demand of Soccer: A Brief Review. *Strength Cond. J.* **2020**, *42*, 70–77. [CrossRef]
2. Modric, T.; Versic, S.; Sekulic, D.; Liposek, S. Analysis of the Association between Running Performance and Game Performance Indicators in Professional Soccer Players. *Int. J. Environ. Res. Public Health* **2019**, *16*, 4032. [CrossRef]
3. Stølen, T.; Chamari, K.; Castagna, C.; Wisløff, U. Physiology of Soccer An Update. *Sport. Med.* **2005**, *35*, 501–536. [CrossRef] [PubMed]
4. Vigne, G.; Gaudino, C.; Rogowski, I.; Alloatti, G.; Hautier, C. Activity Profile in Elite Italian Soccer Team. *Int. J. Sports Med.* **2010**, *31*, 304–310. [CrossRef] [PubMed]
5. Faude, O.; Koch, T.; Meyer, T. Straight Sprinting Is the Most Frequent Action in Goal Situations in Professional Football. *J. Sports Sci.* **2012**, *30*, 625–631. [CrossRef]
6. Chmura, P.; Konefał, M.; Chmura, J.; Kowalczuk, E.; Zajac, T.; Rokita, A.; Andrzejewski, M. Match Outcome and Running Performance in Different Intensity Ranges among Elite Soccer Players. *Biol. Sport* **2018**, *35*, 197–203. [CrossRef] [PubMed]
7. Di Salvo, V.; Baron, R.; González-Haro, C.; Gormasz, C.; Pigozzi, F.; Bachl, N. Sprinting Analysis of Elite Soccer Players during European Champions League and UEFA Cup Matches. *J. Sports Sci.* **2010**, *28*, 1489–1494. [CrossRef]
8. Bustamante-Garrido, A.; Izquierdo, M.; Miarka, B.; Cuartero-Navarrete, A.; Pérez-Contreras, J.; Aedo-Muñoz, E.; Cerda-Kohler, H. Mechanical Determinants of Sprinting and Change of Direction in Elite Female Field Hockey Players. *Sensors* **2023**, *23*, 7663. [CrossRef]
9. Zabaloy, S.; Freitas, T.T.; Pareja-Blanco, F.; Alcaraz, P.E.; Loturco, I. Narrative Review on the Use of Sled Training to Improve Sprint Performance in Team Sport Athletes. *Strength Cond. J.* **2023**, *45*, 13–28. [CrossRef]
10. Carlos-Vivas, J.; Perez-Gomez, J.; Eriksrud, O.; Freitas, T.T.; Marín-Cascales, E.; Alcaraz, P.E. Vertical versus Horizontal Resisted Sprint Training Applied to Young Soccer Players: Effects on Physical Performance. *Int. J. Sports Physiol. Perform.* **2020**, *15*, 748–758. [CrossRef]
11. Gil, S.; Barroso, R.; Crivoi do Carmo, E.; Loturco, I.; Kobal, R.; Tricoli, V.; Ugrinowitsch, C.; Roschel, H. Effects of Resisted Sprint Training on Sprinting Ability and Change of Direction Speed in Professional Soccer Players. *J. Sports Sci.* **2018**, *36*, 1923–1929. [CrossRef] [PubMed]

