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Elena Isabel Pardos Mainer

Evaluación del rendimiento físico y asimetrías funcionales en jugadoras de fútbol adolescentes
Evaluation of physical performance and functional asymmetries in adolescent female soccer players

Departamento
Fisiatría y Enfermería

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EVALUATION OF PHYSICAL PERFORMANCE AND FUNCTIONAL ASYMMETRIES IN ADOLESCENT FEMALE SOCCER PLAYERS

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Elena Pardos Mainer

A aquellas personas que han entrado y salido de mi vida en este periodo, que han participado y me han ayudado.

A mis directores José Antonio y Oliver.

A mi familia, en especial a mis abuelos maternos, Ignacio, Pilar, Rosa, Alejandro y Natalia.

A ti, que llegaste inesperadamente y has sabido soportar el final.

A mi energía, a mi fuerza, a mi luchadora, a mi ejemplo a seguir, a mi madre, tú me has enseñado lo que soy hoy.

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Universidad Zaragoza
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En Zaragoza a 2 de abril de 2020

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Fdo. Oliver Gonzalo Skok

En Zaragoza a 2 de abril de 2020

Tabla de contenidos

Table of contents

Publicaciones incluidas en la Tesis Doctoral [Doctoral Thesis publications]

Para la confección de la presente Tesis Doctoral se ha optado por seguir la modalidad de compendio de publicaciones. Por ello, este documento está compuesto por distintos trabajos científicos, aceptados para publicación o sometidos a revisión, cuyas referencias se presentan a continuación.

Artículo I

Pardos-Mainer E, Casajús JA, Julián C, Bishop C, Gonzalo-Skok O. Determining the reliability and usability of change of direction speed tests in adolescent female soccer players: a systematic review. **J Sport Med Phys Fitness.** 2020 (in press). Aceptado para publicación. [*Accepted for publication]*.

Artículo II

Pardos-Mainer E, Casajús JA, Gonzalo-Skok O. Reliability and sensitivity of jumping, linear sprinting and change of direction ability tests in adolescent female football players**. Sci Med Football.** 2019;3(3):183-190.

Artículo III

Pardos-Mainer E, Casajús JA, Gonzalo-Skok O. Adolescent female soccer players' soccer-specific warm-up effects on performance and inter-limb asymmetries. **Biol Sport.** 2019;36(3):199-207.

Artículo IV

Pardos-Mainer E, Casajús JA, Bishop C, Gonzalo-Skok O. Effects of combined strength and power training on physical performance and inter-limb asymmetries in adolescent female soccer players. **Int J Sports Phsyiol Perform.** Aceptado para publicación. [*Accepted for publication*].

Artículo V

Pardos-Mainer E, Casajús JA, Gonzalo-Skok O. Age-related differences in acceleration and maximal sprinting speed in adolescent female soccer players. **Kinesiology.** Sometido. [*Submitted*].

Listado de Abreviaturas

ADM	Amplitud de movimiento
ANOVA	Análisis de varianza
ANCOVA	Análisis de la covarianza
CCI	Coeficiente de correlación intra-clase
CD	Cambio de dirección
CDD	Cambio de dirección con la pierna derecha
CDI	Cambio de dirección con la pierna izquierda
CEA	Ciclo estiramiento-acortamiento
CEICA	Comité de Ética de Investigación Clínica de Aragón
CMJ	Salto con contramovimiento
CMJD	Salto con contramovimiento con la pierna derecha
CMJI	Salto con contramovimiento con la pierna izquierda
CV	Coeficiente de variación
DJ	Salto tras altura
DJU	Salto tras altura unilateral
DJUD	Salto tras altura unilateral con la pierna derecho
DJUI	Salto tras altura unilateral con la pierna izquierda
JR J	Juegos reducidos
MCA	Mínimo cambio apreciable
N	Newtons
PEE	Prueba de equilibrio de la estrella
PEP	Programa de Santa Mónica para prevenir lesiones y mejorar el rendimiento
ROM	Rango de movimiento
SH	Salto horizontal bilateral
SHU	Salto horizontal unilateral
SHUD	Salto horizontal unilateral con la pierna derecha
SHUI	Salto horizontal unilateral con la pierna izquierda
TE	Tamaño de efecto

*Abbreviations in English language are show within Chapter 4

Listado de tablas y figuras

List of tables and figures

Resumen

El fútbol femenino ha tenido un crecimiento espectacular en la última década, lo que ha supuesto un aumento del número de investigaciones en esta población. Dichos estudios se han llevado a cabo, principalmente, en jugadoras adultas, sin embargo, hay una carencia considerable de estudios con jugadoras adolescentes. Además, en los últimos años, se ha observado que la asimetría entre extremidades inferiores, a parte de detectar jugadoras con alto riesgo de lesión, podría tener también un papel relevante en el rendimiento. Se han llevado a cabo diversos programas de intervención para mejorar las capacidades físicas y asimetrías funcionales aunque existen ciertas discrepancias en cuáles son los mejores ejercicios para mejorar el rendimiento de las jugadoras adolescentes debido al escaso número de estudios presentes en la literatura científica. Por otro lado, la fiabilidad y la sensibilidad de los test que se utilizan para valorar las capacidades físicas en jugadoras adolescentes de fútbol prácticamente no se han evaluado. De este modo, sería necesario analizar tales cuestiones para conocer si los diferentes test evalúan lo que quieren evaluar y si son capaces de detectar cambios relevantes tras una intervención.

El principal objetivo de esta Tesis Doctoral es analizar la fiabilidad y la sensibilidad de diferentes test físicos, así como analizar la influencia de diferentes programas de entrenamiento y la maduración en la fuerza, la velocidad lineal, el cambio de dirección (CD) y las asimetrías funcionales en jugadoras de fútbol adolescentes.

En primer lugar, el artículo I trata de contextualizar y mostrar el estado actual de la literatura científica en cuanto al CD y el rendimiento en jugadoras de fútbol adolescentes. El artículo II utiliza una muestra de 68 jugadoras adolescentes para analizar la fiabilidad y sensibilidad de diferentes test de fuerza, velocidad lineal y CD. En el artículo III y IV se exponen los resultados de un entrenamiento neuromuscular y un entrenamiento combinado de fuerza y potencia en extremidades inferiores de 8-10

semanas (2 veces/ semana) en 38 jugadoras de fútbol adolescentes, mientras que un grupo control compuesto por 35 futbolistas adolescentes proseguían su rutina de entrenamiento de fútbol. Por último, en el artículo V se muestra un estudio que examina la asociación entre variables antropométricas y de maduración biológica con el rendimiento en la velocidad lineal.

Los resultados principales de la presente Tesis Doctoral muestran que la fiabilidad de los test de CD depende de los instrumentos utilizados, la superficie o el nivel de las jugadoras de fútbol. Además, los resultados de las pruebas de CD deben interpretarse con precaución, ya que pueden estar influenciados por el periodo de crecimiento y la maduración del sujeto, la posición de la jugadora y el momento de la temporada. El estudio de fiabilidad y sensibilidad muestra que los test de salto (CMJ y salto horizontal), velocidad lineal y CD (180ºCD y test V-cut) pueden ser fiables y sensibles a los cambios inducidos por el entrenamiento a corto y medio plazo en jugadoras de fútbol adolescentes. En nuestros estudios longitudinales, el entrenamiento neuromuscular durante 10 semanas produjo efectos positivos en la fuerza, la potencia y el equilibrio dinámico, así como redujo la asimetría entre extremidades inferiores, mientras que el entrenamiento combinado de fuerza y potencia sólo mostró efectos beneficiosos en la velocidad lineal y el CD. Finalmente, el peso corporal guarda una relación significativa con el rendimiento de la velocidad lineal en jugadoras de fútbol adolescentes.

Tabla 1. Resumen del estado de arte y los resultados que añade la Tesis Doctoral

Artículo	¿Qué se sabe y no se sabe en este ámbito?	¿Qué añade esta Tesis Doctoral?
1	La habilidad del cambio de dirección (CD) es uno de los componentes físicos más importantes en la práctica del fútbol. Para proporcionar una evaluación segura, efectiva y válida del rendimiento del CD, es necesario examinar la frecuencia con la que se utilizan los test de esta habilidad en chicas futbolistas adolescentes. Además, es importante conocer qué factores influyen en el rendimiento del CD y qué estrategias de intervención se utilizan para su mejora. A través de estos conocimientos se pretende guiar a los especialistas en el diseño de entrenamientos más específicos y eficaces.	El test de CD180º parece ser el más apropiado para reproducir el movimiento de los patrones de las futbolistas adolescentes. La fiabilidad de los test de CD depende de los instrumentos utilizados (p. ej. células fotoeléctricas), la superficie y/o el nivel de las jugadoras. Los resultados del test deberían ser interpretados con precaución ya que pueden estar influenciados por el periodo de crecimiento y maduración, la posición de la jugadora y el momento de la temporada. Concretamente, los ejercicios de fuerza y potencia parecen mejorar la habilidad del CD.
2	Debido a su simplicidad, al bajo coste y el mínimo uso de material, los test de campo específicos de fútbol son popularmente utilizados por los entrenadores. En chicos futbolistas, tanto la fiabilidad como la sensibilidad de los test de salto, de velocidad lineal y de CD han sido evaluados. No obstante, en chicas ocurre lo contrario y apenas se ha evaluado la fiabilidad y sensibilidad de estos test.	Los test de salto, de velocidad lineal y de CD parecen ser fiables y sensibles a los cambios inducidos por el entrenamiento observado durante la temporada competitiva a corto y medio plazo en jugadores adolescentes. Además, se observan resultados más fiables conforme aumenta la edad de las participantes.
3	Los resultados científicos actuales son limitados y controvertidos. Se ha demostrado que el programa FIFA 11+ reduce las lesiones, sin embargo, no se han detectado mejoras en el rendimiento. En los últimos años, las baterías de test que utilizan los equipos de fútbol para valorar el rendimiento físico de sus participantes también incluyen la valoración de las asimetrías entre extremidades inferiores debido a su relación con las lesiones y el rendimiento físico. No obstante, ningún estudio ha analizado el efecto del FIFA 11+ en la asimetría entre extremidades.	El programa FIFA 11+ podría suponer un estímulo suficiente para mejorar diferentes variables del rendimiento y reducir la asimetría entre extremidades inferiores en jugadoras de fútbol adolescentes. Este programa mejora la fuerza explosiva unilateral y la potencia muscular, así como el equilibrio dinámico y funcional. También reduce la asimetría entre extremidades inferiores, aunque no mejora el CD.
4	Se ha demostrado que las intervenciones de entrenamiento individualizado mejoran el rendimiento de las futbolistas. Por el contrario, tan apenas existen estudios que analicen la efectividad de un entrenamiento combinado de fuerza y potencia (ECFP) en el rendimiento físico y la asimetría entre extremidades inferiores de jugadoras de fútbol adolescentes.	Un ECFP durante la temporada en jugadoras de fútbol adolescentes puede mejorar el rendimiento de la velocidad lineal y el CD. Estas adaptaciones se pueden conseguir en unas pocas semanas logrando incrementar el rendimiento competitivo y minimizar el riesgo de lesión. Por contra, la asimetría entre extremidades inferiores no se reduce.
5	La aceleración y la velocidad máxima de sprint (VMS) están estrechamente relacionadas con el rendimiento durante un partido. La altura, el peso y el estado madurativo son factores determinantes en el rendimiento del sprint. Ningún estudio ha analizado la contribución de estas características en la aceleración y la VMS en jugadoras de fútbol adolescentes.	Los efectos de la edad en las cualidades de la velocidad durante el crecimiento están probablemente relacionados con factores antropométricos (p. ej. el peso) en jugadoras de fútbol adolescentes. A mayor edad de la jugadora, mayor distancia de sprint necesita para lograr la VMS.

Abstract

Women's soccer has had a spectacular growth in the last decade which has increased the number of researches in this population. These studies have been mainly performed in adult female soccer players, however, studies in adolescent players are scarcer. In addition, for the past few years it has been observed that lower interlimb asymmetries have a relevant role in performance. Besides, it has been used as a valid tool to detect players of a high injury risk as a valid tool, this could also have a relevant role in performance. Different intervention programs have been performed to improve physical capacities and functional asymmetries although there are discrepancies about which are the best exercises to improve adolescent female soccer players performance due to the lack of studies. On the other hand, the reliability and sensitivity of tests that are used to assess physical capacities in adolescent female soccer players have hardly been observed. Thus; it would be necessary to observe it to consider if different tests assess what they want to assess and if they are able to detect relevant changes after an intervention.

The main aim of the present Doctoral Thesis is to broaden reliability and sensitivity of different physical tests, as well as analysing the influence of different training programs and strength, speed, change of direction (COD) maturation and the functional asymmetries in adolescent female soccer players.

Firstly, the purpose of the manuscript I is to examine and contextualize the current state of scientific literature in relation to change of direction and performance in adolescent female soccer players. Manuscript II includes a sample of 68 adolescent female soccer players in order to examine the reliability and sensitivity of different strength, speed and COD tests. For manuscript III and IV, we performed a neuromuscular training program and combined strength and power training in lower extremities during

8-10 weeks (2 times per week) in 38 adolescent female soccer players, while the 35 soccer players included in the control group continued with the habitual soccer routine. Finally, manuscript V shows a study that examines the association between anthropometrics variables and biological maturation in lineal speed performance.

The results of the present Doctoral Thesis show that reliability of the change of direction (COD) tests depends on the instruments that have been used, the surface and/or the playing level of the female soccer player. In addition, test results should be interpreted with caution as they may be influenced by the period in growth and maturation of the subject, the playing position of the player and the period of the soccer season. Reliability and sensitivity study shows that jumping (CMJ and standing broad jump test), lineal sprinting and change of direction tests (180º COD and V-cut test) may be reliable and sensitive to training-induces changes observed during the short and mid-term competitive season in adolescent female soccer players. In our longitudinal studies, neuromuscular training program during 10 weeks showed positive effects in strength, power and dynamic balance and reduced lower extremity symmetries. With a combined strength and power training this induced greater speed and COD performance improvements. Finally, body mass has a significant relation with speed performance in adolescent female soccer players.

Table 1. Summary of state of the art and what this Ph.D. Thesis add.

Nº article	What is already known on this topic?	What does this Ph.D. Thesis add?
1	Change of direction (COD) ability is one of the most important fitness components in soccer. It is necessary to examine the most frequently used COD tests in adolescent female soccer players in order to provide a safe, effective and valid assessment of COD performance. Providing details about factors that may impact COD performance and how these can be improved with different intervention strategies will guide practitioners to appropriate training design and prescription.	The 180ºCOD seems to be the most appropriate to replicate the movement patterns of soccer in adolescent female soccer players. The reliability of the COD tests depends on the instruments used such as electronic timing gates, the surface and/or the playing level of the soccer player. Test results should be interpreted with caution as they may be influenced by the period in growth and maturation, the playing position of the player and the period of the soccer season. Specifically, strength and power drills can improve COD ability.
2	Soccer specific field tests are popular among coaches, due to their simplicity, lower costs and minimal use of equipment. While the reliability and sensitivity of jumping, linear sprinting and COD tests have been assessed in male soccer players, it has been poorly investigated in females.	Jumping, linear sprinting and COD tests may be reliable and sensitive to training-induced changes typically observed during the short and mid-term competitive season in adolescent female soccer players. Better reliability results are found as the age participants increases.
3	The FIFA 11+ program has reported injury reductions however but did not detect improved performance. Limited and conflicting data are currently available. Lower extremity asymmetries have been included in test batteries performed by different soccer clubs due to their relation to lower-limb injuries and physical performance. No studies have analysed the effects of the FIFA 11+ on inter-limb asymmetries.	The FIFA 11+ could be a stimulus sufficient enough to improve different performance variables and reduce inter-limb asymmetries in adolescent female soccer players. This program improves unilateral explosive and muscular power as well as dynamic and functional balance and also reduces inter-limb asymmetries of skill-related physical tests. However, COD showed no improvements.
4	Individual training interventions have been shown to produce enhancements in measures of athletic performance for soccer players, however, there is a lack of studies looking at the effectiveness of strength and power training on performance measures in adolescent female soccer populations. No studies have analysed the effects of a combined strength and power training (CSPT) on inter-limb asymmetries.	A CSPT during the in-season period in adolescent female soccer players can improve speed and COD performance. These adaptations can be achieved in a few weeks and may potentially increase competitive performance and minimize the injury of risk. On the contrary, interlimb asymmetries did not decrease.
5	Acceleration and maximal sprinting speed (MSS) are related to match performance. Height, body mass and maturity status are determinants of sprint-running performance. No studies have analysed the contribution of these characteristics to acceleration and MSS in adolescent female soccer players.	The age effects on running speed qualities during growth are likely related with anthropometric factors (i.e., body mass) in adolescent female soccer players. As female players are older, a longer distance seems to be required to achieve MSS.

Capítulo 1. Introducción y Justificación

Ilusión es mi camino, victoria mi destino.
Anónimo

La introducción se basará en distintos aspectos relativos a los factores determinantes del rendimiento físico, a los test que se utilizan para evaluarlos, al análisis de las asimetrías funcionales y a los programas que se proponen para mejorar estos factores del rendimiento físico en chicas futbolistas adolescentes, dado que el objetivo central de la presente Tesis Doctoral gravita en torno a estos aspectos.

El fútbol es el deporte más practicado a nivel mundial (1). En España destaca sobre los demás, siendo la disciplina deportiva con mayor número de licencias federativas (2). Esto es aplicable al fútbol masculino, pero no ocurre así en el fútbol femenino, siendo el cuarto deporte femenino con mayor número de licencias federativas (2). A pesar de ello, los datos muestran que, en los últimos cinco años, el número de licencias de jugadoras ha aumentado en un 31% (**Tabla 2**), demostrando el espectacular crecimiento en popularidad y profesionalismo que está logrando este deporte en nuestro país (2).

Tabla 2. Número de licencias federativas de fútbol en España en los últimos 5 años. Extraído del histórico de licencia del Consejo Superior de Deportes (2).

Año	Hombre	Mujer	Total
2014	829.220	44.873	874.093
2015	869.237	40.524	909.093
2016	898.551	44.123	942.574
2017	967.578	60.329	1.027.907
2018	997.999	65.091	1.053.090

Debido al éxito y crecimiento del fútbol femenino, en los últimos cinco años ha aumentado el número de estudios sobre el rendimiento en el fútbol de jugadoras adultas (3-5), sin prestar gran atención a las jugadoras adolescentes. A lo largo de la presente Tesis doctoral entenderemos como “adolescente” al periodo de vida entre los 10 y 19 años (definición de la Organización Mundial de la Salud) (6). Es necesario un mayor número de investigaciones en la iniciación y formación de las categorías bases o escalafones inferiores para conocer cómo valorar, trabajar y mejorar las capacidades básicas y específicas en el fútbol femenino.

En el fútbol, la actividad física se manifiesta a través de la sucesión de esfuerzos cortos intercalados con periodos de trabajo de baja y moderada intensidad junto a pausas de recuperación (7). Además de los aspectos técnicos y tácticos, otras capacidades como la potencia, la fuerza, la velocidad lineal, el cambio de dirección (CD) y la resistencia son fundamentales en el rendimiento de las jóvenes futbolistas (8).

Se han llevado a cabo diferentes estudios en esta población para mejorar las capacidades anteriormente nombradas mediante programas de intervención tales como un calentamiento neuromuscular estructurado (9), ejercicios pliométricos (10), de fuerza (11) o de repetición de sprints (12). A pesar de la existencia de estas investigaciones, es muy escaso el número de estudios en chicas futbolistas adolescentes, por lo que sería necesario un mayor número junto a nuevos estudios enfocados a la mejora de las capacidades con el objetivo de conocer cuáles son las intervenciones más efectivas en esta población.

Las futbolistas han sido evaluadas mediante una gran diversidad de test físicos (p. ej. salto vertical, T-test, velocidad lineal 40 m). Estos test se pueden realizar tanto en laboratorio, más fiables, como en el propio campo de fútbol, más populares entre los entrenadores y preparadores físicos por su facilidad de llevar a cabo junto a un menor coste (13). La fiabilidad y la sensibilidad son dos capacidades clave a tener en cuenta en los test (14) y, desafortunadamente, se pasan muy a menudo por alto en las investigaciones científicas. Además, hay una considerable carencia de estudios que evalúen estas propiedades en test de fuerza, velocidad lineal, resistencia, flexibilidad y CD en futbolistas adolescentes. Por lo tanto, sería interesante que se llevasen a cabo estudios para conocer si los diferentes test evalúan lo que quieren evaluar y si son capaces de detectar cambios relevantes tras una intervención.

En los últimos años, diversos autores han estudiado la asimetría entre extremidades inferiores, comparando la funcionalidad de la extremidad derecha con la izquierda (15). Se ha observado que, además de considerarse una herramienta válida para detectar jugadores con un alto riesgo de lesión (16), también podría jugar un papel importante en el rendimiento (jugadores más simétricos parecen ser más rápidos que los asimétricos) (17). Por ello y por la escasez de estudios, es interesante observar estos patrones de asimetría en extremidades inferiores en chicas futbolistas adolescentes.

1.1. Factores determinantes del rendimiento en las jugadoras de fútbol y test empleados para su evaluación

En una definición amplia del término "condición física" se engloban todos los factores físicos, psíquicos, técnico-tácticos, cognitivos y sociales (18). Una definición más concreta, utilizada en la metodología del deporte y el entrenamiento, se centra en los factores físicos, es decir, resistencia, fuerza, velocidad y flexibilidad (18) (**Figura 1**). Estos factores, que vienen englobados por el concepto de condición física, tienen un papel fundamental en el rendimiento del futbolista, el cual está formado por múltiples habilidades, capacidades y particularidades (18) (**Figura 2**).

El entrenamiento específico en el fútbol debe orientarse hacia las exigencias de la competición. En fútbol femenino, Vescovi (2014) reflejó en su estudio que las jugadoras adolescentes corrían una distancia de 8558 m de los cuáles 658 m y 235 m los hacían a velocidad moderada y alta, respectivamente. Además, realizaban una media de 13 sprints, en los que solían recorrer unos 19 m a una velocidad máxima de 25,6 km/h por partido (19). No existen en la literatura científica datos referentes al número de CDs por partido en chicas futbolistas adolescentes. Por último, es importante recalcar que si se utilizan estímulos de entrenamiento adecuados ligados al crecimiento natural y al proceso de maduración se podría acelerar y mejorar el desarrollo físico en futbolistas adolesentes (20).

Dentro de la literatura científica, encontramos múltiples pruebas que evalúan los diferentes factores de rendimiento. En base al análisis de movimiento del fútbol, se han diseñado nuevos test que analizan sus demandas específicas. En este apartado, se van a analizar las diferentes pruebas desarrolladas para valorar los factores de rendimiento en jugadoras de fútbol adolescentes en los que se centra la presente Tesis Doctoral.

Figura 1. Componentes de la condición del jugador. Tomado de Schmidtbleicher et al. (1987) (21).

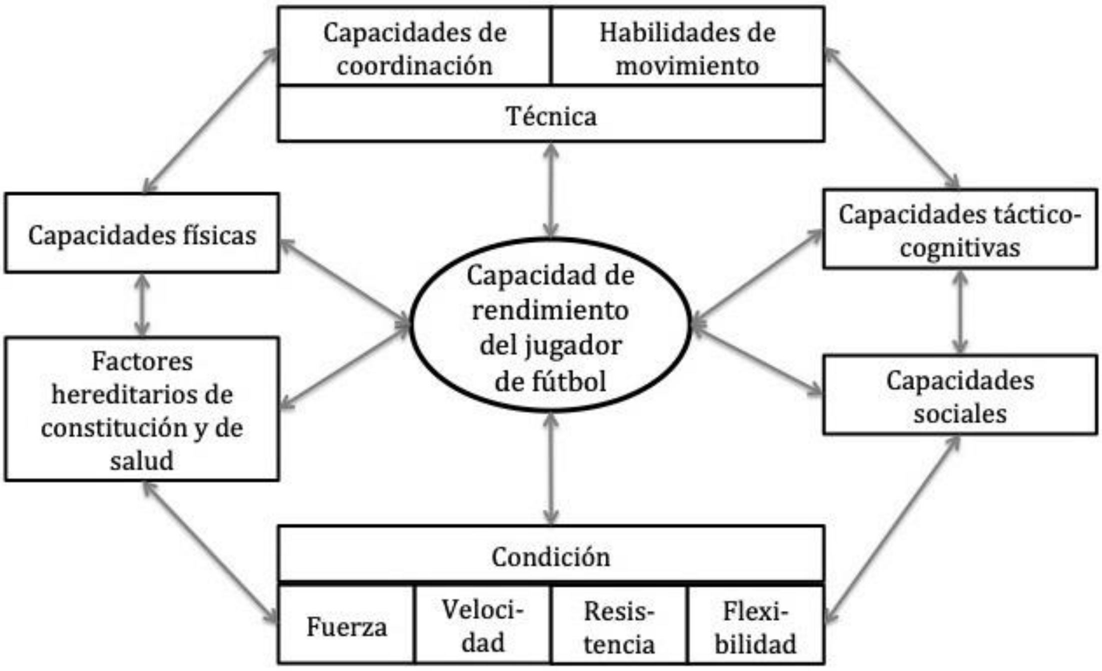


Figura 2. Componentes de la capacidad de rendimiento del jugador de fútbol. Tomada de Weineck (2005) (18).

1.1.1. Fuerza

Para comenzar es interesante revisar el concepto de fuerza. Desde el punto de vista de la mecánica, la fuerza se define como toda causa capaz de modificar el estado de reposo de un cuerpo, definida como el producto de una masa por una aceleración (F= m·a) y expresada en Newtons (N). Bosco (2000) define el término de fuerza como "lo que empuja o tira por medio de un contacto mecánico directo o por la acción de la gravedad y que altera o varía el movimiento del objeto". De forma más concreta, la fuerza muscular es definida como "la capacidad de la musculatura para deformar un cuerpo o para modificar la aceleración del mismo" (22). Desde el punto de vista de la fisiología, la fuerza es entendida como la capacidad que tiene el músculo para producir tensión al activarse. Esta tensión depende de numerosos factores como, el número de puentes cruzados de miosina que pueden interactuar con los filamentos de actina (23), la tensión específica que una fibra es capaz de ejercer por unidad de sección transversal ($N \cdot m^{-2}$) o el tipo de fibra muscular. De acuerdo con Manno (1999), "la fuerza muscular es la capacidad del hombre que permite vencer una resistencia u oponerse a ella mediante la utilización de la tensión de la musculatura". Analizando la definición, el autor hace referencia al hombre en un sentido genérico pero esta capacidad física evoluciona a lo largo de la vida de manera distinta para hombres y mujeres. Desde la infancia hasta aproximadamente los 10-12 años (inicio de la pubertad) existen pequeñas diferencias; a partir de esa etapa, se denotan diferencias en los niveles de fuerza entre los sexos, superando el masculino al femenino. Con la maduración del sistema endocrino (hormonal), en la pubertad, la adaptación al entrenamiento es más rápida y se acentúa la diferencia en la fuerza muscular entre los sexos debido a la producción de testosterona, inherente a cada género, siendo el sexo masculino el que alcanza niveles más altos de hipertrofia muscular (24).

Badillo y Gorostiaga (2002) identifican 5 manifestaciones de la fuerza (25), aunque nos centraremos en la definición de 2 de ellas debido a su posterior aplicación en la presente Tesis Doctoral.

- Fuerza explosiva: la fuerza explosiva es "*la manifestación explosiva de la fuerza es una relación entre la fuerza aplicada y el tiempo necesario para ello. Por lo tanto, la fuerza explosiva máxima se definiría como la mejor relación entre la fuerza aplicada y el tiempo empleado para ello en la manifestación de la máxima fuerza contra cualquier resistencia".* Esta manifestación de la fuerza corresponde con una fase muy concreta de la curva fuerza-tiempo del sujeto, concretamente con la de mayor pendiente. Es en este momento, en el que el sujeto estaría produciendo el mayor incremento de la tensión muscular por la unidad de tiempo, comúnmente conocido en la literatura científica como "*rate of force development"*.

- Fuerza elástico-explosiva: la tensión elástico-explosiva sucede al vencer una resistencia relativamente liviana (inferior al 50% de la capacidad máxima), alcanzándose un pico de fuerza hacia el principio del desarrollo de la tensión. La fase concéntrica del movimiento está precedida por un estiramiento previo. Cuando la transición entre la fase excéntrica y concéntrica se realiza de forma muy rápida, existe una importante facilitación neural debido al efecto del reflejo miotático, que interviene por la activación del ciclo estiramiento-acortamiento (CEA) (25). En este caso, la manifestación de la fuerza pasaría a ser elástico-explosivo-refleja.

Si analizamos los movimientos de las futbolistas (golpear el balón, saltar, acelerar, cambiar de dirección...) observamos que el factor de fuerza más importante es la fuerza-explosiva y, más específicamente, la fuerza de aceleración (concéntrica: saltos, tiros, salidas) y de frenado (excéntrica: rápidas paradas, CD, fase de frenado al correr y saltar). Centrándonos en la fuerza de frenado y más concretamente en los CDs, es importante conocer que en el fútbol las jugadoras están obligadas a realizar frecuentes CDs, tales como zig-zag, realizar salidas abiertas o cerradas o ejecutar carreras de ida y vuelta que, como norma general, se realizan en respuesta a un estímulo como el movimiento de un contrario o del balón (26). Cambiar de dirección rápidamente es considerado como determinante en el rendimiento de la futbolista (27). Por ello, se ha decido desarrollar más específicamente esta capacidad en el punto 1.1.4. La importancia de un buen desarrollo de la fuerza de salto supone un juego efectivo de cabeza, el trabajo de fuerza de los grupos musculares implícitos en el movimiento del tiro y el lanzamiento provoca tanto una mayor velocidad en la pelota como en el impacto del golpeo y una buena aceleración puede hacer que un jugador se adelante en un contraataque o en una acción defensiva o llegue a un balón dividido con antelación (7, 18). Es evidente que el futbolista necesita de un entrenamiento de fuerza específico de extremidades inferiores para mejorar su salto, su tiro, su lanzamiento (puesta en juego de la pelota) y su capacidad de aceleración (7), las cuales son variables clave en el rendimiento. Además, se ha observado que existen relaciones significativas entre la fuerza de extremidades inferiores y el salto vertical (28) y que la fuerza de extremidades inferiores está relacionada con una alta habilidad de mantener el rendimiento durante el juego (29).

1.1.1.1. Test empleados para la evaluación de la fuerza

Dentro de la literatura científica se pueden encontrar una gran diversidad de pruebas que evalúan la fuerza de las extremidades inferiores en las futbolistas. Los test enfocados a evaluar la fuerza explosiva y elástico-explosiva como el salto horizontal, el triple salto, el salto vertical, el salto con contramovimiento (*countermovement jump* [CMJ] en inglés) o el salto tras caída (*drop jump* (DJ) en inglés) (9, 11, 30, 31), los test que se centran en la evaluación de la fuerza isométrica de cuádriceps e isquiosurales, abducción y aducción de cadera utilizando un dinamómetro manual (9, 32, 33) y los test que valoran la fuerza isocinética de la acción excéntrica y concéntrica en los músculos flexores y extensores de las articulaciones de la rodilla mediante un dinamómetro isocinético computarizado (9).

En la presente Tesis Doctoral nos centraremos en evaluar la fuerza explosiva y elástico-explosiva ya que los diferentes test requieren de un material más económico y de fácil utilización para realizar las pruebas en el entorno de las futbolistas, es decir en el campo de césped artificial. Algunos de estos test son:

- Countermovement jump: es un test en el que la posición inicial del sujeto es con piernas estiradas, empezando el salto con un movimiento de flexión hacia abajo, hasta alcanzar un ángulo en la rodilla de 90 grados. Las manos se apoyan en las caderas durante el salto para evitar cualquier efecto de movimiento de brazos (**Figura 3**).

El CMJ deriva del salto Sargent (34) y se utiliza en multitud de deportes debido a su relación con la velocidad (35), la agilidad (36) y la potencia (37, 38). Este test ha sido validado por Markovic et al. (2004), mostrando unos valores de fiabilidad óptimos (coeficiente de correlación intra-clase (CCI): 0,98 y coeficiente de variación (CV): 2,8) en estudiantes de Educación Física. En diferentes estudios con chicos futbolistas se han encontrado valores elevados de CCI (0,92- 0,98) (39-41) aunque menor es el número de estudios que lo han observado en chicas futbolistas (42).

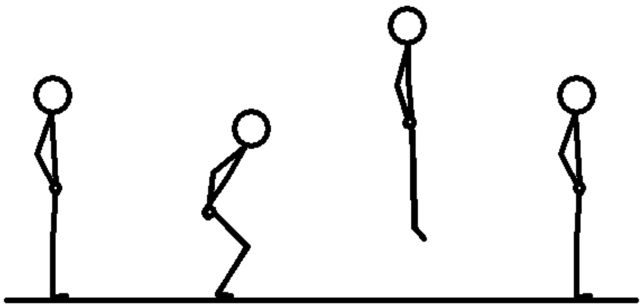


Figura 3. Fases del countermovement jump.

- <u>Drop jump:</u> es un salto desde una altura determinada. El sujeto se "deja caer" y salta con el máximo esfuerzo cuanto toca el suelo. El sujeto está libre de emplear los brazos pudiendo doblar las rodillas en cualquier grado al dejar el suelo (**Figura 4**).

  Respecto a la altura de salto, la literatura científica reporta un amplio rango, desde 12 a 90 cm, lo que permite observar diferentes características en los saltos (43). El comportamiento del movimiento reactivo, explicado previamente en CEA, es un componente importante en el rendimiento deportivo (44, 45) y dicho test ha reflejado buenos resultados de fiabilidad con valores del CCI entre 0,76-0,92 y con un CV entre 5-9% (42, 46).

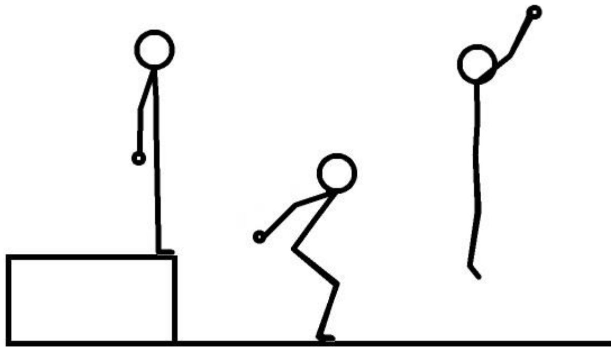


Figura 4. Fases del *drop jump.*

- Salto horizontal: es una prueba en la que el sujeto comienza de pie con las piernas estiradas, empezando el salto con un movimiento de flexión hacia abajo e impulsándose hacia delante. Se permite utilizar los brazos en el salto (**Figura 5**). Este test tiene una alta correlación con la velocidad lineal (47), el CD (17) y con las características físicas (musculatura de piernas), con esto nos referimos a que la distancia que logra un sujeto tiene una relación muy importante con la cantidad de fuerza que producen sus fibras musculares (48). Además, ha mostrado altos valores de fiabilidad (CCI: 0,90-0,95; CV: 2,1-3) en futbolistas adolescentes (49).