12. Loturco, I.; Loturco, I.; Loturco, I.; Jeffreys, I.; Kobal, R.; Reis, V.P.; Fernandes, V.; Rossetti, M.; Pereira, L.A.; Pereira, L.A.; et al. Resisted Sprint Velocity in Female Soccer Players: Influence of Physical Capacities. *Int. J. Sports Med.* **2020**, *41*, 391–397. [CrossRef] [PubMed]
13. Alcaraz, P.E.; Palao, J.M.; Elvira, J.L.L.; Linthorne, N.P. Effects of Three Types of Resisted Sprint Training Devices on the Kinematics of Sprinting at Maximun Velocity. *J. Strength Cond. Res.* **2008**, *22*, 890–897. [CrossRef] [PubMed]
14. Alcaraz, P.E.; Carlos-Vivas, J.; Oponjuru, B.O.; Martínez-Rodríguez, A. The Effectiveness of Resisted Sled Training (RST) for Sprint Performance: A Systematic Review and Meta-Analysis. *Sport. Med.* **2018**, *48*, 2143–2165. [CrossRef] [PubMed]
15. Petrakos, G.; Morin, J.B.; Egan, B. Resisted Sled Sprint Training to Improve Sprint Performance: A Systematic Review. *Sport. Med.* **2016**, *46*, 381–400. [CrossRef]
16. McMorrow, B.J.; Ditroilo, M.; Egan, B. Effect of Heavy Resisted Sled Sprint Training during the Competitive Season on Sprint and Change-of-Direction Performance in Professional Soccer Players. *Int. J. Sports Physiol. Perform.* **2019**, *14*, 1066–1073. [CrossRef]
17. Morin, J.B.; Capelo-Ramirez, F.; Rodriguez-Pérez, M.A.; Cross, M.R.; Jimenez-Reyes, P. Individual Adaptation Kinetics Following Heavy Resisted Sprint Training. *J. Strength Cond. Res.* **2022**, *36*, 1158–1161. [CrossRef]
18. Impellizzeri, F.M.; Marcora, S.M.; Coutts, A.J. Internal and External Training Load: 15 Years On. *Int. J. Sports Physiol. Perform.* **2019**, *14*, 270–273. [CrossRef]
19. Alcaraz, P.E.; Palao, J.M.; Elvira, J.L.L. Determining the Optimal Load for Resisted Sprint. *J. Strength Cond. Res.* **2009**, *23*, 480–485. [CrossRef]
20. Bachero-Mena, B.; González-Badillo, J.J. Effects of Resisted Sprint Training on Acceleration with Three Different Loads Accounting for 5, 12.5, and 20% of Body Mass. *J. Strength Cond. Res.* **2014**, *28*, 2954–2960. [CrossRef]
21. Morin, J.B.; Petrakos, G.; Jiménez-Reyes, P.; Brown, S.R.; Samozino, P.; Cross, M.R. Very-Heavy Sled Training for Improving Horizontal-Force Output in Soccer Players. *Int. J. Sports Physiol. Perform.* **2017**, *12*, 840–844. [CrossRef] [PubMed]
22. Cross, M.R.; Samozino, P.; Brown, S.R.; Morin, J.B. A Comparison between the Force–Velocity Relationships of Unloaded and Sled-Resisted Sprinting: Single vs. Multiple Trial Methods. *Eur. J. Appl. Physiol.* **2018**, *118*, 563–571. [CrossRef] [PubMed]
23. Nagahara, R.; Matsubayashi, T.; Matsuo, A.; Zushi, K. Kinematics of Transition during Human Accelerated Sprinting. *Biol. Open* **2014**, *3*, 689–699. [CrossRef] [PubMed]
24. Ward, C.; Catháin, C.Ó.; Chéilleachair, N.N.; Grassick, S.; Kelly, D.T. Does Resisted Sprint Training Improve the Sprint Performance of Field-Based Invasion Team Sport Players? A Systematic Review and Meta-Analysis. *Sports Med.* **2024**, *54*, 659–672. [CrossRef]
25. Aldrich, E.K.; Sullivan, K.; Wingo, J.E.; Esco, M.R.; Richardson, M.T.; Winchester, L.J.; Fedewa, M.V. The Effect of Resisted Sprint Training on Acceleration: A Systematic Review and Meta-Analysis. *Int. J. Exerc. Sci.* **2024**, *17*, 986–1002. [PubMed]
26. Myrvang, S.; van den Tillaar, R. The Longitudinal Effects of Resisted and Assisted Sprint Training on Sprint Kinematics, Acceleration, and Maximum Velocity: A Systematic Review and Meta-Analysis. *Sport. Med.—Open* **2024**, *10*, 110. [CrossRef] [PubMed]
27. Loturco, I.; Pereira, L.A.; Mercer, V.P.; Oliveira, L.P.; Zanetti, V.; Lima, L.; Bastos, T.; Moura, T.B.M.A.; McGuigan, M.R. Jump Squat Vs. Resisted Sprint Training Programs Applied to Elite Youth Soccer Players: Effects on Sprint and Power-Related Performance. *J. Strength Cond. Res.* **2024**, *38*, 2107–2113. [CrossRef]
28. Mainer-Pardos, E.; Mahmoudzadeh Khalili, S.; Villanueva-Guerrero, O.; Clemente, F.M.; Nobari, H. The Effects of Resisted Sprint Training Programs on Vertical Jump, Linear Sprint and Change of Direction Speed in Male Soccer Players: A Systematic Review and Meta-Analysis. *Acta Kinesiol.* **2024**, *18*, 31–47. [CrossRef]
29. Cross, M.R.; Brughelli, M.; Samozino, P.; Brown, S.R.; Morin, J.B. Optimal Loading for Maximizing Power during Sled-Resisted Sprinting. *Int. J. Sports Physiol. Perform.* **2017**, *12*, 1069–1077. [CrossRef]
30. Comfort, P.; Dos'Santos, T.; Beckham, G.K.; Stone, M.H.; Guppy, S.N.; Haff, G.G. Standardization and Methodological Considerations for the Isometric Midthigh Pull. *Strength Cond. J.* **2019**, *41*, 57–79. [CrossRef]
31. McMahon, J.J.; Suchomel, T.J.; Lake, J.P.; Comfort, P. Understanding the Key Phases of the Countermovement Jump Force-Time Curve. *Strength Cond. J.* **2018**, *40*, 96–106. [CrossRef]
32. Lockie, R.G.; Stage, A.A.; Stokes, J.J.; Orjalo, A.J.; Davis, D.L.; Giuliano, D.V.; Moreno, M.R.; Risso, F.G.; Lazar, A.; Birmingham-Babauta, S.A.; et al. Relationships and Predictive Capabilities of Jump Assessments to Soccer-Specific Field Test Performance in Division i Collegiate Players. *Sports* **2016**, *4*, 56. [CrossRef]
33. Taylor, J.M.; Cunningham, L.; Hood, P.; Thorne, B.; Irvin, G.; Weston, M. The Reliability of a Modified 505 Test and Change-of-Direction Deficit Time in Elite Youth Football Players. *Sci. Med. Footb.* **2019**, *3*, 157–162. [CrossRef]
34. Dos'Santos, T.; Mcburnie, A.; Thomas, C.; Comfort, P.; Jones, P.A. Biomechanical Determinants of the Modified and Traditional 505 Change of Direction Speed Test. *J. Strength Cond. Res.* **2020**, *34*, 1285–1296. [CrossRef]
35. Cross, M.R.; Lahti, J.; Brown, S.R.; Chedati, M.; Jimenez-Reyes, P.; Samozino, P.; Eriksrud, O.; Morin, J.B. Training at Maximal Power in Resisted Sprinting: Optimal Load Determination Methodology and Pilot Results in Team Sport Athletes. *PLoS ONE* **2018**, *13*, e0195477. [CrossRef]