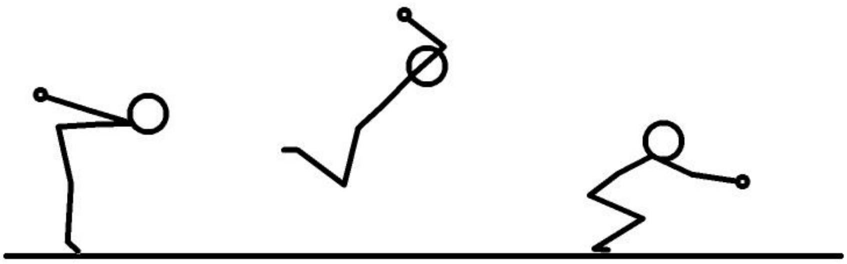


Figura 5. Fases del salto horizontal.

1.1.2. Velocidad

La velocidad según Zatsiorky (1978) es *"la capacidad física que nos permite llevar a cabo acciones motrices en el menor tiempo posible"* (50). Grosser (1992) la define como *"la capacidad para conseguir, en base a procesos cognitivos, máxima fuerza volitiva y funcionalidad del sistema neuromuscular, una rapidez máxima de reacción y de movimiento en determinadas condiciones establecidas"* (51). Una última definición más actual y completa es la de Ortiz (2004), quien establece que la velocidad, como capacidad motriz, incluye cuestiones esenciales e inseparables a la fisiología, al metabolismo energético, a la conducta psicológica y al desarrollo biológico del ser humano (52). Ésta es una de las capacidades más importantes para que un jugador pueda ser competitivo en un deporte de equipo (53). La velocidad del futbolista es una capacidad múltiple y compleja, compuesta por características parciales como la velocidad de reacción, de anticipación, de decisión, de movimiento cíclicos y acíclicos, de aceleración, gestual y máxima (18). Sólo si están completas todas las capacidades parciales, la velocidad podrá desarrollarse como una característica compleja. Una mejora y desarrollo de la velocidad supondrá que el jugador tenga la capacidad para anticiparse al desarrollo del juego, al comportamiento del contrario, a situaciones imprevistas y a decidir en el menor tiempo posible, para ejecutar movimientos cíclicos y acíclicos con y sin pelota y con o sin presión a un ritmo elevado y para realizar las situaciones de juego y sus modificaciones lo más rápido y eficazmente posible (18). Por consiguiente, se entendería la velocidad en el fútbol como una capacidad compleja que condiciona la realización y eficacia de las acciones de los jugadores y equipos, siendo un factor de rendimiento al que se le atribuye una gran importancia (54). Se pueden distinguir diferentes manifestaciones de la velocidad como la de reacción, de acción, de aceleración, de resistencia, gestual o máxima (52). En la presente Tesis Doctoral nos centramos principalmente en las siguientes:

- Velocidad máxima: es la máxima capacidad de desplazamiento de un sujeto, manteniendo la máxima velocidad, en un espacio determinado y en el menor tiempo posible. Se suele alcanzar a partir de los 30 m o a los 4,5 s y sólo se puede mantener durante 2,5 o 3 s.
- Velocidad aceleración: es la capacidad para incrementar la velocidad del mínimo al máximo nivel en el menor tiempo posible. Está completamente relacionada con la capacidad para expresar fuerza explosiva. Se manifiesta desde los primeros pasos de salida hasta aproximadamente los 20 m.

La velocidad máxima está frecuentemente asociada con un mayor rendimiento en los deportes de equipo, pero la realidad es que, en un partido, una futbolista no suele correr distancias lo suficientemente largas como para alcanzar la velocidad máxima (53), sino que realiza un elevado número de carreras de duración y distancia muy cortas (10-20 m y <4 s) (27, 55), de rápida aceleración. La habilidad para acelerar, definida como el ratio de cambio en la velocidad (5-14 m), es más influyente en el rendimiento que la velocidad máxima (56, 57). La diferencia existente entre un jugador más rápido que otro recorriendo 10 m a sprint está entre los 1,79 y 1,90 s, y en 20 m entre 30-50 cm (0,04-0,06 s) es decir el jugador más rápido puede ganarle un metro de distancia (7, 58). Por ello, las futbolistas deben poseer la habilidad de correr distancias cortas en el menor tiempo posible. También hay que tener en cuenta que una buena técnica de carrera será vital para ser más rápido.

Se dice que el dominio de la técnica es esencial para alargar y aumentar el tiempo de vuelo de la zancada y disminuir la frecuencia de la misma (59). Además, las acciones de alta intensidad y corta duración están estrechamente relacionadas con la fuerza explosiva del futbolista, como hemos comentado anteriormente. La velocidad y la fuerza muscular son necesarias para las diferentes situaciones que pueden tener lugar en un partido tales como atacar o defender (44), llegando a ser consideradas como variables de predicción de éxito en el fútbol (60). Por consiguiente, la mejora de la fuerza conlleva la mejora de la velocidad (61). En relación a esta información, los programas de entrenamiento que se llevasen a cabo para mejorar la velocidad en futbolistas deberían ir enfocados al entrenamiento de la aceleración, la fuerza explosiva y la técnica de carrera.

1.1.2.1. Test empleado para la evaluación de la velocidad

Los test que se centran en evaluar la velocidad se pueden clasificar en velocidad lineal, CD, sprint repetidos y la combinación de estas categorías (62). En base a esta clasificación, en la presente Tesis Doctoral nos vamos a centrar en la velocidad lineal, la cual se relaciona con la velocidad en línea recta en varias distancias, incluyendo la fase de aceleración y de velocidad máxima (63). Concretamente, en fútbol, las distancias que se suelen valorar van desde los 5 m a los 40 m (64). Altmann et al. (2019), en una reciente revisión sistemática en jugadores jóvenes de fútbol, concluyeron que todas las distancias investigadas (de 5 a 40 m) parecen ser igualmente importantes, aunque en una situación real de juego aparezcan con mayor frecuencia los sprints cortos y las aceleraciones (p. ej.: 5-10 m) que los sprints largos (p. ej.: 40 m) (62). La fiabilidad de este test exhibe valores entre 0,77 y 0,98 para el CCI y entre 0,5 y 10,9 % para el CV (62).

1.1.3. Flexibilidad

La flexibilidad es una de las cualidades físicas básicas para el rendimiento deportivo (65). Diferentes autores coinciden en la definición de flexibilidad como la amplitud de movimiento (ADM) de una articulación determinada (66). Cejudo et al. (2014), define la flexibilidad como la habilidad para mover una o varias articulaciones a través de toda la ADM requerida para una actividad o acción específica (67). Para

Thacker et al. (2004), la flexibilidad es una propiedad intrínseca del tejido corporal que determina la ADM alcanzable por una articulación o grupo de articulaciones sin provocar lesión (68).

Por otro lado, Alter (1996), explica que el tipo de flexibilidad es específico al tipo de movimiento y depende de la velocidad y del ángulo de dicho movimiento, no sólo de la ADM (69). Por el contrario, Norris (1996), señala que la ADM hace referencia a la longitud del músculo en cualquier punto del movimiento (*Range of Motion – ROM* en inglés) (70) mientras que para Alter (1996) y Monteiro (2000) es la libertad de movimiento de una articulación (69, 71).

Podemos observar que existe un gran número de definiciones y clasificaciones para la flexibilidad y la tendencia actual es simplificarlas y agruparlas. Por lo tanto, según Stiff y Verkhoshansky (2000), la flexibilidad se puede dividir en dos tipos (72):

- <u>Flexibilidad activa:</u> se refiere a la ADM máxima producida bajo un control muscular activo con un grado concreto de libertad articular.
- <u>Flexibilidad pasiva:</u> corresponde a la ADM máxima que se produce de manera pasiva por la imposición de una fuerza externa que no llega a provocar una lesión articular.

La flexibilidad es un componente determinante en ciertas disciplinas deportivas como la gimnasia rítmica y artística o patinaje artístico. Por el contrario, esta capacidad se necesita en niveles más bajos para realizar movimientos dinámicos implícitos en la ejecución de los gestos técnicos (73) como ocurre en fútbol o baloncesto. Dicha capacidad física, considerada un componente integrador de la movilidad articular y de la elasticidad muscular, es una de las menos trabajadas en el entrenamiento deportivo (74, 75). Existe la creencia de que el desarrollo de la fuerza mediante el aumento de las células musculares (hipertrofia muscular) limita la flexibilidad y, por el contrario, el trabajo de desarrollo de flexibilidad reduce la fuerza. Aunque esta situación es aún controvertida, se empieza a concluir que el desarrollo de la flexibilidad favorece el aumento de la fuerza muscular (75). La medición indirecta de la flexibilidad muscular viene representada por el ROM.

Cuando un deportista presenta los valores normales y específicos de flexibilidad en cada articulación se dice que se encuentra en un ROM óptimo para favorecer el máximo rendimiento físico-técnico deportivo, así como una menor predisposición a la lesión deportiva (76). Se ha observado que el rendimiento deportivo puede provocar ROM extremo (77) o ROM limitado por una menor extensibilidad muscular (78) es decir, hipermovilidad o cortedad muscular, pudiendo provocar en ambos casos lesión muscular. Por último, además de la práctica deportiva y el entrenamiento, la flexibilidad también está condicionada por factores como la edad, el género y el nivel de crecimiento. Durante la infancia, existe una gran flexibilidad pero al llegar la adolescencia, a partir de los 12 años, la flexibilidad tiende a estabilizarse y después a disminuir, haciéndose cada año más limitada (79). Las mujeres tienen más flexibilidad que los hombres por las diferencias hormonales y por el mayor incremento de masa muscular por parte de ellos (80).

En el deporte que nos concierne, tener una buena flexibilidad supondrá lograr una perfecta ejecución de las técnicas específicas del fútbol (18). Por ejemplo, para regatear el jugador necesita además de, un buen desarrollo de la fuerza de tronco, de una excelente flexibilidad y capacidad extensora de la cadera o para un golpeo de balón preciso, el jugador necesita de una buena técnica y capacidad de estiramiento en la articulación del tobillo. Por ello, el trabajo de la flexibilidad puede ser de gran interés, ya que permitirá junto al resto de capacidades físicas, mejorar el rendimiento y la calidad técnica de los movimientos del futbolista y disminuir el riesgo de lesión, favoreciendo el éxito deportivo del jugador.

1.1.3.1. Test empleados para la evaluación de la flexibilidad

Multitud de test en las extremidades inferiores se han utilizado para valorar la flexibilidad en futbolistas. En la articulación del tobillo y cadera encontramos pruebas como la flexión dorsal del tobillo de pie y tumbado o la prueba de equilibrio de la estrella (PEE), en la valoración de la extensibilidad de los isquiosurales el *Sit and Reach*, el *Toe Touch* o el *V-sit reach flexibility* (81). A continuación, explicaremos los dos test en los cuales se va a centrar la presente Tesis Doctoral:

- Test de flexión dorsal del tobillo de pie: se evalúa la flexión dorsal del tobillo mediante la propia carga del peso corporal realizando una zancada en estático y contra la pared o una varilla (**Figura 6**). Diferentes materiales se utilizan para valorar dicho test como el goniómetro, el inclinómetro, la cinta métrica o el *Leg Motion System*. Todos ellos han resultado ser métodos fiables (82, 83). El goniómetro es un método barato, pero requiere de una cierta dificultad técnica, el inclinómetro es un método sencillo en el que sólo hay que identificar la tuberosidad tibial, el método cinta métrica no requiere de un material específico, ya que se realiza contra la pared, pero hay que tener especial cuidado con que no se levante el talón (83). Por último, el *Leg Motion System* valora la máxima distancia que hay entre el dedo del pie y una varilla de metal sobre una lámina escalada situada en el suelo y con diferentes referencias visuales que ayudan a realizar correctamente el test (82).

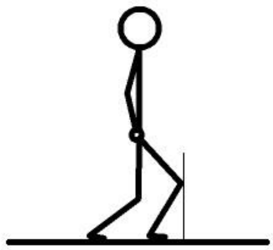


Figura 6. Ilustración del test de flexión dorsal del tobillo de pie.

- Prueba de equilibrio de la estrella: se evalúa el equilibrio dinámico en tres u ocho direcciones. El objetivo es, alcanzar con el pie que se encuentra sin apoyo, la mayor distancia manteniendo la postura durante un segundo y, después, volver a la posición inicial sin desequilibrarse (**Figura 7**). El material que se utiliza para evaluarlo es la cinta métrica o el Octobalance de *Check your MOtion*. Ambos métodos han reportado altos valores de fiabilidad (84, 85).

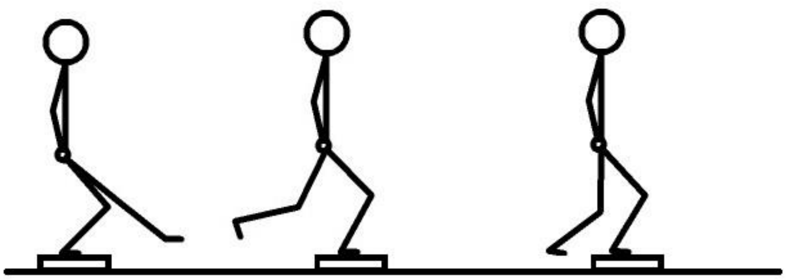


Figura 7. Ilustración de la prueba de equilibrio de la estrella

1.1.4. Cambio de dirección

En la literatura científica, la aceleración, desaceleración y rápidos CDs son considerados como un componente clave en las demandas del juego (86, 87). Esta capacidad compleja, conocida en la literatura anglosajona como agilidad, permite a los jugadores driblar a un defensor en una acción de ataque o presionar en defensa en los deportes de equipo (88). En el fútbol, los jugadores se ven frecuentemente implicados en repentinos CDs durante el juego, por ello la agilidad es considerada como un prerrequisito determinante (89). Varios son los autores que han definido el término agilidad, aunque contrariamente a otras cualidades físicas, no existe una definición universalmente aceptada (88). No obstante, la gran mayoría de los profesionales en este campo, clasifican la agilidad como la capacidad de realizar un movimiento que implique rápidos CDs (89).

En los últimos años, se ha explicado la agilidad desde otro punto de vista, justificando que en la gran mayoría de los deportes los CDs se producen en respuesta a un estímulo. Es por ello que, Sheppard & Young (2006), consideraron la agilidad como un término que engloba a las exigencias físicas (velocidad de movimiento y fuerza), los procesos cognitivos (percepción y toma de decisiones) y las habilidades técnicas (trabajo de pies y técnica de movimiento), definiéndola como "*un rápido movimiento de todo el cuerpo mediante un cambio de velocidad o dirección en respuesta a un estímulo*" (90).

En los deportes de equipos, como el fútbol o el baloncesto, los jugadores están obligados a realizar frecuentes CDs como correr en zig-zag, realizar salidas abiertas y cerradas o ejecutar carreras de ida y vuelta que normalmente se realizan en respuesta a un estímulo como el movimiento de un contrario o del balón (26). Se ha analizado que durante un partido de fútbol se producen entre 1000 y 1500 movimientos discretos, llevándose a cabo 1 cada 5-6 s y sin presencia de movimiento durante 3 s por cada 2 min de juego (91). Bloomfield et al. (2007) comprobaron, en jugadores de la "*Premier*

League", que aproximadamente el 32% del tiempo de juego lo empleaban para realizar movimientos laterales, diagonales, hacia detrás y giros, efectuando estos últimos unos 726 por partido (92). En conclusión, los continuos cambios en el patrón de movimiento y la constante presencia de acciones de giro y CD, permite considerar a el CD como un requisito fundamental en el rendimiento del fútbol. Por último, futuros estudios deberían proporcionar un análisis más detallado del número de aceleraciones, CDs y otro tipo de movimientos requeridos durante un partido de fútbol femenino, ya que dicha información no existe a día de hoy en la literatura científica (93).

1.1.4.1. Test empleados para la evaluación del cambio de dirección

Existen una gran diversidad entre las diferentes pruebas desarrolladas para valorar el CD en futbolistas. Dichas pruebas pueden ser clasificadas en tres áreas:

- En función del tiempo en completar el test: 1-5 s, 5-9 s y >10 s.
- En función del número de CDs: 2-3, 4-6 y >7.
- En función de la principal aplicación de fuerza durante el test: horizontal, lateral y ambas.

En fútbol se han utilizado pruebas como el T-test, *Illinois test*, *Pro-Agility test*, test 505, CD180º, test V-cut, Slalom test..., reportando todos ellos valores elevados de fiabilidad (CCI: > 0,75; CV: <3%) (62). Procederemos a explicar los dos test que se van a utilizar en la presente Tesis Doctoral:

- <u>CD180º:</u> es un desplazamiento que incluye un sprint de 10 m. Las participantes inician el test desde la línea de salida/llegada, cruzan la línea de 5 m con el pie derecho o izquierdo, giran 180° y esprintan de nuevo hacia la línea de salida/llegada. Este test es una modificación del tradicional test 505 (94) el cual ha reportado altos niveles de fiabilidad (95).

- <u>Test V-cut:</u> es un sprint de 25 m con 4 CDs (1 cada 5 m) con un ángulo de salida de 45º. Este test ha sido validado y, además ha obtenido valores de fiabilidad óptimos (CCI: 0,92; CV: 1,4%) (84, 96) (**Figura 8**).

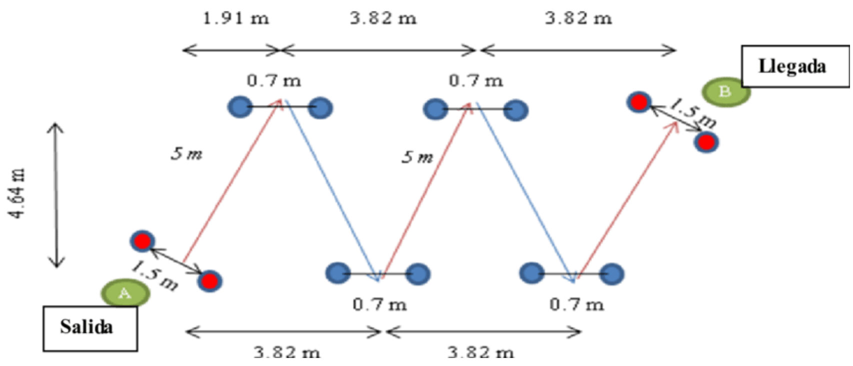


Figura 8. Ilustración esquemática del test V-cut

1.2. Análisis de las asimetrías funcionales en el fútbol

La asimetría o desequilibrio funcional se refiere a la diferencia de rendimiento o función entre extremidades (15). Estos déficits pueden aparecer por un inadecuado proceso de readaptación tras una lesión, el tipo de programa de entrenamiento, la posición de juego, los años jugando o las demandas físicas de la modalidad deportiva (97-99). Hay algunos ejemplos claros que podemos encontrarlos en deportes en los que existe una clara predominancia de una extremidad superior o inferior, como ocurre en tenis, fútbol, hockey o balonmano. Concretamente, en el fútbol, el dominio lateral tiene lugar en las piernas, siendo una de ellas la dominante por la jugadora para golpear, pasar o quitar el balón. Este hecho y la modificación de la mecánica del gesto deportivo por las asimetrías, repercute en una mayor tendencia a sufrir desequilibrios funcionales, relacionándose con un incremento de la incidencia lesional y una disminución del rendimiento (17, 100-102).

Por lo tanto, es preciso monitorizar la fuerza unilateral de las extremidades inferiores (103). Para cuantificar estas diferencias, frecuentemente se han utilizado test de fuerza y salto (104, 105), ya que estas son consideradas variables físicas fundamentales para mejorar el rendimiento de las futbolistas. Algunos de los test de fuerza implementados son la sentadilla trasera, la sentadilla isométrica o las pruebas isocinéticas (106-108). Mientras el CMJ, el DJ y el salto horizontal son utilizados como pruebas de salto (106, 109). Habitualmente, se utilizan más las pruebas de salto para cuantificar la asimetría, debido a su similitud con los patrones de movimiento (aceleración-desaceleración) del fútbol, que imitan o se asemejan a las demandas de la estabilidad dinámica de la rodilla durante esta actividad deportiva (110) junto a su fácil y rápida implementación. Estas pruebas no sólo se utilizan para determinar el estado de preparación de la futbolista durante el proceso de recuperación tras una lesión (111), sino que también se utilizan en futbolistas sanas para detectar una simetría anormal de las extremidades inferiores (112). Diferentes estudios, han observado que existen valores críticos y asociaciones a partir de los cuales parece que el riesgo de padecer una lesión aumenta y el nivel del rendimiento disminuye (16, 99, 113). Los jugadores con > 10% asimetría tienen 4 veces más probabilidad de lesionarse (16), mientras aquellas asimetrías > 15% se asocian con jugadores que han sufrido recientemente una lesión (99). Por otro lado, Bishop et al. (2018) observaron que mayores niveles de asimetría en el salto están significativamente asociados con aumentar el tiempo del sprint y reducir altura de salto en jugadoras adolescentes de fútbol (113).

Por otro lado, es necesario establecer programas de acción para compensar estas asimetrías. Bishop et al. (2017) tras realizar una revisión de la literatura, observaron que los ejercicios de fuerza y salto unilateral y bilateral, de equilibrio y de core mostraron ser efectivos para reducir la diferencia entre extremidades (114). No obstante, tras analizar la literatura científica, hemos observado que hay una gran carencia de entrenamientos específicos para reducir la asimetría de extremidades inferiores (114-116) y aún menos en jugadoras de fútbol adolescentes, por lo que sigue existiendo un amplio campo de investigación tanto a nivel de monitorización como de intervención acerca de las asimetrías funcionales en esta población.

1.3. Entrenamiento para la mejora del rendimiento en las jugadoras de fútbol

En la literatura científica, existen diferentes estudios que han analizado la influencia de diversos métodos de entrenamiento sobre la fuerza, la flexibilidad, la velocidad lineal y el CD en chicas futbolistas adolescentes (**Tabla 3**). A continuación, haremos un análisis de los efectos que han tenido los diferentes entrenamientos, tratando de identificar los métodos más efectivos.

1.3.1. Programas de entrenamiento para mejorar la fuerza

Los tipos de entrenamientos que se han propuesto en futbolistas adolescentes para mejorar las variables anteriormente expuestas de fuerza son principalmente dos. Por un lado, el entrenamiento pliométrico, que consiste en el aprovechamiento del CEA del complejo músculo-tendinoso, implicando sus ejercicios un estiramiento del músculo antes de realizar una rápida contracción concéntrica (5, 117) y por otro el entrenamiento de fuerza que pretende poner al deportista en disposición de conseguir la óptima manifestación de fuerza en las actividades específicas (118-120). Sin embargo, revisando la literatura, tal y como concluyen algunos estudios (121, 122), existen pocas investigaciones sobre el trabajo de fuerza en chicas futbolistas adolescentes (9-12, 31, 123-126) a pesar de que se considera un entrenamiento eficaz y seguro para mejorar la fuerza muscular y el rendimiento en atletas adolescentes (127). De los 10 estudios presentes, 4 de ellos han mostrado resultados positivos (10-12, 124), mientras 6 estudios no alcanzaron un mejor rendimiento (9, 31, 31, 123, 126). Se comenzará con el análisis de los programas de trabajo neuromuscular. En un estudio reciente, Pérez-Parra et al. (2017) han observado mejoras significativas en la fuerza abdominal y lumbar (evaluación de la fuerza-resistencia) en jugadoras entre 14 y 18 años tras 6 meses de un programa de entrenamiento neuromuscular denominado FIFA 11+ en el que se incluía ejercicios de velocidad, fuerza, equilibrio, saltos y CDs (124). Por el contrario, Steffen et al. (2008) utilizando el mismo programa de entrenamiento durante 10 semanas en chicas futbolistas entre 16 y 18 años no encontraron diferencias significativas en las variables de fuerza isocinética e isométrica de extremidades inferiores, fuerza isométrica de cadera, salto vertical y distancia de tiro (9). Los autores sugirieron que esto podría ser debido a que la intensidad y el volumen de entrenamiento fue demasiado bajo en cada ejercicio para el grupo de población con el trabajaban. A pesar de utilizar el mismo programa de entrenamiento, es posible que la duración de la intervención (6 meses vs. 10 semanas) y el nivel futbolístico de las jugadoras (amateur vs. élite) pueda explicar las posibles diferencias entre ambos estudios. Continuando en la línea de los entrenamientos neuromusculares, Noyes et al. (2013) obtuvieron mejoras triviales en el salto vertical, pero no en el CMJ tras un programa denominado *Sportsmetrics* que combina trabajo de fuerza, saltos y flexibilidad (31). Los autores sugirieron que eran necesarias intervenciones de mayor duración y diferentes ejercicios pliométricos para mejorar la altura del salto vertical. En la misma línea, Vescovi et al. (2010) observaron los efectos del "Santa Monica Prevent Injury Enhance Performance Program (PEP)", que combinó un trabajo pliométrico con agilidad en jugadoras de fútbol americanas U-18, sin presentar una mejora del rendimiento en el CMJ (126). Por lo tanto, parece ser que los programas de entrenamiento neuromuscular no tienen un efecto realmente positivo en la mejora de la fuerza en jugadoras de fútbol adolescentes. Normalmente, estos programas están enfocados a la prevención de lesiones, lo que hace que las cargas de entrenamiento sean muy ligeras y, por lo tanto, el estímulo sea menor que un trabajo específico de fuerza con el control de la carga individualizada. En el estudio de Rubley et al. (2011) se establecieron dos grupos de entrenamiento: un grupo que entrenaba a fútbol y otro grupo seguía el mismo entrenamiento de campo más un entrenamiento pliométrico de bajo impacto (1-4 series x 5-20 R x 14 semanas). El grupo experimental obtuvo una mejora en el rendimiento de la distancia de tiro (tamaño de efecto (TE)= 2,73 vs. -1,72) y el salto vertical (TE= 0,90 vs. -0,26), respecto al grupo control. Los autores concluyen que este entrenamiento es una alternativa segura y eficaz al entrenamiento pliométrico de alto impacto (10), el cual puede estar contraindicado para adolescentes debido al alto riesgo de lesión que puede producir en las placas de crecimiento (128, 129). En un estudio más específico del entrenamiento de fuerza con cargas altas, González-García et al. (2019) dividieron la muestra de jugadoras adolescentes en grupo de trabajo de *hip thrust*, grupo de trabajo de sentadilla trasera y grupo control (11). Los autores observaron que tanto el entrenamiento de *hip thrust* como el de sentadilla trasera tenía un efecto beneficioso en el rendimiento del CMJ pero entre ambas intervenciones no estaba claro el efecto. Esto podría ser explicado por la importancia de la extensión de cadera en el salto vertical. Los ejercicios que enfatizan la potencia concéntrica de extensión de cadera (p. ej. *hip thrust*) podrían mejorar el rendimiento del salto vertical de manera similar a los ejercicios en los que se producen una extensión de cadera, rodillo y tobillo (p. ej. sentadilla trasera). Ness et al. (2016) analizaron el efecto de un programa de acondicionamiento y fuerza durante 8 semanas. Las jugadoras fueron evaluadas mediante un test isométrico de fuerza obteniendo mejoras sustanciales en la fuerza de la rotación externa de cadera (TE: 0,87 –

1), pero no en la abducción (TE: 0,05 – 0,12) (33). Siegler et al. (2003) combinaron un trabajo de fuerza, pliométrico y anaeróbico de alta intensidad en jugadoras americanas adolescentes durante 10 semanas (123). El grupo experimental no mejoró significativamente en el salto vertical ni en el test de potencia de piernas respecto al grupo control. Los datos fueron muy similares entre ambos grupos tras la intervención. Analizando los datos se observa que, el grupo control en el pre-test solía obtener resultados ligeramente mejores que el grupo experimental y, además, tras la intervención también mejoraba. Por lo tanto, es posible que el grupo control estuviese contaminado por alguna variable externa como el entrenamiento habitual de fútbol que realizaban (no fueron recogidos por los investigadores) o el propio nivel de las jugadoras. También se observa, que el grupo control mostró mejores resultados en el pretest que el grupo experimental. Además, es conocido que el entrenamiento de resistencia puede inhibir parte de las adaptaciones resultantes del entrenamiento de fuerza (130) y, ese hecho, puede que también haya repercutido en los resultados negativos obtenidos. Johson et al. (2013) cumplimentaron un estudio en el que la intervención consistía en el desarrollo de un programa de aceleración mediante un trabajo de saltos, agilidad, core y 10 min en cinta de correr. Había tres grupos, dos realizaron el programa de aceleración con la diferencia de que un grupo trabajaba soportando su propio peso en la cinta de correr y el otro no lo soportaba y un grupo control (32). Ninguno de los grupos experimentales mejoró en el test isométrico de abducción de cadera y flexión de rodilla. Parece ser que un entrenamiento específico de velocidad y agilidad no reporta datos concluyentes en la ganancia de fuerza. Además, este entrenamiento es dinámico y las pruebas ejecutadas fueron isométricas, por lo que no existe una transferencia positiva entre los ejercicios del programa y los test elegidos para el estudio. Un estudio interesante ha observado cómo influye el entrenamiento por medio de juegos reducidos (JR) en 12 jugadoras alevines de fútbol femenino (125). Los JR son el inicio de tareas que optimizan el tiempo de entrenamiento satisfaciendo la amplia gama de los requisitos, la toma de decisiones y de compromiso de las habilidades requeridas por la competición (131), además de que son muy populares con independencia de la edad y el nivel de los jugadores (132). Sin embargo, en nuestro conocimiento, este es el único estudio que ha observado cómo influyen los JR en esta población. En cuanto a las variables de fuerza, sólo analizaron el efecto sobre el salto horizontal a pies juntos, donde no existieron diferencias significativas tras 14 sesiones de intervención. Es posible que, al ser jugadoras en formación, que aún no han desarrollado toda su fuerza, necesiten de un estímulo más específico para que esa mejora sea significativa.

Una vez analizados los resultados de los diferentes estudios, la mejora provocada por el entrenamiento de fuerza genera ciertas dudas en esta población, ya que entre los autores no se ponen de acuerdo en qué dosis y ejercicios son los recomendables para mejorar la fuerza de las extremidades inferiores. Parece ser que debería de incluir un periodo de larga duración, variedad de ejercicios pliométricos de bajo impacto y adaptar el programa al nivel de las jugadoras.

1.3.2. Programas de entrenamiento para mejorar la velocidad

En la última década, el uso de medios de análisis durante los partidos ha sugerido que el fútbol actual es muy exigente en cuestiones de demandas energéticas, siendo la capacidad de repetir esfuerzos de alta intensidad uno de los trabajos más realizados por las jugadoras (133, 134). En la literatura, encontramos nueve programas de entrenamiento enfocados a mejorar la velocidad lineal en chicas futbolistas adolescentes (9, 11, 32, 123, 125, 126, 135-137). En un estudio reciente, González-García et al. (2019) realizaron una investigación con 24 jugadoras españolas U-17. Se dividieron en grupo de trabajo de *hip thrust*, grupo de trabajo de sentadilla trasera y grupo control. Los autores observaron que el grupo de *hip thrust* mejoró en la velocidad lineal 20 m respecto al grupo de sentadilla trasera, pero no encontraron diferencias con el grupo control por lo que no está clara la transferencia de estos ejercicios en el sprint (11). Un estudio reciente evaluó el efecto de un programa de acondicionamiento y fuerza sobre un grupo de 14 jugadoras U-14. El entrenamiento incluía ejercicios técnicos, propioceptivos, pliométricos y de fuerza una vez a la semana durante 3 temporadas (137). El grupo experimental mostró mejoras sustanciales en la velocidad lineal 20 m, aunque los autores expresan que para asegurar la progresión continua de las jugadoras con más años de experiencia quizá sea necesario un mayor estímulo de entrenamiento. No obstante, el estudio no reporta los años que llevan jugando a fútbol sus jugadoras, por lo que no podemos conocer a qué número de años de experiencia se refieren los autores. Otro estudio analizó el efecto de un programa combinado de ejercicios de fuerza de carga baja y pliométricos en la carrera de corta distancia (20 m) en jugadoras U-18 de fútbol (11). Las participantes mejoraron significativamente la velocidad lineal en 20 m (TE: -0,67; *p*: <0,01). Parece ser que un programa de entrenamiento de cargas altas con unos ejercicios tan específicos como el *hip thrust* y la sentadilla trasera no muestran una mejora sustancial en la velocidad lineal, aunque es interesante destacar que el grupo de *hip thrust* obtuvo mejores resultados que el de sentadilla trasera en la velocidad lineal 10 m y esto podría ser debido a la importancia que tienen los músculos de extensión de cadera durante los primeros pasos de aceleración del sprint. Por el contrario, cuando se combinan ejercicios de fuerza con cargas bajas y pliométricos, se obtienen resultados más positivos en el rendimiento de la velocidad lineal. Se observa que el programa propuesto por Siegler et al. (2003), el cual tiene una duración menor pero una mayor frecuencia semanal, implica una mejora más sustancial en la velocidad lineal (TE: -0,67) y en un contexto con un tiempo limitado, reflejando la situación actual de los deportes de equipo, pudiendo ser una alternativa interesante (123).

Tres estudios han llevado a cabo un programa de entrenamiento neuromuscular (9, 13, 126) y, aunque son programas más orientados a prevenir lesiones, dichos estudios tuvieron como objetivo observar qué efecto tenía en el rendimiento de las jugadoras adolescentes. Sólo, Noyes et al. (2013) con el programa *Sportsmetric*, mostraron mejoras significativas en la velocidad lineal de 37 m aunque el TE (0,14) fue muy bajo y además no existía grupo control, lo que supone una limitación metodológica que impide dilucidar si dicho entrenamiento es responsable de la mejora en el test o, por el contrario, se produjo una mayor familiarización con la ejecución del test al no encontrarse diferencias sustanciales entre ambos grupos (31). Los otros dos estudios no mostraron mejoras sustanciales, manteniéndose prácticamente el mismo tiempo en el pre y el post (9, 126). Por lo tanto, parecer ser que programas de prevención de lesiones que combinan el trabajo de varias capacidades a la vez (velocidad, flexibilidad, agilidad y/o saltos) en tan poco tiempo (15-20 min) no tienen un impacto positivo en el rendimiento de la velocidad lineal en jugadoras U-18 de fútbol. Johnson et al. (2013) llevaron a cabo un entrenamiento muy específico y diferente durante seis semanas, dos días por semana y en tres grupos de entrenamiento: un grupo que combinaba un programa de aceleración con entrenamiento tradicional en la cinta de correr, otro grupo que combinaba un programa de aceleración con trabajo de alta intensidad junto a un sistema de arnés de soporte de peso corporal en cinta de correr y un tercer grupo que mantenía su entrenamiento ocasional de fútbol. Los grupos experimentales mejoraron significativamente en la velocidad lineal de 40 yardas respecto al grupo control, pero, entre ellos, no existieron diferencias significativas (32). Los autores sugirieron que un programa de aceleración combinado con cinta de correr, pero no necesariamente utilizando un soporte de peso corporal, es un método viable para aumentar la velocidad máxima en futbolistas adolescentes. Muy pocos son los clubes que cuentan con un elevado número de cintas de correr, teniendo en cuenta que nos encontramos ante un deporte colectivo, debido al alto coste y el tamaño que ocupan. Por lo tanto, es interesante este programa, pero no es realista para el trabajo diario y en campo. Otro estudio analizó los efectos de un entrenamiento mixto de acciones de alta intensidad (velocidad + intervalos) en 37 jugadoras de fútbol U-15 (135). A pesar de la especificidad del entrenamiento, tras ocho semanas, no fueron concluyentes que éste produjera mejoras en el rendimiento de la velocidad lineal en 20 m. En base a estos resultados, los autores enfatizan en la importancia del entrenamiento individualizado. No obstante, existen ciertas limitaciones metodológicas como la ausencia de grupo control y que fue realizado en pre-temporada, lo que podría influir en estos resultados poco concluyentes. Al contrario, Mathisen et al. (2014) evaluaron el efecto que tenía un entrenamiento similar de velocidad de alta intensidad introduciendo tres sesiones de entrenamiento durante ocho semanas en 26 jugadoras U-14. Las mejoras fueron significativas tanto en la velocidad lineal de 10 m como 20 m (136). La fuerza de contracción a alta velocidad mejora la aceleración y requiere de una recuperación completa para aumentar la potencia muscular (138). Los autores recalcan que en todas las sesiones hubo personal cualificado controlando que los ejercicios se realizasen a máxima intensidad y con un tiempo de recuperación adecuado, lo que pudo influir en la mejora de la velocidad lineal de las jugadoras. Por otro lado, en un estudio más reciente, 12 jugadoras alevines participaron en JR de 3 vs. 3 y 4 vs. 4. Sin embargo, se produjo un empeoramiento de la velocidad lineal en 20 m tras 14 sesiones de entrenamiento (125). De esta forma, el recurso alternativo de los JR para obtener mejoras en el rendimiento de la velocidad lineal plantearía ciertas dudas al respecto. A pesar de ello, sería interesante analizar diferentes tipos de JR, en los que se modificaran algunas variables (tiempo de juego, número de jugadores, espacio, etc.) con el objetivo de conocer en cuáles se realizan un mayor número de sprints, aceleraciones, distancias y, así, poder plantear una intervención con tales diseños para comprobar sus efectos en la velocidad lineal. En resumen, a pesar de que se conoce que el entrenamiento específico de velocidad mejora esta capacidad en futbolistas (139), en la población que nos concierne no está tan claro. Por ello, son necesarios más estudios que repliquen estudios con mejoras significativas en chicos futbolistas adolescentes en chicas, o que se propongan métodos de entrenamientos más populares que producen efectos integrales sobre la velocidad lineal y la aceleración como el método SAQ "*speed, agility, quickness*" o ejercicios basados en la habilidad de repetir sprints. No obstante, siempre sería interesante combinar estos entrenamientos con ejercicios de fuerza y pliométricos, ya que son los únicos que han reportados resultados positivos en la mejora del rendimiento de la velocidad lineal en jugadoras adolescentes de fútbol femenino.