36. Romero-Franco, N.; Jiménez-Reyes, P.; Castaño-Zambudio, A.; Capelo-Ramírez, F.; Rodríguez-Juan, J.J.; González-Hernández, J.; Toscano-Bendala, F.J.; Cuadrado-Peñafiel, V.; Balsalobre-Fernández, C. Sprint Performance and Mechanical Outputs Computed with an IPhone App: Comparison with Existing Reference Methods. *Eur. J. Sport Sci.* **2017**, *17*, 386–392. [CrossRef]
37. Hopkins, W.G.; Marshall, S.W.; Batterham, A.M.; Hanin, J. Progressive Statistics for Studies in Sports Medicine and Exercise Science. *Med. Sci. Sports Exerc.* **2009**, *41*, 3–12. [CrossRef]
38. Merino-Muñoz, P.; Pérez-Contreras, J.; Aedo-Muñoz, E. The Percentage Change and Differences in Sport: A Practical Easy Tool to Calculate. *Sport Perform. Sci. Rep.* **2020**, *118*, 446–450. [CrossRef]
39. Chaalali, A.; Bouriel, K.; Rouissi, M.; Chtara, M.; Mkaouer, B.; Cronin, J.; Chaouachi, A.; Chamari, K. Resisted Sprint Training with Partner Towing Improves Explosive Force and Sprint Performance in Young Soccer Players—A Pilot Study. *Biol. Sport* **2022**, *39*, 379–387. [CrossRef]
40. Pareja-Blanco, F.; Asián-Clemente, J.A.; Sáez de Villarreal, E. Combined Squat and Light-Load Resisted Sprint Training for Improving Athletic Performance. *J. Strength Cond. Res.* **2019**, *35*, 2457–2463. [CrossRef]
41. Rodríguez-Rosell, D.; Sáez De Villarreal, E.; Mora-Custodio, R.; Asián-Clemente, J.A.; Bachero-Mena, B.; Loturco, I.; Pareja-Blanco, F. Effects of Different Loading Conditions During Resisted Sprint Training on Sprint Performance. *J. Strength Cond. Res.* **2022**, *36*, 2725–2732. [CrossRef] [PubMed]
42. West, D.J.; Cunningham, D.J.; Bracken, R.M.; Bevan, H.R.; Crewther, B.T.; Cook, C.J.; Kilduff, L.P. Effects of Resisted Sprint Training on Acceleration in Professional Rugby Union Players. *J. Strength Cond. Res.* **2013**, *27*, 1014–1018. [CrossRef] [PubMed]
43. Sinclair, J.; Edmundson, C.J.; Metcalfe, J.; Bottoms, L.; Atkins, S.; Bentley, I. The Effects of Sprint vs. Resisted Sled-Based Training; an 8-Week in-Season Randomized Control Intervention in Elite Rugby League Players. *Int. J. Environ. Res. Public Health* **2021**, *18*, 9241. [CrossRef] [PubMed]
44. Harrison, A.J.; Bourke, G. The Effect of Resisted Sprint Training on Speed and Strength Performance in Male Rugby Players. *Strength Cond.* **2009**, *23*, 275–283. [CrossRef]
45. Alcaraz, P.E.; Elvira, J.L.L.; Palao, J. Kinematic, Strength, and Stiffness Adaptations after a Short-Term Sled Towing Training in Athletes. *Scand. J. Med. Sci. Sport.* **2012**, *24*, 279–290. [CrossRef]
46. Rumpf, M.C.; Lockie, R.G.; Cronin, J.B.; Jalilvand, F. Effect of Different Sprint Training Methods on Sprint Performance Over Various Distances: A Brief Review. *J. Strength Cond. Res.* **2016**, *30*, 1767–1785. [CrossRef]
47. Formenti, D.; Trecroci, A.; Cavaggioni, L.; Caumo, A.; Alberti, G. Heart rate response to a marathon cross-country skiing race: A case study. *Sport Sci. Health* **2014**, *11*, 125–128. [CrossRef]
48. Fornaziero, A.M.; Novack, L.F.; Nascimento, V.B.; Osiecki, R. Acute Responses of Youth Elite Players to a Football Match in Terms of Blood Markers. *Sports* **2023**, *11*, 242. [CrossRef]
49. Impellizzeri, F.M.; Maffiuletti, N.A. Convergent evidence for construct validity of a 7-point likert scale of lower limb muscle soreness. *Clin. J. Sport Med.* **2007**, *17*, 494–496. [CrossRef]