1.3.3. Programas de entrenamiento para mejorar la flexibilidad

Analizando la literatura científica hemos observado que hay una escasez de intervenciones para mejorar la flexibilidad en futbolistas. Diferentes estudios han asociado que una limitada flexibilidad supone una mayor predisposición a sufrir lesiones músculo-esqueléticas por sobreuso afectando directamente a la funcionalidad y al rendimiento físico del deportista (140, 141). En este sentido, es frecuente encontrar que unos isquiosurales cortos que se relacionan con una de las lesiones más típicas en jugadores de fútbol como es la lesión muscular de los isquiosurales (142) con dolor lumbar (143), distensión muscular (144) o desarrollo de tendinopatía del tendón rotuliano (145) y, por consiguiente, mayor riesgo de sufrir lesión (140). En la población que nos concierne, son sólo cinco los estudios que han analizado el efecto de un programa de entrenamiento sobre la flexibilidad (30, 33, 124, 146, 147). Un primer estudio en 2013, que analizó la influencia del FIFA 11+ sobre la PEE, fue llevado a cabo en jugadoras U-16 y U-18 (146). Las futbolistas fueron divididas en grupo control en el que los entrenadores recibieron únicamente información sobre el programa de manera online, grupo regular en el que los entrenadores recibieron un taller sobre cómo implementar el programa y, por último, el grupo experimental en el que entrenadores y fisioterapeutas cumplimentaron conjuntamente el FIFA 11+. Los resultados mostraron que para los tres grupos de estudio hubo diferencias significativas inter-grupo en todas las direcciones del PEE. Dicho programa incluía un trabajo de equilibrio, pliometría, core y fuerza lo cual podría tener una estrecha relación con la mejora en la PEE. El tipo de movimiento que requiere la PEE es multiarticular y el poder llegar más lejos en cualquiera de las direcciones está muy influenciado, además de por otras variables, por la flexión de rodilla y la dorsiflexión de tobillo, lo cual logra un mejor posicionamiento y control del cuerpo para golpear el balón o para driblar al contrario (148). Otro estudio observó qué efecto tenía este mismo programa sobre el *test de Wells* o *Sit and Reach* en un grupo control y experimental (124). La diferencia intra e inter-grupo resultó significativa en dicha prueba. Por lo tanto, el FIFA 11+ parece mejorar la flexibilidad en jugadoras de fútbol adolescentes, lo cual podría ayudar a prevenir lesiones y mejorar el rendimiento. Por el contrario, Lindblom et al. (2012) analizaron la influencia de un programa neuromuscular, muy similar al FIFA 11+, en la PEE en 73 jugadoras U-16 (30). El grupo experimental no mejoró en ninguna de las direcciones de la PEE. Es posible que los ejercicios incluidos en el presente programa no fueran los suficientemente exigentes como para mejorar el rendimiento en esta población y hubiesen sido necesarios ejercicios más intensos para observar mejorías. Además, los estudios que han implementado el FIFA 11+ lo hicieron durante al menos media temporada, mientras que el otro programa neuromuscular se llevó a cabo durante 11 semanas. Es probable que esa diferencia de semanas haya repercutido en los resultados de las jugadoras. En la misma línea, encontramos el estudio de Filipa et al. (2010) en el que 20 jugadoras U-17 mejoraron en todas las direcciones de la PEE, después de ocho semanas de entrenamiento (147). El tipo de entrenamiento utilizado era neuromuscular y estaba centrado, principalmente, en el trabajo de fuerza de extremidades inferiores y core. Es posible que esa mayor flexión de rodilla y cadera observada en las jugadoras esté relacionada con el trabajo específico de fuerza, es decir, las participantes que mostraron una mayor flexión de rodilla y cadera tuvieron más fuerza en las extremidades inferiores para llegar más lejos. Por último, en un estudio más reciente, 17 futbolistas adolescentes participaron en un programa de acondicionamiento y fuerza (33). Tras ocho semanas de intervención, el grupo experimental mejoró significativamente en la dirección anterior y posterolateral de la PEE, pero no en la posteromedial. Esto pudo ser debido a que los ejercicios propuestos no supusieron un estímulo suficiente como para fortalecer los abductores, de los cuales se conoce que su fuerza está estrechamente relacionada con lograr una mayor distancia en la dirección posteromedial (149). Debido a la escasez de estudios, sería interesante realizar más estudios en es esta población que implementasen otro tipo de entrenamientos, tales como pliométricos, de JRs, de velocidad, de CDs, de fuerza específica de extremidades inferiores... para conocer sus efectos sobre la flexibilidad, de la cual se ha observado que es importante tanto para la prevención de lesiones como para la mejora del rendimiento.

1.3.4. Programas de entrenamiento para mejorar el cambio de dirección

Esta capacidad es una de las más trabajadas en el fútbol, así se demuestra en el elevado número de estudios que tratan sobre la influencia de diversos programas de entrenamiento en el CD en jugadoras de fútbol adolescentes (9, 11, 30, 125, 135-137). De los ocho estudios presentes, seis han mostrado resultados positivos (11, 31, 125, 135-137), mientras que dos estudios no alcanzaron un mejor rendimiento (30, 126). Pérez et al. (2019) analizaron como afectaban los JR sobre el CD. Las participantes mejoraron tanto en el *Modified Agility test* con balón como sin balón (125). Al ser una intervención en la que los sujetos entrenan situaciones reales de partido en espacios reducidos, la transferencia de la práctica al rendimiento es muy positiva pudiendo dar una posible explicación a estos resultados significativos. Tres estudios analizaron el efecto de un programa de entrenamiento neuromuscular sobre tres test diferentes de CD (30, 31, 126). Dos de estos estudios no observaron mejoras en el rendimiento del CD (30, 126). Los test utilizados (*Illinois* y *Pro-Agility*) requieren de rápidos CD > 90º durante la carrera y ambos programas no incluyeron ni ejercicios explosivos ni con un ángulo mayor de 90º, más bien se les pedía a las participantes que los realizasen a una velocidad lenta para centrarse en el alineamiento del tobillo, rodilla y cadera. Por lo tanto, parece ser que la falta de especificidad entre los ejercicios escogidos para el entrenamiento y los test pudieron afectar en la habilidad de transferir la práctica al rendimiento de las jugadoras. Mientras, Noyes et al. (2013) mostraron mejoras significativas (31), esto puede estar relacionado a que el programa neuromuscular utilizado incluía ejercicios de velocidad lineal y agilidad cercanos a las demandas que exige la competición. Wright et al. (2016) y Mathisen et al. (2014) analizaron la influencia de un entrenamiento de acciones de alta intensidad en el rendimiento de la agilidad en jugadoras U-15. Ambos estudios mostraron mejoras significativas tras ocho semanas de intervención (135, 136). Se supone que la fuerza de contracción muscular a alta velocidad mejora las acciones explosivas, la aceleración y el CD (138). Estos resultados positivos podrían estar relacionados con que los ejercicios de aceleración, de velocidad lineal y de CD que se les pedían a las jugadoras debían ser realizados a la máxima velocidad. Por último, dos estudios analizaron cómo afectaba la introducción de un trabajo de fuerza en jugadoras U-14 y U-18 (11, 137). Los programas de entrenamiento eran muy diferentes entre un estudio y otro. González-García et al. (2019) compararon tres grupos, uno se centraba en un trabajo de sentadillas traseras, otro en *hip thrust* y el último era un grupo control. Sólo el grupo de *hip thrust* mejoró en el test de CD (11). Ejecutar un CD a mayor velocidad requiere de un aumento proporcional del control excéntrico para desacelerar, por lo que la mejora en el test puede estar relacionada con la mejora de esta fase gracias al trabajo excéntrica que somete a las jugadoras el programa de *hip thrust*. Wright et al. (2019) evaluaron el efecto que tenía un entrenamiento de acondicionamiento y fuerza introduciendo una sesión a la semana a lo largo de tres temporadas en un grupo experimental de 14 jugadoras de fútbol inglesas U-14 (137). La hipótesis de por qué se observan mejoras significativas a lo largo de tres temporadas en el test CD180º es muy similar a la que se ha discutido en el anterior estudio. Este programa también somete a las jugadoras tanto a un trabajo excéntrico como neuromuscular, lo que contribuye a controlar y reducir la fase de desaceleración del CD. Para acabar, hay que tener especial cuidado con el momento de pico de crecimiento de los niños y niñas adolescentes, ya que parece empeorar el CD debido a la descoordinación y desajuste temporal por el crecimiento. En conclusión, prácticamente todos los programas de entrenamiento analizados reportan mejoras en el rendimiento del CD, aunque es posible que lo ideal fuera combinar ejercicios de extremidades inferiores neuromusculares con el ejercicio de *hip thrust* ejecutados a máxima velocidad.

Tabla 3. Estudios longitudinales en los que se ha analizado la influencia de un tipo de entrenamiento en la fuerza, la velocidad lineal, la flexibilidad y el cambio de dirección.

Autor	Año	Participantes	Frecuencia y duración	Tipo de entrenamiento	Test de F	Test de V	Test de Flex	Test de CD	Resultados (TE/S/NS/CSUS/NSUS)
Filipa et al. (147)	2010	20 jugadoras de fútbol U-17 GC (n = 7) GE (n = 13)	8 sem (2 días x sem) Temporada	EN Core, F extremidades inferiores			PEE		GC- PEE PL_D: -0,04/PM_D: -0,22 /A_D: -0,27, PL_I: -0,13/PM_I: -0,43 /A_I: -0,58 GE- PEE PL_D: 0,85 S /PM_D: 0,36 /A_D: 0,31 PL_I: 0,72 S/PM_I: 0,48 S/A_I: 0
González -García et al. (11)	2015	24 jugadoras sub-élite fútbol U-18 G1 (n= 8) sentadilla profunda G2 (n= 8) *hip thrust* GC (n = 8) No experiencia en F Distribuidas aleatoriamente	7 sem (2 días x sem) Final temporada competitiva	G1: entrenamiento sentadilla trasera G2: entrenamiento *hip thrust* Ejercicios 60% 1RM hasta 90%1RM aumenta gradualmente en 7 sem	CMJ	20 m		T-test	NRD del análisis intragrupo
Johnson et al. (32)	2013	32 jugadoras de fútbol U-18 G1 (n = 13) CC+ soportar propio peso corporal G2 (n = 11) CC + no soportar propio peso GC (n = 8) Distribuidas aleatoriamente	6 sem (2 días x sem)	G1- SAP Pliometría, agilidad, F, core + CC soportando propio peso corporal (10 min) G2- SAP Pliometría, agilidad, F, core + CC no soportando propio peso corporal (10 min)	Flex I Ext I	40 yardas			G1- Flex I: NS Ext I: NS 40 yardas: S G2- Flex I: S Ext I: NS 40 yardas: S GC- Flex I: NS Ext I: NS

									40 yardas: NS
Lindblom et al. (30)	2012	52 jugadoras de fútbol U16 GC (n = 24) GE (n = 28) Distribuido aleatoriamente	11 sem (2 días x sem) Temporada	EN “Knäkontroll SISU Idrottsböcker” Equilibrio, core, técnica salto, alineación rodilla	CMJ TS	10 m 20 m	PEE	*Illinois*	GC- CMJ: 0,03 TS: -0,03 10 m: 0,13/20 m: 0 PEE PL_D: 0.62 S/PM_D: 0,48 S/A_D: -0,17 PL_I: 0,27/PM_I: 0,89 S/A_I: 0,08 *Illinois*: -0,26/ S GE- CMJ: -0,13 TS: -0,30/ S 10 m: 0/20 m: -0,05 PEE PL_D: 0,09/PM_D: 0,04/A_D: -0,22 PL_I: -0,26/PM_I: 0,09/A_I: -0,32 Illinois: 0,07
Mathisen et al. (136)	2014	26 jugadoras de fútbol U-14 GC (n = 13) GE (n = 13)	8 sem (1 día x sem) Pretemporada	HIIT		10 m 20 m			GC- 10 m: 0 20 m: 0,04 Agility test course: -0,45 GE- 10 m: -1,37/ S 20 m: -0,86/ S Agility test course: -0,987 S
Ness et al. (33)	2016	17 jugadoras I División de fútbol U-20	8 sem (2-3 días x sem)	EF + Acondicionamiento Multiarticulares, tronco, extremidades inferiores, potencia	F Isom abd cadera F Isom RE cadera		PEE		F Isom abd $cadera_{DOM}$: 0,05 F Isom abd $cadera_{NDOM}$: 0,12 F Isom RE $cadera_{DOM}$: 1 F Isom RE $cadera_{NDOM}$: 0,87 PEE PL_{DOM}: 0,62/PM_{DOM}: 0,37/A_{DOM}: 0,40 PL_{NDOM}: 0,85/PM_{NDOM}: 0,31/A_{NDOM}: 0,66

Noyes et al. (31)	2013	62 jugadoras de fútbol de instituto U-16 No experiencia EN	6 sem (3 días x sem) Pretemporada	EN “Sportsmetrics” Saltos, agilidad y reacción, aceleración, velocidad aeróbica, resistencia, juego de pies y tareas de salto	DJ SV CMJ	37 m		T-test	VJ: 0,08/S CMJ: 0,02/NS 37 m: 0,14/S T-test: 0,43/S
Pérez-Parra et al. (124)	2017	40 jugadoras de fútbol U-18 GC (n = 20) GE (n = 20) Distribuidas aleatoriamente	6 meses Temporada	EN “FIFA 11+” Estabilidad de core, F, extremidades inferiores, saltos, equilibrio, agilidad	Abdominales en un min Paravertebrales en un min		“Sit and Reach”		GC- Abdominales: 0,05/NS Paravertebrales: 0,01/NS Sit and reach: 0,30/NS GE- Abdominales: 1,24/ S Paravertebrales: 0,47/ NS Sit and reach: 0,72/ S
Pérez et al. (125)	2019	12 jugadoras de fútbol U-13	14 sesiones	Juegos reducidos 3 v 3 30x20 m o 4 v 4 36x24 m	SH	20 m		MAT con/sin balón	SH: NS 20 m: S CN: S MAT sin balón: S MAT con balón: S
Rubley et al. (10)	2011	16 jugadoras de fútbol U-15 GC (n = 6) GE (n = 10) No experiencia en EP	12 sem (1 día x sem) Temporada	EP de baja frecuencia e impacto	SV Distancia de tiro				GC- SV: -1,72 Distancia de tiro: -0,26 GE- SV: 2,73 Distancia de tiro: 0,90
Siegler et al. (123)	2003	34 jugadoras de instituto de fútbol U-18 GC (n = 17) GE (n = 17)	10 sem (EF: 2 días x sem/ EP: 3 días x sem) Temporada	EF (peso libre squat, extensión de cuádriceps e isquiosurales, gemelos) + EP (saltos cajón, rebote, skipping)	SV	20 m			CG- SV: 0,74 20 m: -0,30 LIST: 0,26 GE- SV: 0,36 20 m: -0,66 LIST: 2,35/ S
Steffen et al. (9)	2008	34 jugadoras de élite de instituto de fútbol U-18 GC (n = 16) GE (n = 18) Distribuidas aleatoriamente	10 sem (3 días x sem) Temporada	EN “FIFA 11+” Estabilidad de core, F extremidades inferiores, saltos, equilibrio, agilidad	DJ CMJ Distancia de tiro	40 m			CG- DJ: NS CMJ: NS Distancia de tiro: NS F isoc: NS

					F isoc F isom				F isom: NS 40 m: NS GE- DJ: NS CMJ: NS Distancia de tiro: NS F isoc: NS F isom: NS 40 m: NS
Steffen et al. (146)	2013	226 jugadoras de fútbol U-18 G1 (n = 68) Entrenador formado en FIFA11+ G2 (n = 78) Entrenador+ fisioterapeuta FIFA11+ GC (n = 80) Entrenador no formado FIFA11+	1 temporada (2-3 días x sem)	EN "FIFA 11+" Estabilidad de core, F extremidades inferiores, saltos, equilibrio, agilidad			PEE		G1, G2, GC PEE (todas direcciones): S
Vescovi et al. (126)	2010	58 jugadoras de fútbol U-18 GC (n = 27) GE (n = 31) No experiencia Distribuidas aleatoriamente	12 sem (3 días x sem)	EN "PEP program" F, pliometría, agilidad	CMJ	36,6 m		*Illinios* *Pro-agility*	GC- CMJ: S 36,6 m: S *Illinois*: NS *Pro-agility*: NS GE- CMJ: NS 36,6 m: S *Illinois*: NS *Pro-agility*: NS
Wrigth et al. (135)	2016	37 jugadoras de fútbol U-17 U-13 (n= 13) U-15 (n= 14) U-17 (n=10)	8 sem (1 día x sem) Pretemporada	HIIT		20 m		T-test	U-13 20 m: NSUS YYIR: NSUS RSA: CSUS T-test: NSUS U-15 20 m: NSUS YYIR: CSUS RSA: CSUS T-test: CSUS U-17 20 m: CSUS

							YYIR: CSUS RSA: NSUS T-test: CSUS
Wrigth et al. (137)	2019	14 jugadoras de fútbol U-14	3 temporadas (1 día x sem)	EF + Acondicionamiento Pliometría, propiocepción, F	5 m 20 m	CD180º	5 m: CSUS 20 m: CSUS RSA: CSUS CD180º: CSUS

A: Anterior; Abd: Abducción; CC: Cinta de correr; CD: Cambio de dirección; CMJ: Countermovement jump; CN: Course Navette; CSUS: Cambio sustancia; D: Derecha; DJ: Drop jump; EF: Entrenamiento de fuerza; EN: Entrenamiento neuromuscular; EP: Entrenamiento pliométrico; ER: Entrenamiento resistencia; Ext I: Fuerza de extensión isométrica; F: Fuerza; F isoc: Fuerza isocinética; F isom: Fuerza isométrica; Flex: Flexibilidad; Flex I: Fuerza de flexión isométrica; GC: Grupo control; GE: Grupo experimental; HIIT: High-intensity interval training; I: Izquierda; LIST: Loughborough Intermittent Shuttle test; MAT: Modified Agility test; NS: No significativo; NSUS: No cambio sustancial; PEP program: Santa Monica Prevent Injury Enhance Performance program; PL: Poterolateral; PM: Posteromedial; R: Resistencia; RE: Rotación externa; RSA: Repeated sprint ability; S: Significativo p<0,05; SAP: Sport acceleration program; PEE: Prueba de equilibrio de la estrella; SH: Salto horizontal bilateral; SR: Salto con rebote; SV: Salto vertical; TE: Tamaño de efecto; TS: Triple salto; V: Velocidad; YYIR: 1 yo-yo intermittent recovery; NRD: No reporta datos

Capítulo 2. Hipótesis y Objetivos

Solo hay un bien, el conocimiento; solo hay un mal, la ignorancia.
Sócrates

Hipótesis

Los test de rendimiento físico serán fiables y sensibles a los cambios inducidos por el entrenamiento realizado durante la temporada por las futbolistas adolescentes. Además, la reproducibilidad de los test estará relacionada con la edad de las participantes.

El rendimiento físico de las futbolistas adolescentes mejorará y se reducirá la asimetría entre extremidades tras un programa de calentamiento neuromuscular y un programa de entrenamiento combinado de fuerza y potencia.

Hypothesis

Physical performance tests are reliable and sensitive to changes introduced by the training performed during the season by adolescent female soccer players. In addition, reproducibility of tests will be related to the age of the participant.

Adolescent female soccer players improved physical performance and reduced lower interlimb asymmetries after a neuromuscular training program and combined strength and power training program.

Objetivos

El objetivo principal de la presente Tesis Doctoral es ampliar el conocimiento científico de los factores de rendimiento determinantes en jugadoras de fútbol adolescentes y el efecto de intervenciones específicas sobre esos factores de rendimiento y las asimetrías funcionales.

Más concretamente, los *objetivos específicos* que componen esta Tesis Doctoral son:

I. Examinar la fiabilidad y la sensibilidad de los diferentes test de fuerza, velocidad lineal y CD en jugadoras futbolistas adolescentes.
II. Determinar los cambios a corto y medio plazo en diferentes test de fuerza, velocidad lineal y CD durante la temporada en jugadoras de fútbol adolescentes.
III. Analizar el efecto de un programa de calentamiento neuromuscular en el rendimiento físico y las asimetrías funcionales de jugadoras de fútbol adolescentes.
IV. Evaluar el efecto de un programa combinado de fuerza y potencia en el rendimiento físico y las asimetrías funcionales de jugadoras de fútbol adolescentes.
V. Investigar la relación entre la aceleración y la velocidad pico en jugadoras de fútbol adolescentes.
VI. Comprobar la influencia del peso corporal y la maduración biológica en la aceleración y la velocidad pico en jugadoras futbolistas adolescentes.
VII. Establecer el intervalo en el que alcanzan la velocidad pico las jugadoras de fútbol adolescentes de diferentes edades en la velocidad lineal de 40 m.

Aims

The *general aim* of this Doctoral Thesis is to enlarge the scientific knowledge of detrimental performance factors in adolescent female soccer players and the effect of specific interventions of these performance factors and functional asymmetries.

The *specific aims* included in this Doctoral Thesis are:

I. To examine the reliability and sensitivity of jumping, strength, lineal sprinting and COD tests.
II. To determine short- and mid-term changes across the season in strength, lineal sprinting and COD tests in adolescent female soccer players.
III. To analyse the effect of a neuromuscular training program on physical performance and functional asymmetries in adolescent female soccer players.
IV. To assess the effect of a combined strength and power training program on physical performance and functional asymmetries in adolescent female soccer players.
V. To investigate the relationship between acceleration and maximal sprinting speed in different age-groups of adolescent female soccer players.
VI. To substantiate the influence of body mass and biological maturation on acceleration and maximal sprinting speed in combined strength and power training program.
VII. To establish the split in which adolescent female soccer players will reach the maximal sprinting speed in 40 m sprint.

Capítulo 3. Material y Métodos

Es mejor perseguir un sueño que rendirse a no tenerlos. Prefiero perseguir utopías.
Julia Navarro

A continuación, se detalla la metodología general del proyecto de investigación "Evaluación del rendimiento físico y asimetrías funcional en jugadoras de fútbol adolescentes". No obstante, en el capítulo 4 (resultados y discusión) aparece una descripción específica de la metodología utilizada en cada estudio.

3.1. Comité de ética

El estudio se llevó a cabo siguiendo los Principios Éticos para las Investigaciones Médicas en Seres Humanos reconocidas por la Declaración de Helsinki de 1975 (revisado en las 67° Asamblea General en Taipei 2016, Taiwan), y cumpliendo la legislación y la normativa legal Española (ley 14/2007, de 3 de Julio, de Investigación Biomédica). El proyecto fue aprobado por el Comité de Ética de Investigación Clínica de Aragón (**Anexo I**; CEICA ref. CP19/039). Además, previo a la participación en el proyecto se organizó una reunión donde se explicaron los objetivos y procedimientos a llevar a cabo en el mismo. Finalmente, todos los padres/tutores legales tuvieron que firmar un consentimiento informado para que sus hijas pudieran participar en el estudio. Las futbolistas comunicaron verbalmente su conformidad para participar en este proyecto. El proyecto se registró en la base de datos pública (ClinicalTrial.gov número de identificación [NCT03862560]).

3.2. Características de la muestra y diseño del proyecto

La muestra total del estudio fue de 80 jugadoras de fútbol adolescentes con edades comprendida entre 12 y 18 años. Los criterios de inclusión fueron los siguientes: 1) tener una edad comprendida entre 12 y 19 años, 2) no padecer ninguna enfermedad, 3) no padecer ningún tipo de lesión en el periodo de mediciones o durante la intervención ni haber estado lesionada en los últimos tres meses, 4) caucásicas, 5) no practicar un segundo deporte, a parte del fútbol. Además, las jugadoras tenían que participan en un mínimo de 4,5 h de práctica deportiva (entrenamientos técnicos-tácticos + físicos + partidos) semanal y tener una experiencia mínima de 4 años entrenando a fútbol. A continuación, se resume con mayor detalle las muestras finalmente incluidas en el cada estudio.

El **artículo I,** al tratarse de una revisión sistemática, tiene una metodología propia y diferente a los estudios experimentales. Esta metodología se explica en profundidad en el capítulo 4.1.

El **artículo II.** contiene datos longitudinales y cuenta con la muestra total de 68 futbolistas U-16 y U-18.

El **artículo III.** es un estudio longitudinal, y fue realizado con una muestra de 36 futbolistas U-14.

El **artículo IV**. es un estudio longitudinal en el que participaron 37 jugadoras de fútbol U-18.

El **artículo V.** contiene un diseño transversal y cuenta con la muestra total de 80 jugadoras (U-18).

3.3. Pruebas y valoraciones

A continuación, se muestras las pruebas de valoración funcional desarrolladas en la presente Tesis Doctoral.

3.3.1. Valoración de la fuerza

- **Countermovement jump:** El CMJ es realizado para medir la fuerza explosiva de las extremidades inferiores. Se utilizó la plataforma de fuerza (*Optojump, Microgate, Bolzano, Italia*) para medir el tiempo de vuelo (cm). En esta prueba la jugadora se encontraba en una posición erguida con las manos en la cintura, teniendo que efectuar un salto vertical después del contramovimiento hacia abajo (grado de flexión fue autoseleccionado), sobre la plataforma de fuerza. Durante la acción de flexión, el tronco permaneció lo más erguido posible para evitar cualquier posible influencia en el rendimiento de los miembros inferiores. Cada participante realizó 3 repeticiones máximas. Se esperó un mínimo de 60 s entre cada repetición. El mejor intento fue seleccionado para el posterior análisis. Durante el CMJ, el sujeto utilizó zapatillas de deporte.

- **Countermovement jump unilateral:** En este salto la deportista se encontró en posición erguida con las manos detrás de la espalda, teniendo que efectuar un salto vertical con una pierna después del contramovimiento hacia abajo (grado de flexión fue autoseleccionado), sobre la plataforma de fuerza (*Optojump, Microgate, Bolzano, Italia*), la cual se empleará para medir el tiempo de vuelo (cm). Durante la acción de flexión, el tronco debía permanecer lo más erguido posible para evitar cualquier posible influencia en el rendimiento de los miembros inferiores. En el salto unilateral, se permitió el balanceo de la pierna libre. La participante debía de caer sobre la misma pierna de impulso teniendo que permanecer sobre dicha pierna durante 2-3 s para considerar el intento cómo válido. Se permitió 3 repeticiones máximas, seleccionando el mejor intento para el posterior análisis. Se esperó un mínimo de 45 s entre cada repetición. Durante la ejecución del test, el sujeto utilizó zapatillas de deporte. Las variables utilizadas para el análisis fueron CMJ con la pierna derecha (CMJD) y CMJ con la pierna izquierda (CMJI).
- **Salto horizontal bilateral:** El salto horizontal bilateral (SH) fue realizado para medir la fuerza explosiva de las extremidades inferiores en la aplicación de fuerza

horizontal. Se utilizó una cinta métrica estándar (*30m M13; Stanley, New Britain, EEUU*). Las futbolistas, de pie, con los pies colocados justo detrás de la línea (marcada con cinta) y con los brazos relajados a los lados del cuerpo, debía impulsarse para saltar la máxima distancia horizontal para ejecutar una caída controlada y mantener el equilibrio sobre ambas piernas hasta que el evaluador registrase (2-3 s) la posición de caída. La distancia se medió en cm desde la punta del pie (salida) hasta el talón en la posición de salida. Cada participante realizó 2 intentos con 30 s de recuperación entre saltos. El mejor intento fue seleccionado para el posterior análisis. Durante el SH, el sujeto utilizó zapatillas de deporte.

- **Salto horizontal unilateral:** La jugadora comenzó sobre un apoyo para, posteriormente, saltar con dicha pierna tratando de llegar lo más lejos posible y caer sobre la misma pierna de impulso, en el salto horizontal unilateral (SHU). El balanceo de la pierna contraria fue permitido. Las manos debían de colocarse agarradas detrás de la espalda. La jugadora fue instruida para ejecutar una caída controlada y mantener el equilibrio sobre la pierna de caída (no se permitieron saltos extra) hasta que el evaluador registrase (2-3 s) la posición de caída. La distancia fue medida en cm desde la punta del pie (salida) hasta el talón en la posición de salida. Cada participante realizó 3 intentos con cada pierna con 30 s de recuperación entre saltos. El mejor intento fue seleccionado para el posterior análisis. Durante la ejecución del test, el sujeto utilizó zapatillas de deporte. Las variables utilizadas para el análisis fue SH sobre pierna derecha (SHMD) y SH sobre pierna izquierda (SHMI).
- ***Drop jump* bilateral:** El test de salto tras altura bilateral (DJ) se llevó a cabo para valorar la manifestación "reflejo-elástico-explosiva" de las extremidades inferiores. La deportista, con los brazos sueltos, se dejó caer por la gravedad desde

una altura determinada (31,5 cm) avanzando un pie para, posteriormente a la caída, elevarse lo máximo posible. Cada participante realizó 3 repeticiones máximas y se seleccionó el mejor intento para el análisis. Se utilizó la plataforma de fuerza (*Optojump, Microgate, Bolzano, Italia*) para medir la altura de vuelo (cm). Se esperó un mínimo de 60 s entre cada repetición. Durante el SH, el sujeto utilizó zapatillas de deporte.

Se ha escogido una caja de 31,5 cm ya que es una altura similar a la que se suele utilizar en la literatura científica en jugadoras de fútbol (150). En relación a este hecho, se ha observado que saltos desde cajas de 30 cm son significativamente más altos que desde alturas mayores como 60 o 90 cm (151).

- ***Drop jump* unilateral:** En el test de salto tras altura unilateral (DJU), la futbolista, con los brazos sueltos, se dejó caer por la gravedad desde una altura determinada (31,5 cm) avanzando un pie, con el cual se elevó verticalmente lo máximo posible tras la caída en la plataforma de fuerza, permaneciendo sobre dicha pierna 2-3 s para considerar el intento como válido. Cada participante realizó 2 repeticiones máximas y se seleccionó el mejor intento para el análisis. Se esperó un mínimo de 60 s entre cada repetición con la misma pierna. Durante la ejecución del test, el sujeto utilizó zapatillas de deporte. Las variables utilizadas para el análisis fueron DJ con la pierna derecha (DJUD) y DJ con la pierna izquierda (DJUI). Se utilizó la plataforma de fuerza (*Optojump, Microgate, Bolzano, Italia*) para medir la altura de vuelo (cm).

3.3.2. Valoración de la velocidad

- **Velocidad lineal de carrera de 40 m:** Cada jugadora realizó 2 sprints corriendo 40 m a la máxima velocidad (con una recuperación de ~3 min), con el mejor intento siendo registrado. El pie de salida se colocó 0,5m antes de la primera célula fotoeléctrica. Un set de células fotoeléctricas (*Witty, Microgate, Bolzano, Italia*) fue colocado a cada extremo cada 10 m para medir el tiempo necesario para recorrer los 40 m. Durante la ejecución del test, el sujeto utilizó botas de fútbol.

3.3.3. Valoración de la flexibilidad

- **Prueba funcional de equilibrio en estrella modificado:** La estabilidad dinámica se evaluó mediante el sistema OctoBalance (*OctoBalance, Check your MOtion, Albacete, España*). Se le solicitó a la jugadora que colocase su pie sobre la base octogonal, coincidiendo el 2º dedo con la línea roja. Con la pierna que quedaba libre se debía desplazar el metro (inicio 30 cm) lo más lejos posible, tocando con el 1º dedo del pie el tapón blanco. No se permitieron los golpes sobre el tapón blanco. En todo momento, la jugadora tenía que mantener el equilibrio con el talón en contacto con la plataforma y las manos apoyadas en la cadera. En primer lugar, se comenzó con la pierna izquierda para continuar posteriormente con la pierna derecha. Se realizaban 4 intentos de calentamiento con cada pierna y acto seguido se registraban 3 intentos, entre los cuales no debía existir una diferencia mayor de 3 cm, con una recuperación pasiva de 10 s entre cada intento. Se llevaron a cabo tantas pruebas de calentamiento y registros oficiales como direcciones se midieron. En este caso, se registró la línea anterior, posteromedial y posterolateral siguiendo las recomendaciones de Hertel (152). El mejor resultado de los dos intentos en cada pierna fue utilizado para el posterior análisis.
- **Test de flexión dorsal del tobillo**: Se evaluó la flexión dorsal del tobillo a través del LegMotion system (LegMotion, Check your Motion, Albacete, España) (82). Sin un calentamiento previo se le pidió a la deportista que colocase su pie izquierdo sobre la base sin pisar la línea negra transversal de la plataforma y haciendo coincidir el dedo índice con la línea negra longitudinal de la plataforma.

La varilla que registraba la flexión dorsal del tobillo tenía una altura que correspondía a la distancia que hay desde el suelo hasta la patela o rótula. Se inició desde el número 10 y se fue regulando la posición de la varilla conforme a la mayor o menor flexión que realizaba la futbolista. La distancia alcanzada se registró en cms. El pie de detrás se colocaba en la línea horizontal donde acababa la base, apoyando el pie entero con la opción de poder levantar el talón cuando se llevaba a cabo la flexión de tobillo con el otro pie, en el que no estaba permitido levantar el talón en ningún momento de la base. Se permitieron 3 intentos con cada tobillo (derecha e izquierda) con 10 s de recuperación pasiva entre cada intento. El tercer valor de cada tobillo fue seleccionado para el análisis posterior.