6. LIMITACIONES y APLICACIONES PRÁCTICAS

El bajo número de participantes en los estudios publicados impide realizar una generalización de los resultados.

En cuanto a las aplicaciones prácticas, análisis longitudinales de estas variables permitirían construir parámetros de condición física para los entrenadores de los clubes de futbol, tanto en series profesionales como formativas. De este modo se propone generar un marco contextual y comparativo que aporte a la toma de decisiones en cuanto a la selección, proyección y diseño de estrategias de entrenamiento.

Si bien los hallazgos de esta tesis aportan evidencia valiosa sobre la influencia de variables contextuales en el rendimiento muscular de futbolistas, es importante reconocer ciertas limitaciones metodológicas y de alcance. En primer lugar, varios de los estudios incluidos emplean diseños transversales o de corta duración, lo que restringe la posibilidad de establecer relaciones causales robustas entre las variables analizadas. Asimismo, las muestras, aunque diversas en edad y nivel competitivo, fueron relativamente acotadas en tamaño y localización geográfica, lo cual podría limitar la generalización de los resultados a otros contextos culturales o ligas profesionales con dinámicas distintas.

Además, no fue posible controlar de forma exhaustiva todos los factores externos que pueden influir en la respuesta muscular, como la carga acumulada de entrenamiento, la nutrición, el descanso o el entorno psicosocial del deportista. A esto se suma que la evaluación de las adaptaciones fisiológicas se realizó principalmente a través de pruebas de campo e indicadores mecánicos indirectos, sin incorporar mediciones neurofisiológicas o bioquímicas que podrían haber enriquecido el análisis de los mecanismos subyacentes.

Pese a estas limitaciones, los resultados de esta investigación ofrecen importantes aplicaciones prácticas para el ámbito del entrenamiento deportivo. En particular, destacan la necesidad de individualizar las cargas de entrenamiento en función de variables como la composición corporal, la maduración biológica o el nivel competitivo, lo cual resulta especialmente relevante en futbolistas jóvenes en etapa de formación. Asimismo, se evidencia el valor de incorporar evaluaciones funcionales que reflejen las demandas reales del juego, como el perfil fuerza-velocidad o las pruebas de esprints repetidos, para tomar decisiones basadas en datos concretos y contextualizados.

Por otra parte, la exploración de protocolos de entrenamiento específicos, como las carreras resistidas con manipulación del volumen, ofrece herramientas aplicables para la mejora del rendimiento explosivo en situaciones clave del juego. Todo ello refuerza la importancia de una planificación ajustada a las características individuales y situacionales del futbolista, promoviendo así un entrenamiento más eficaz, preciso y con mayor impacto sobre el rendimiento global.

7. CONCLUSIONES GENERALES

Las condiciones ambientales e individuales pueden modular el rendimiento físico en futbolistas en formación y adultos. La respuesta aguda y crónica a estímulos de entrenamiento se encuentra determinada por las características de la carga – dosis – así como por el estado actual de condición física de los atletas.

En cuanto a la composición corporal, menores niveles de tejido adiposo y mayores de masa magra favorecen la respuesta física, de modo que favorecen gestos de alta intensidad, como saltos, cambios de dirección, producción de fuerza por unidad de tiempo. En la misma línea, el nivel de competitividad influye en el rendimiento físico de los atletas. De este modo, se observa una relación inversamente proporcional entre la categoría en la cual compite el futbolista y su rendimiento aeróbico de alta intensidad.

Del mismo modo, el rendimiento físico se ve mermado producto de la aplicación de estímulos de alta intensidad. En este sentido, es interesante observar el comportamiento de variables vinculadas con la producción de fuerza en esfuerzos horizontales y lineales – esprint – y como estas responden a medida que se acumula fatiga. De este modo, las variables vinculadas a la fase de máxima velocidad son las mayormente afectadas en cuanto a su expresión (Velocidad máxima teórica, Potencia máxima y Tasa de disminución de la fuerza). Por otro lado, aquellas que tributan a la fuerza en el comienzo del esprint (Fuerza máxima teórica) no se ven alteradas tras la realización de un protocolo de esprint repetidos de alta intensidad (RSA).

Finalmente, la manipulación de la dosis de entrenamiento puede ser efectiva para la mejora del rendimiento muscular en futbolistas en formación. En este sentido, las carreras lastradas se han descrito como una estrategia adecuada para el cumplimiento de este objetivo. Tradicionalmente, la variable manipulada con mayor descripción en la literatura es la intensidad. Esta se cuantifica mediante la carga añadida al lastre, así como porcentajes de pérdida de velocidad. En cuanto a la distancia, no existen diferencias en la magnitud de la adaptación a partir esprint realizados entre 10 y 30 m. Estas son igualmente efectivas para la mejora de esfuerzos vinculados a la producción de fuerza por unidad de tiempo, altura de salto y cambios de dirección.

El presente estudio aporta evidencia relacionada con la manipulación de los factores contextuales del entrenamiento, así como el análisis de los estados actuales de condición física. A partir de esto es posible proyectar el rendimiento en futbolistas adultos y en formación. Esta información es relevante para entrenadores y profesionales del ejercicio, facilitando insumos que enriquecen el proceso de programación del entrenamiento.

8. REFERENCIAS.

Alcaraz, P. E., Palao, J. M., & Elvira, J. L. L. (2009). Determining the Optimal Load for Resisted Sprint. *Journal of Strength and Conditioning Research*, *23*(2), 480–485. https://doi.org/10.1519/JSC.0b013e318198f92c

Bachero-Mena, B., & González-Badillo, J. J. (2014). Effects of resisted sprint training on acceleration with three different loads accounting for 5, 12.5, and 20% of body mass. *Journal of Strength and Conditioning Research*, *28*(10), 2954–2960. https://doi.org/10.1519/JSC.0000000000000492

Borges, P. H., da Costa, J. C., Ramos-Silva, L. F., Menegassi, V. M., Praça, G. M., Moura, F. A., & Ronque, E. R. V. (2023). Maturity-associated variation in the body size, physical fitness, technical efficiency, and network-based centrality measures in young soccer players. *Scientific Reports*, *13*(1), 1–10. https://doi.org/10.1038/s41598-023-34833-1

Bustamante-Garrido, A., Izquierdo, M., Miarka, B., Cuartero-Navarrete, A., Pérez-Contreras, J., Aedo-Muñoz, E., & Cerda-Kohler, H. (2023). Mechanical Determinants of Sprinting and Change of Direction in Elite Female Field Hockey Players. *Sensors*, *23*(18). https://doi.org/10.3390/s23187663

Campa, F., Semprini, G., Júdice, P. B., Messina, G., & Toselli, S. (2019). Anthropometry, Physical and Movement Features, and Repeated-sprint Ability in Soccer Players. *International Journal of Sports Medicine*, *40*(2), 100–109. https://doi.org/10.1055/a-0781-2473

Chen, S., Zmijewski, P., & Bradley, P. S. (2025). Establishing reference values for the match running performances of thirteen specific positional roles at UEFA Euro 2024. *Biology of Sport*, *42*(3), 257–268.