3.3.4. Valoración de los cambios de dirección

- **Test de cambio de dirección 180º:** En el test de CD 180°, se realizó un desplazamiento que incluía un sprint de 10 m. Las participantes iniciaban el test desde la línea de salida/llegada, cruzaban la línea de 5 m con el pie derecho o izquierdo, giraban 180° y esprintaban de nuevo hacia la línea de salida/llegada. Las jugadoras ejecutaron 2 pruebas válidas con cada pie, separadas por al menos 90 s, guardándose el mejor tiempo. La prueba se realizó con botas de fútbol. Las variables utilizadas en el análisis fueron CD180º con la pierna derecha (CDD) y con la pierna izquierda (CDI).
- **Test V-cut:** En el test “V-cut”, las jugadoras ejecutaron un sprint de 25 m con 4 CD (1 cada 5 m) con un ángulo de salida de 45°. El pie de salida se colocaba 0,5 m antes de la primera célula fotoeléctrica (*Byomedic fotoelectric cells, Barcelona*). Para que un intento fuese considerado como válido, los jugadores tenían que pasar completamente un pie de la línea dibujada en el suelo, entre cada par de conos, en cada uno de los CD. Si la prueba era considerada como nula o

fallida, las jugadoras disponían de una nueva oportunidad para realizar el test. Entre cada intento, se permitió un descanso de 2 minutos. La distancia entre cada par de conos fue de 0.7 m. El mejor registro de los 2 intentos realizados fue guardado para su posterior análisis. La prueba se realizó con botas de fútbol.

3.4. Análisis estadístico

A continuación, se resumen brevemente las pruebas estadísticas que se efectuaron para obtener los resultados de esta Tesis Doctoral; no obstante, en el capítulo 4 aparece una descripción más detallada de todos los análisis estadísticos realizados. Dependiendo del estudio, los análisis se realizaron con el paquete informático SPSS (versión 19.0 para Mac OS X, SPSS Inc., Chicago, IL, EEUU) o utilizando las hojas proporcionadas por Hopkins (153) para realizar las magnitudes basadas en inferencias (o “magnitude-based inference”, en la literatura científica). En general, los datos se presentan como media ± desviación estándar. En primer lugar, se estudió la normalidad en la distribución de las variables continuas mediante el test de *Shapiro-Wilk* o *de Kolmogorov-Smirnov*.

Para analizar la fiabilidad relativa se utilizó el CCI y para la fiabilidad absoluta el CV. La sensibilidad del test fue evaluada comparando el mínimo cambio apreciable (MCA) con los cambios producidos a lo largo de la temporada.

Si la distribución de una variable era normal, las diferencias entre grupos se establecían mediante el test para muestras independientes (test *t* de Student) o con el test de análisis de la varianza (ANOVA). En algunas pruebas estadística se utilizó como covariables el pre-test, el peso corporal o el pico de velocidad de crecimiento para ajustar variables que podían estar influenciadas por otras. En esos casos se efectuó el test de análisis de la covarianza (ANCOVA) junto con el test post hoc de Bonferroni. El nivel significativo estadístico fue tomado, como normal general como $p < 0,05$.

Para analizar el efecto del entrenamiento FIFA 11+ y el programa combinado de fuerza y potencia, se utilizaron las hojas de Hopkins para determinar el tamaño del efecto por medio del MCA. Se usaron los puntos de corte establecidos por Hopkins et al. (154): el tamaño del efecto de la *d* de Cohen puede ser trivial (0,0-0,2), pequeño (> 0,2-0,6), moderado (> 0,6-1,2), o grande (> 1,2-2,0).

La asimetría entre extremidades fue calculada utilizando las siguientes fórmulas:

Asimetría entre extremidades (155) = 100/Max valor (derecha e izquierda)* Min valor (derecha e izquierda)*-1+100

Simetría entre extremidades (%) (156) = (extremidad fuerte-extremidades débil/extremidades fuerte) x100

Por último, para el estudio de la aceleración y la velocidad máxima de sprint, la distancia asociada con el mejor intervalo en función de la edad se analizó con el test de Chi-cuadrado. Se utilizó una ANOVA para observar el efecto de la edad en la distancia media del mejor ntervalo.

Capítulo 4. Resultados y Discusión

[En inglés]

Rêves ta vie, vis tes rêves
Mahatma Gandhi

Resultados generales

Los resultados y la discusión de la presente Tesis Doctoral quedan reflejados en los siguientes artículos científicos.

General Results

The results and discussion of this Doctoral Thesis are shown in the following research manuscripts.

4.1. Artículo I [Manuscript I]

Determining the reliability and usability of change of direction speed tests in adolescent female soccer players: a systematic review

__**Pardos-Mainer E**__**,** Casajús JA, Julián C, Bishop C, Gonzalo-Skok O. Determining the reliability and usability of change of direction speed tests in adolescent female soccer players: a systematic review. **J Sport Med Phys Fitness**. *Accepted for publication.*

ABSTRACT

INTRODUCTION: This review aimed 1) to describe the most common tests used for assessing change of direction (COD) performance; 2) to detail the reliability of current COD tests; 3) to provide an overview of current intervention strategies used to improve COD performance in adolescent female soccer players.

EVIDENCE ACQUISITION: A computerized search was conducted in the PubMed, Cochrane Plus and Web of Science (from 1995 to January 2020) for English and Spanish language and peer-reviewed investigations.

EVIDENCE SYNTHESIS: A total of 221 studies were identified, with only 16 meeting the specific search criteria. The main findings were that eleven different tests have been used to assess COD performance with intraclass correlation coefficient and coefficient of variation values between 0.72-0.99 and 1-10.6%, respectively. The number of CODs performed during each test ranged from 1 to 9 within a range of 45º to 180º and with a duration <5 s, 5-9 s and >10 s.

CONCLUSIONS: Findings indicate that the reliability of the COD tests seems to depend on: test familiarization, the equipment used, the surface tested on and the technical level of the soccer player. These results should be interpreted with caution as they may be influenced by the period of growth and maturation, the menstrual cycle, the playing position of the player and the period of the soccer season. Finally, speed, agility and interval training could be considered as appropriate modalities of training to improve COD performance.

Keywords: Reliability, change of direction, training, youth, football

INTRODUCTION

Soccer has become increasingly popular among females worldwide and according to the Women´s Football Survey of the Fédération Internationale de Football Association (FIFA), there were more than 30 million registered women soccer players in 2014 (157). At youth standards, popularity is increasing at a rapid rate. There has been almost a 4% increase in participation in the last 5 years in youth female soccer players (158). In 2017, over 960,000 youth female were registered in Europe (158), which represents a huge increase in the popularity of the female game.

Historically, agility has been defined as the ability to change direction rapidly, without losing balance using a combination of strength, power and neuromuscular coordination (159, 160). More recently, this definition has been questioned, with some suggesting that it does not really reflect the nature of true agility in a sports context. Consequently, new definitions have recognised the reactive nature of agility. Sheppard and Young (90) suggest that agility must also encompass an athlete´s perceptual and decision-making skills. However, given that these types of skills typically occur in competition, they can be extremely challenging to measure objectively. Thus, measuring performance during pre-planned movements (e.g., 5-0-5, T-test, pro-agility), may be better described as COD speed and more appropriate for practitioners to monitor reliably (161).

The COD can be defined as the ability to decelerate, reverse or change movement direction and accelerate again and is influenced by a number of physical and technical attributes such as straight, sprinting, speed/acceleration, eccentric and concentric strength, power and reactive strength (162, 163). In team sports, COD manoeuvres (e.g., side-step cutting) are frequently performed and can be considered as one of the most important physical qualities to develop, given the associated multi-directional nature of movement patterns seen in team sports (164, 165). Specifically, COD ability is one of the most important fitness components in soccer (27, 166) and previous literature has highlighted that players can change direction between 1200-1400 times in a match (167). Given the prevalence of COD in soccer, its improvement has become an important focus of training programmes (168, 169).

It has been shown that fitness testing is fundamental for sport performance optimization (165, 169, 170). In soccer, there is a strong interest in developing and validating COD field tests like the T-test (171), the Illinois agility test (IAT) (168) or the sprint 9-3-6-3-8 m with 180º turns (S180º) (171), that could allow researchers, coaches and practitioners to effectively measure COD performance in soccer players.

Similar motion characteristics between the sexes at youth standards have been found (19, 172). Buchheit et al. (173) established that the duration of sprints during a match in adolescent male soccer players is less 3 s. Typical COD tests do replicate the movement patterns of soccer; however, time to completion can range from 7-18 s. Thus, this value might not represent a sport-specific test for adolescent soccer players. In addition, these tests might be overly strenuous for adolescent players, which might also affect the validity and/or reliability of the test (169). For these reasons, it is necessary to examine the most frequently used COD tests in adolescent female soccer players in order to provide a safe, effective and ecologically valid assessment of COD performance.

Appropriate and reliable tests are also a strong consideration for test selection. Reliability can be defined as the consistency or reproducibility of test results when carried out on more than one occasion (174). Many influencing factors like test type, physical condition, test duration or inter-trial time are susceptible to the reliability of a test (175, 176). Testing and monitoring players' COD performance is crucial and can have multiple purposes such as comparing between players, controlling training efficacy, talent identification and monitoring long-term player development; however, test reliability must first be considered before being informed by data. Issues surrounding named above the reliability are important to determine the integrity of a test. For the practitioner to provide meaningful results to adolescent female soccer players and the coaching staff, it is their prerogative to use testing methods regarded as possessing high levels of reliability. Furthermore, providing details about factors that may impact COD performance and how these can be improved with different intervention strategies will guide practitioners to appropriate training design and prescription.

Therefore, the aims of this systematic review were to: (1) describe the most common tests used for assessing COD performance in adolescent female soccer players, (2) detail the reliability of current COD tests, (3) provide an overview of current intervention strategies used to improve COD performance in adolescent female soccer players.

EVIDENCE ACQUISITION

Search strategy

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (176, 177). A systematic search was undertaken to observe quality in COD tests in adolescent female soccer players within the scientific literature. A computerized search was performed in PubMed, Cochrane Plus and Web of Science (up to January 2020).

A systematic search of three electronic databases (PubMed, Cochrane Plus and Web of Science) was conducted in January 2019 and included all papers until this time. The search period ranged from 1995 to 2020. The keywords used to identify the articles and restrict the population investigated in this review were: “young”, “youth”, “adolescent”, “adolescence”, “female”, “children” and “child”, which were combined with “reliability”, “repeatability”, “smallest worthwhile change”, “reproducibility”, “minimal detectable change”, “agility”, “unanticipated”, “cutting”, “manoeuvre”, “change of direction”, “side-step”, “side-cutting”, “training”, “intervention”, “test”, “testing”, “football” and “soccer”. Unpublished data or unpublished full-text reports were not included in the analysis, as well as those not published in English or Spanish.

Inclusion and exclusion criteria

Although no restrictions were made on the study design, eligibility criteria for study inclusion consisted of one of the following: (1) tests comparing results on two separate occasions under similar conditions (test-retest study design) to determine reliability, (2) at least one COD in tests, (3) tests examining factors that may affect COD performance, and/or (4) studies examining the effect of an intervention on COD performance. The principal author coded the studies according to the selection criteria. Moreover, studies were included if they: (1) were published in peer-reviewed journals, (2) used a COD test without a ball, (3) included female adolescents (using the World Health Organization´s definition of adolescent as the period of life between 10 and 19 years) (6) , and (4) included soccer players. Unpublished data and studies in new-borns or infants, adults or seniors and males were subsequently excluded.

Quality assessment

Eligible studies were assessed for methodological quality using two different tools. For cross-sectional studies, the “Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies” proposed by the National Hearts, Lung and Blood Institute (NIH National Heart, Lung, and Blood Institute, website) was used. This rates validity on a scale of 1-14 according to the following criteria: 1) Was the research question or objective in this paper clearly stated? 2) Was the study population clearly specified and defined? 3) Was the participation rate of eligible persons at least 50%? 4) Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants? 5) Was a sample size justification, power description, or variance and effect estimates provided? 6) For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured? 7) Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed? 8) For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome? 9) Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants? 10) Was the exposure(s) assessed more than once over time? 11) Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants? 12) Were the outcome assessors blinded to the exposure status of participants? 13) Was loss to follow-up after baseline 20% or less? 14) Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)? The scale used to assess studies interventions was adopted from a modified quality-assessment screening scoring system (8). This scale includes a 10-item scale (range 0–20) designed for rating the methodological quality of the studies. The items are as follows: 1) Inclusion criteria were clearly stated. 2) Subjects were randomly allocated to groups. 3) Intervention was clearly defined. 4) Groups were tested for similarity at baseline. 5) A control group was used. 6) Outcome variables were clearly defined. 7) Assessments were practically useful. 8) Duration of intervention was practically useful. 9) Between-group statistical analysis was appropriate. 10) Point measures of variability.

Table 4. Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies scores for the cross-sectional studies.

Studies	Item 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Score
Emmonds et al. (2018) (183)	+	+	+	-	+	NA	NA	NA	+	NA	+	-	NA	+	7
Hirose et al. (2015) (182)	+	+	-	+	+	NA	NA	NA	+	NA	+	-	NA	+	7
Mathisen et al. (2014) (181)	+	-	-	-	+	NA	NA	+	+	NA	+	-	NA	+	6
Meylan et al. (2014) (180)	+	+	-	-	+	NA	NA	NA	+	NA	+	-	NA	+	6
Mujika et al. (2009) (60)	+	+	-	-	+	NA	NA	+	+	NA	+	-	NA	+	7
Pardos-Mainer et al. (2019) (170)	+	+	-	+	+	NA	NA	NA	+	NA	+	-	NA	+	7
Vescovi et al. (2008) (179)	+	+	-	+	+	NA	NA	NA	+	NA	+	-	NA	+	7

Note: += yes; - = no; NA= Not applicable

Table 5. Modified quality-assessment screening scoring system scores for the intervention studies.

Studies	Item 1	2	3	4	5	6	7	8	9	10	Score
Lindblom et al. (2012) (30)	-	++	-	++	++	++	++	-	++	++	17
Mathisen et al. (2015) (184)	-	-	-	++	++	++	++	-	++	++	16
Noyes et al. (2013) (31)	-	/	++	++	++	++	++	++	++	-	16
Pardos-Mainer et al. (2019) (185)	/	++	++	++	++	++	++	++	++	++	19
Pardos-Mainer et al. (2019) (186)	/	++	++	++	++	++	++	++	++	++	19
Pérez et al. (2019) (125)	/	-	++	++	-	++	++	++	++	++	15
Vescovi et al. (2010) (126)	-	++	-	++	++	-	++	++	++	++	17
Wright et al. (2016) (135)	-	/	++	++	/	++	++	++	++	++	15
Wright et al. (2019) (137)	-	/	++	++	++	++	++	++	++	++	17

Note: ++ = Clearly yes; - = Clearly no; / = Maybe

Statistical analysis

The relative change in performance outcomes if mean and standard deviation were available was calculated by equation 1.

Equation 1: $((Mean_{post} – Mean_{pre}) / Mean_{pre}) \times 100$

$Mean_{pre}$ represents the baseline value, $Mean_{post}$ is the postintervention value.

Effect sizes (ES) were calculated according to Cohen (1988) and represent the difference between experimental and control condition means divided by the baseline standard deviation. This method permits the determination of the magnitude of the differences or the changes between the groups or experimental conditions for each study that provided absolute mean data and standard deviations. Magnitudes of change were classified as follow: ES<0.2 was defined as trivial; 0.2-0.6 was defined as small; 0.6-1.2 was defined as moderate; 1.2-2.0 was defined as large; >2.0 was defined as very large; and >4.0 was defined as extremely large.

EVIDENCE SYNTHESIS

Literature search

The initial search procedure yielded 221 records through the electronic databases. After removing duplicates and adding additional records identified through other sources, 185 publications were retained for the article selection process. Title and abstract selection excluded 44 articles. The remaining 35 records were further examined using the specified inclusion/exclusion criteria, and 19 records were subsequently rejected. Finally, 16 studies were included in the final analysis after performing the appropriate quality assessment. A summary of the article selection process can be found in **Figure 9**.

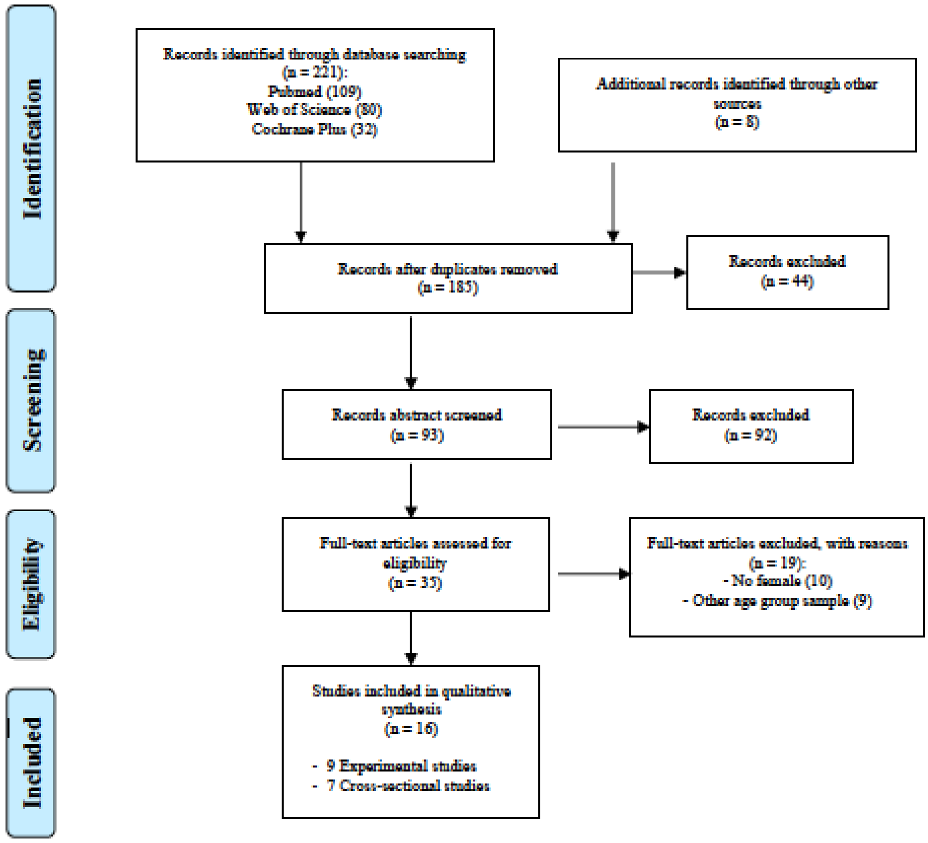


Figure 9. — Flow-diagram of study identification and exclusion process.