Cormie, P., McGuigan, M. R., & Newton, R. U. (2011). Developing Maximal Neuromuscular Power Part 1 - Biological Basis of Maximal Power Production. *Sports Med*, *41*(1), 17–38. https://doi.org/10.1002/polb.23243

Coutinho, D., Gonçalves, B., Wong, D. P., Travassos, B., Coutts, A. J., & Sampaio, J. (2018). Exploring the effects of mental and muscular fatigue in soccer players' performance. *Human Movement Science*, *58*(March), 287–296. https://doi.org/10.1016/j.humov.2018.03.004

Dolci, F., Hart, N. H., Kilding, A. E., Chivers, P., Piggott, B., & Spiteri, T. (2020). Physical and Energetic Demand of Soccer: A Brief Review. *Strength and Conditioning Journal*, *42*(3), 70–77. https://doi.org/10.1519/SSC.0000000000000533

Faude, O., Koch, T., & Meyer, T. (2012). Straight sprinting is the most frequent action in goal situations in professional football. *Journal of Sports Sciences*, *30*(7), 625–631. https://doi.org/10.1080/02640414.2012.665940

Figueiredo, D. H., Dourado, A. C., Stanganelli, L. C. R., & Gonçalves, H. R. (2020). Evaluation of body composition and its relationship with physical fitness in professional soccer players at the beginning of pre-season. *Retos*, *2041*(40), 117–125. https://doi.org/10.47197/retos.v1i40.82863

França, C., Gouveia, É. R., Martins, F., Ihle, A., Henriques, R., Marques, A., Sarmento, H., Przednowek, K., & Lopes, H. (2024). Performance among Youth Soccer Players. *Sports (Basel)*, *12*, 1–9.

Gil, S., Barroso, R., Crivoi do Carmo, E., Loturco, I., Kobal, R., Tricoli, V., Ugrinowitsch, C., & Roschel, H. (2018). Effects of resisted sprint training on sprinting ability and change of direction speed in professional soccer players. *Journal of Sports Sciences*, *36*(17), 1923–1929. https://doi.org/10.1080/02640414.2018.1426346

Girard, O., Mendez-Villanueva, A., & Bishop, D. (2011). Repeated-Sprint Ability – Part I. *Sports Medicine*, *41*(8), 673–694. https://doi.org/10.2165/11590550-000000000-00000

Hansen, D. M. (2014). Successfully Translating Strength Into Speed. In D. Joyce & D. Lewindon (Eds.), *High-Performance Training for Sports – Human Kinetics* (First, p. 145).

Haugen, T. A., Tønnessen, E., Hisdal, J., & Seiler, S. (2014). The role and development of sprinting speed in soccer. *International Journal of Sports Physiology and Performance*, *9*(3), 432–441. https://doi.org/10.1123/IJSPP.2013-0121

Healy, R., Smyth, C., Kenny, I. C., & Harrison, A. J. (2019). Influence of Reactive and Maximum Strength Indicators on Sprint Performance. *Journal of Strength and Conditioning Research*, *33*(11), 3039–3048. https://doi.org/10.1519/JSC.0000000000002635

Hernández, R., Fernández, C., & Baptista, P. (2016). *Metodologia de la investigación* (6th ed.). Mc Graw Hill.

Hostrup, M., & Bangsbo, J. (2023). Performance Adaptations to Intensified Training in Top-Level Football. *Sports Medicine*, *53*(3), 577–594. https://doi.org/10.1007/s40279-022-01791-z

Hrysomallis, C. (2012). The effectiveness of resisted movement training on sprinting and jumping performance. *Journal of Strength and Conditioning Research*, *26*(1), 299–306. https://doi.org/10.1519 / JSC.0b013e3182185186

Jimenez-Reyes, P., García-Ramos, A., Cuadrado-Peñafiel, V., Párraga-Montilla, J. A., Morcillo-Losa, J. A., Samozino, P., & Morin, J.-B. (2018). Differences in sprint mechanical force-velocity profile between trained soccer and futsal players. *International Journal of Sports Physiology and Performance*, *14*(4), 478–485. https://doi.org/10.1123/ijspp.2018-0402

López Cáceres, P. A., Chena Sinovas, M., Asín Izquierdo, I., Moreno Ortega, A., & Rojas, R. M. (2019). Effect of contextual factors on body composition in professional soccer players. A retrospective study. *Nutricion Hospitalaria*, *36*(6), 1324–1331. https://doi.org/10.20960/nh.02783

Marqués-Jiménez, D., Calleja-González, J., Arratibel, I., Delextrat, A., & Terrados, N. (2017). Fatigue and Recovery in Soccer: Evidence and Challenges. *The Open Sports Sciences Journal*, *10*(Suppl 1: M5), 52–70. https://doi.org/10.2174/1875399x01710010051

McMorrow, B. J., Ditroilo, M., & Egan, B. (2019). Effect of heavy resisted sled sprint training during the competitive season on sprint and change-of-direction performance in professional soccer players. *International Journal of Sports Physiology and Performance*, *14*(8), 1066–1073. https://doi.org/10.1123/ijspp.2018-0592

Metaxas, T. I. (2021). Match Running Performance of Elite Soccer Players: VO2max and Players Position Influences. *Journal of Strength and Conditioning Research*, *35*(1), 162–168.

Modric, T., Versic, S., Sekulic, D., & Liposek, S. (2019). Analysis of the association between running performance and game performance indicators in professional soccer players. *International Journal of Environmental Research and Public Health*, *16*(20). https://doi.org/10.3390/ijerph16204032

Morin, J. B., Capelo-Ramirez, F., Rodriguez-Pérez, M. A., Cross, M. R., & Jimenez-Reyes, P. (2020). Individual Adaptation Kinetics Following Heavy Resisted Sprint Training. *Journal of Strength and Conditioning Research*, *Publish Ah*(February). https://doi.org/10.1519/jsc.0000000000003546

Morin, J. B., Gimenez, P., Edouard, P., Arnal, P., Jiménez-Reyes, P., Samozino, P., Brughelli, M., & Mendiguchia, J. (2015). Sprint acceleration mechanics: The major role of hamstrings in horizontal force production. *Frontiers in Physiology*, *6*(DEC), 1–14. https://doi.org/10.3389/fphys.2015.00404

Morin, J. B., Petrakos, G., Jiménez-Reyes, P., Brown, S. R., Samozino, P., & Cross, M. R. (2017). Very-heavy sled training for improving horizontal-force output in soccer players. *International Journal of Sports Physiology and Performance*, *12*(6), 840–844. https://doi.org/10.1123/ijspp.2016-0444

Murphy, A., Burgess, K., Hall, A. J., Aspe, R. R., & Swinton, P. A. (2023). The Effects of Strength and Conditioning Interventions on Sprinting Performance in Team Sport Athletes: A Systematic Review and Meta-Analysis. *Journal of Strength and Conditioning Research*, *37*(8), 1692–1702. https://doi.org/10.1519/JSC.0000000000004440

Oliva-Lozano, Jose M., Fortes, V., Krustrup, P., & Muyor, J. M. (2020). Acceleration and sprint profiles of professional male football players in relation to playing position. *PLoS ONE*, *15*(8 August), 1–12. https://doi.org/10.1371/journal.pone.0236959

Oliva-Lozano, José M., Riboli, A., Fortes, V., & Muyor, J. M. (2023). Monitoring physical match performance relative to peak locomotor demands: implications for training professional soccer players. *Biology of Sport*, *40*(2), 553–560. https://doi.org/10.5114/BIOLSPORT.2023.116450

Oliva-Lozano, José M., Rojas-Valverde, D., Gómez-Carmona, C. D., Fortes, V., & Pino-Ortega, J. (2021). Impact of contextual variables on the representative external load profile of Spanish professional soccer match-play: A full season study. *European Journal of Sport Science*, *21*(4), 497–506. https://doi.org/10.1080/17461391.2020.1751305

Oliver, J., Armstrong, N., & Williams, C. (2008). Changes in jump performance and muscle activity following soccer-specific exercise. *Journal of Sports Sciences*, *26*(2), 141–148. https://doi.org/10.1080/02640410701352018

Radziminski, L., Szwarc, A., Padrón-Cabo, A., & Jastrzebski, Z. (2020). Correlations between body composition, aerobic capacity, speed and distance covered among professional soccer players during official matches. *Journal of Sports Medicine and Physical Fitness*, *60*(2), 257–262. https://doi.org/10.23736/S0022-4707.19.09979-1

Sánchez-López, S., López-Sagarra, A., Ortega-Becerra, M., Jiménez-Reyes, P., & Rodríguez-Pérez, M. A. (2023). Change of Direction Performance in Soccer Players: Comparison Based on Horizontal Force–Velocity Profile. *Applied Sciences (Switzerland)*, *13*(23). https://doi.org/10.3390/app132312809

Schimpchen, J., Gopaladesikan, S., & Meyer, T. (2021). The intermittent nature of player physical output in professional football matches: An analysis of sequences of peak intensity and associated fatigue responses. *European Journal of Sport Science*, *21*(6), 793–802. https://doi.org/10.1080/17461391.2020.1776400

Silva, J. R., Rumpf, M. C., Hertzog, M., Castagna, C., Farooq, A., Girard, O., & Hader, K. (2018). Acute and Residual Soccer Match-Related Fatigue: A Systematic Review and Meta-analysis. *Sports Medicine (Auckland, N.Z.)*, *48*(3), 539–583. https://doi.org/10.1007/s40279-017-0798-8

Slimani, M., & Nikolaidis, P. T. (2017). Anthropometric and physiological characteristics of male Soccer players according to their competitive level, playing position and age group: a systematic review. *The Journal of Sports Medicine and Physical Fitness*, *November*. https://doi.org/10.23736/S0022-4707.17.07950-6

Slimani, M., & Nikolaidis, P. T. (2019). Anthropometric and physiological characteristics of male soccer players according to their competitive level, playing position and age group: A systematic review. *Journal of Sports Medicine and Physical Fitness*, *November*, 141–163. https://doi.org/10.23736/S0022-4707.17.07950-6

Slimani, M., Znazen, H., Miarka, B., & Bragazzi, N. L. (2019). Maximum Oxygen Uptake of Male Soccer Players According to their Competitive Level, Playing Position and Age Group: Implication from a Network Meta-Analysis. *Journal of Human Kinetics*, *66*(1), 233–245. https://doi.org/10.2478/hukin-2018-0060

Śliwowski, R., Grygorowicz, M., Hojszyk, R., & Jadczak, Ł. (2017). The isokinetic strength profile of elite soccer players according to playing position. *PLoS ONE*, *12*(7), 1–13. https://doi.org/10.1371/journal.pone.0182177

Stanković, M., Čaprić, I., Đorđević, D., Đorđević, S., Preljević, A., Koničanin, A., Maljanović, D., Nailović, H., Muković, I., Jelaska, I., & Sporiš, G. (2023). Relationship between Body Composition and Specific Motor Abilities According to Position in Elite Female Soccer Players. *International Journal of Environmental Research and Public Health*, *20*(2). https://doi.org/10.3390/ijerph20021327

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of Soccer An Update. *Sports Medicine*, *35*(6), 501–536. https://doi.org/10.2165/00007256-200535060-00004

Stone, M. H. (1993). Position statement: explosive exercises and training. *Natl Strength Cond Assoc J*, *15*(3), 7–15.

Suchomel, T. J., & Comfort, P. (2022). Developing muscular strength and power. In A.

P. Turner & P. Comfort (Eds.), *Advanced Strength and Conditioning* (Second, pp. 13–39). Routledge. https://doi.org/10.4324/9781003044734-4

Suchomel, T. J., Nimphius, S., Bellon, C. R., Hornsby, W. G., & Stone, M. H. (2021). Training for Muscular Strength: Methods for Monitoring and Adjusting Training Intensity. *Sports Medicine*, *51*(10), 2051–2066. https://doi.org/10.1007/s40279-021-01488-9

Suchomel, T. J., Nimphius, S., Bellon, C. R., & Stone, M. H. (2018). The Importance of Muscular Strength: Training Considerations. *Sports Medicine*, *48*(4), 765–785. https://doi.org/10.1007/s40279-018-0862-z

Suchomel, T. J., Nimphius, S., & Stone, M. H. (2016). The Importance of Muscular Strength in Athletic Performance. *Sports Medicine*, *46*(10), 1419–1449. https://doi.org/10.1007/s40279-016-0486-0

Vigne, G., Gaudino, C., Rogowski, I., Alloatti, G., & Hautier, C. (2010). Activity profile in elite Italian soccer team. *International Journal of Sports Medicine*, *31*(5), 304–310. https://doi.org/10.1055/s-0030-1248320

Wing, C. E., Turner, A. N., & Bishop, C. J. (2020). Importance of Strength and Power on Key Performance Indicators in Elite Youth Soccer. *Journal of Strength and Conditioning Research*, *34*(7), 2006–2014. https://doi.org/10.1519/JSC.0000000000002446