Methodological quality of studies

Seven cross-sectional studies (60, 170, 179-183) observed different factors affecting COD performance, yielding a mean score of 7/14 (range 6-7). Some of the criteria assessed were not applicable due to the type of variables measured (exposures that did not vary by amount or level, exposures measured only once over time or blinding assessors). Furthermore, some points were not reported in most of the studies, such as the rate of eligible persons or the drop-outs after baseline. Considering these difficulties, the highest achievable score was 10/14. A list of Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies scores can be found in **Table 4**.

Nine experimental studies (30, 31, 126, 135, 184) examined the effects of an intervention on COD ability performance, yielding a mean score of 16/20 (range 15-19). Most studies provided detailed and repeatable descriptions of methods, clearly defined outcome variables and used appropriate statistical analyses. Some studies did not include inclusion/exclusion criteria and/or a control group, nor test-retest reliability of the methods used. Scores of experimental studies can be observed in **Table 5**.

Cross-sectional studies

A total of 7 studies were of cross-sectional nature (60, 170, 179-183). In total, 885 participants (mean 113, maximum 213, minimum 36) were studied. Participants' age ranged from 9 to 17 years old (median 13 years), and their playing ability varied from recreational to professional. Five studies included only females and 3 included both, males and females (**Table 6**).

Experimental studies

A total of 9 studies were of experimental nature (**Table 7**) (31, 32, 125, 126, 135, 137, 184-186). In total, 349 participants (median 37, maximum 62, minimum 12) were studied. Participants' age ranged from 11 to 17 years old (median 14 years), and playing ability varied from recreational to professional. All studies included only females.

Study findings

ICC and coefficient of variation (CV) values ranged from 0.72 to 0.99 and 1% to 10.6%, respectively for COD tests in cross-sectional studies (**Table 6**). ICC values for COD tests showed in experimental studies ranged from 0.80 to 0.98 (**Table 7**). Three experimental studies (135, 185, 186) showed CV value (1.5-5.3%) for COD tests. The average training intervention period lasted for 9 weeks (range 6-12), except for one study (145) performed a strength intervention one day per week during 3 seasons. A neuromuscular training program has been performed by 4 studies (30, 31, 126, 185), 2 studies implemented a strength training program (137, 186) and three studies performed different training program such us, high intensity interval training program (HITT) (135), small sided game (SSG) (125) and speed (136). Five studies have a control and experimental group (30, 126, 136, 185, 186) and four studies have only experimental group (31, 125, 135, 137). Improvements in time to complete the COD test ranged from -2%; ES= -0.15 (neuromuscular training program) to -8.4%; ES = -1.45 (HIIT).

Table 6. — Cross-sectional studies characteristic regarding the reliability of COD speed tests in adolescent female soccer players.

Study	Population				Test and description	Reliability	QA
	Subjects	Age	Level	Sport			
Emmonds et al. (2018) (183)	157F	U-10: 9.25 ± 0.58 U-12: 11.41 ± 0.98 U-14: 13.22 ± 0.65 U-16: 15.05 ± 0.64	Highly trained	S	**5-0.5 test:** Players were placed 10m front the start point. Each player sprinted from the start, turning 180º at the 15m mark and sprinted back through the finish line.	CV: 2.2%	7
Hirose et al. (2015) (182)	135M/F	16.5 ± 0.5	Highly trained	S	**10m x 5COD:** 2.5 round trips between 2 lines drawn 10m apart, which necessitated four 180º turns alternating between the left and right foot, followed by a sprint for 10m in a straight line.	ICC: 0.89	7
Mathisen et al. (2014) (181)	36F	CG: 13.6 ± 0.2 TG: 13.7 ± 0.3	Trained	S	**Agility test:** 20 m, starting with 5m straight line sprint followed by a 90° turn, 2.5m straight-line sprint followed by a 180° turn, 5m slightly curved sprint followed by a 180° turn, 2.5m straight-line sprint followed by a 90° turn and 5m straight-line sprint. Best of two trials was recorded using photocells.	NS	6
Meylan et al. (2014) (180)	113M/F	F: 11.3 ± 0.9	Recreational	S, B, W, FH, R, N, SLS, A, C	**COD task:** 10m with two 100° turns, 2 m straight sprint section, a turn into backwards running section (4m), 2x2m side steps sections with two 100° turns, and a 1m straight sprint section. Finally, 10m straight sprint.	ICC: 0.72-0.94 CV: 1.6-10.6%	6

Mujika et al. (2009) (60)	68M/F	JF: 17.3 ± 1.6	Highly trained	S	**15m agility run:** Athletes started running 3 m behind the initial set of gates. After 3 m of line running, players entered a 3 m slalom section marked by three sticks 1.6 m high and placed 1.5. m apart, and then cleared a 0.5 m hurdle placed 2 m beyond the third stick, finally players ran 7 m.	NS	7
Pardos-Mainer et al. (2019) (170)	68 F	U-16: 14.2 ± 1.6 U-18: 17.1 ± 0.79	Trained	S	**180º COD:** Each player sprinted from the start/finish line, completely crossed the 5 m line with either right or left foot, and turned 180º to sprint back to the start/finish line. **V-cut test:** A 25 m sprint with four CODs of 45º 5 m each.	180ºCOD ICC: 0.80 to 0.82 CV: 1-1.7% V-cut test ICC: 0.75 to 0.76 CV: 2.1-2.2%	7
Vescovi et al. (2008) (179)	213F	HS: 15.1 ± 1.6	Recreational	S, L	**Modified Illinois test:** Athletes sprinted 9.1m from the start position to the second corner cone, turned to weave down and back through the centre line of cones, made one final change of direction at the third corner code, and finished with another sprint (9.1m) across the finish line. **Pro-agility test:** Athletes sprinted maximally from the starting line to the cone at the other end (9.1m), touched the ground with one hand, changed direction, sprinted back to the star line, again touched the ground with one hand, made a final change of direction to sprint through the finish line at the centre cone (4.6m).	NS	7

HS = High school; F = Female; M = Male; CG = Control group; TG = Training group; U = Under; COD = Change of direction; JF = Junior female; S = Soccer; B = Basketball; W = Waterpolo; FH = Field Hockey; R = Rugby; N = Netball; SLS = Surf lifesaving; A = Athletics; C = Cricket; L = Lacrosse; ICC = Intraclass correlation; CV = Coefficient of variation; QA = Quality assessment; NS = Non stated

Table 7. — Experimental studies characteristics regarding the reliability and results (effect size) of COD speed tests in adolescent female soccer players.

Study	Population				Weeks of intervention	Test and description	Reliability	Effects of intervention	QA
	Subjects	Age	Level	Sport					
Lindblom et al. (2012) (30)	52F	CG: 14.2 ± 1.1 IG: 14.2 ± 0.7	Trained	S	11	**MIT:** Athletes sprint 10 m, turns and returns back the starting line, then, he swerves in and out of four markers, completing two 10 m sprints to finish the agility course	ICC: 0.89	Neuromuscular warm-up 0.4% (ES: 0.08) CG -1.1% (ES: -0.26)	17
Mathisen et al. (2015) (184)	23F	CG: 15.1 ± 0.5 EG: 15.5 ± 0.7	Trained	S	8	**Agility test:** 20m, starting with 5m straight line sprint followed by a 90° turn, 2.5m straight-line sprint followed by a 180° turn, 5m slightly curved sprint followed by a 180° turn, 2.5m straight-line sprint followed by a 90° turn and 5m straight-line sprint.	ICC: 0.81	Speed training -5.2% (ES: -1.38) CG -0.3% (ES: -0.21)	16
Noyes et al. (2013) (31)	62F	15 ± 1	Recreational	S	6	**T-test:** Athletes sprinted from a standing point in a straight line to a cone placed 9.14 m away. Then, athletes shuffled to their left without crossing their feet to another cone placed 4.57 away. After touching this cone, the shuffled to their right to a third cone placed 9.14 m away, shuffled back to the middle cone, and then ran backwards to the starting position.	ICC: 0.90	Neuromuscular training program -6.14% (ES: 0.43)	16

Pardos-Mainer et al. (2019) (185)	36F	CG: 12.5 ± 0.4 EG: 13.1± 0.3	Trained	S	10	**180º COD:** Each player sprinted from the start/finish line, completely crossed the 5 m line with either right or left foot, and turned 180º to sprint back to the start/finish line. **V-cut test:** A 25 m sprint with four CODs of 45º 5 m each.	ICC 0.83-0.93 CV: 1.5-5.3%	Neuromuscular training program 180º COD right: 4% (ES: 0.32) 180º COD left: 0% (ES: -0.01) V-cut: 2% (ES: 0.59) CG 180º COD right: 5% (ES: 0.53) 180º COD left: -9% (ES: 0.28) V-cut: 6.6% (ES: 0.70)	19
Pardos-Mainer et al. (2019) (186)	37F	CG: 16.2 ± 0.9 EG: 15.6 ± 0.9	Trained	S	8	**180º COD:** Each player sprinted from the start/finish line, completely crossed the 5 m line with either right or left foot, and turned 180º to sprint back to the start/finish line. **V-cut test:** A 25 m sprint with four CODs of 45º 5 m each.	ICC: 0.80-0.86 CV: 2.4-2.5%	CSPT 180º COD right: -2% (ES: -0.15) 180º COD left: -7% (ES: -0.52) V-cut: -2.4% (ES: -0.58) CG 180º COD right: 4% (ES: 0.23) 180º COD left: -2% (ES: -0.28)	19

								V-cut: 1% (ES: -0.02)	
Pérez et al. (2019) (125)	12F	11.5 ± 0.5	Trained	S	14 sessions	**Agility test:** 20m, starting with 5m straight line sprint followed by a 90° turn, 2.5m straight-line sprint followed by a 180° turn, 5m slightly curved sprint followed by a 180° turn, 2.5m straight-line sprint followed by a 90° turn and 5m straight-line sprint.	NS	SSG MIT: -9% (ES: NS)	15
Vescovi et al. (2010) (126)	58F	CG: 16.8 ± 0.4 EG: 15.7 ± 1.2	Trained	S	12	**MIT:** Athletes sprinted 9.1m from the start position to the second corner cone, turned to weave down and back through the centre line of cones, made one final change of direction at the third corner code, and finished with another sprint (9.1m) across the finish line. **PAT:** Athletes sprinted maximally from the starting line to the cone at the other end (9.1m), touched the ground with one hand, changed direction, sprinted back to the star line, again touched the ground with one hand, made a final change of direction to sprint through the finish line at the centre cone (4.6m).	ICC MIT: 0.98 PAT: 0.94	PEP program MIT: NS PAT: NS	17
Wright et al. (2016) (135)	37F	13.4 ± 1.5	Highly trained	S	8	**MTT:** Athletes sprinted from a standing point in a straight line to a cone placed 5 m away. Then, athletes shuffled to their left without crossing their feet to another cone placed 2.5 away. After touching this cone, the shuffled to their right to a third cone placed 5 m away, shuffled back to the middle cone,	CV: 2%	HIIT -8.37% (ES: -1.45)	17

						and then ran backwards to the starting position.		
Wright et al. (2019) (137)	32F	12.1 ± 0.9	Trained	S	3 years	**180º COD:** Each player sprinted from the start/finish line, completely crossed the 5 m line with either right or left foot, and turned 180º to sprint back to the start/finish line.	NS	Strength training Year 1 and 2: -6.5% (ES: -1.63) Year 2 and 3: -1.9% (ES: -0.45) Year 1 and 3: -8.3% (ES: -2.09)

F = Female; IG = Intervention group; CG = Control group; MIT = Modified Illinois test; PAT = Pro-agility test; TE = Typical error; MTT = Modified T-test; HIIT = High intensity interval training program; PEP = Prevent injury enhance performance program; CSPT: Combined strength and power training; SSG: Small sided game; ICC =Intraclass correlation; CV: Coefficient of variation; S = Soccer; ES = Effect size; QA = Quality assessment; NS = Non stated

In **Table 8**, a total of 11 different COD tests were used in adolescent female soccer players. Two methods were used to quantify the COD times. Electronic timing gates (ET) were used in 75% of the studies, 10% used a handheld stopwatch (HHS). Mainly, 2 trials were performed in each study. Diverse surfaces were used to performed COD tests like rubber/parquet indoor surface (25%) or natural/synthetic surface (50%). Seven studies did a previous familiarization test at least 1 week before (60, 135, 170, 180, 185, 186). Four, two and five tests had a short (<5 s), middle (5-9 s) and large (>10 s) duration, respectively. The number of CODs was between 1 and 9 and the angle of directional change was within a range of 45º to 180º.

Table 8. Characteristics of the different COD speed tests commonly used.

Study	Test	Trials	Surface	Instrument	Familiarization	Period season	Time (sec)	No. CODs	ADC
Emmonds et al. (2018) (183)	5-0-5 test	3	Indoor	Electronic timing gates	NS	During season	0-5	1	180º
Hirose et al. (2015) (182)	10m x 5COD	2	Artificial turf	Handheld stopwatch	NS	NS	>10	5	180º
Lindblom et al. (2012) (30)	MIT	2	Indoor	Electronic timing gates	NS	March-June	>10	9	NS
Mathisen et al. (2014) (2015) (181, 184)	Agility test	2	Parquet floor	Electronic timing gates	NS	Preseason	5-9	3	90º; 180º
Meylan et al. (2014) (180)	COD task	NS	Rubber indoor surface	Electronic timing gates	Yes	NS	>10	5	100º
Mujika et al. (2008) (60)	15-m agility run	2	Synthetic football pitch	Electronic timing gates	Yes	Precompetitive	0-5	3	NS
Noyes et al. (2013) (31)	T-test	2	NS	Handheld stopwatch	NS	NS	>10	4	NS
Pardos-Mainer et al. (2018) (2019) (2020) (170, 185, 186)	180º COD	2	Artificial turf	Electronic timing gates	Yes	Pre- and midseason	0-5	1	180º
	V-cut	2	Artificial turf	Electronic timing gates	Yes		5-9	4	45º
Perez et al. (2019) (125)	Agility test	2	Artificial turf	NS	Yes	NS	5-9	3	90º; 180º

Vescovi et al. (2008) (179)	MIT	2	Rubbers indoor surface or artificial turf	Electronic timing gates	NS	NS	>10	9	NS
	PAT	2	Rubbers indoor surface or artificial turf	Electronic timing gates	NS		0-5	2	NS
Vescovi et al. (2010) (126)	MIT	2	Natural turf	Electronic timing gates	NS	NS	>10	9	NS
	PAT	2	Natural turf	Electronic timing gates	NS		0-5	2	NS
Wright et al. (2016) (135)	MTT	2	NS	Electronic timing gates	Yes	Preseason	5-9	4	NS
Wright et al. (2017) (137)	180º COD	2	NS	Electronic timing gates	NS	Pre, mid and postseason	0-5	1	180º

MIT = Modified Illinois test; PAT = Pro-agility test; MTT = Modified T-test; NS = Non stated; ADC = Angle of direction change;180ºCOD = 180º change of direction test

DISCUSSION

The purpose of this systematic review was threefold. Firstly, describe the most common tests used for assessing COD performance. Secondly, detail the reliability of current COD tests. Thirdly, provide an overview of current intervention strategies used to improve COD performance in adolescent female soccer players. Eleven COD tests within the searched scientific literature were retrieved. The reliability of the COD tests was dependent on differing factors such as the instrument used, the surface and/or the playing level of the soccer player. Finally, it is not clear what kind of training program is more beneficial to improve COD in this population, although some programs which include specific speed, COD speed or interval training have shown positive results.

Methodological quality

The mean scores of the studies when using the "Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies" and the modified quality assessment were 70% (range 60-80%) and 60% (range 50-80%), respectively. All the studies showed included high scores. Some studies showed a lack of detailed description of the screening tool, which did not allow test replication. For example, information on the type of surface used (31, 135) and the number of trials performed (188) were not reported, as well as a lack of previous familiarization (30, 31, 179, 181, 183, 184) and reliability of the screening tool (60, 125, 179, 181). Therefore, practitioners should be mindful that methods sections should be written so that processes are fully repeatable should practitioners want to it. Consequently, specific detail of the test, number of trials, rest periods taken and equipment used should be clearly described for methodological transparency.

Factors affecting tests reliability

The complexity of each test can be characterized by the time to complete the test, the number of COD, the total distance covered and/or the COD angles (164). Despite such different characteristics, it seems that reliability is similar across all the reported COD tests. Reliability may be quantified using the CV (i.e., absolute) and ICC (i.e., relative). It is worth noting to use both coefficients because of it is highly plausible that one of such coefficients may report strong reliability while the other shows unacceptable variability (187). When they are considered together, average reliability will be considered "good" if ICC > 0.67 and CV <10%, "moderate" if ICC < 0.67 or CV >10% or "poor" if ICC < 0.67 and CV > 10% (195). For instance, **Tables 3** and **4** illustrate the ICC and CV values for COD tests which range from 0.72 to 0.99 and from 1% to 10.6%, respectively. Two studies reported both coefficients (170, 180), while five studies reported ICC values (30, 31, 126, 184) and only one study showed the CV value (135). Pardos-Mainer et al., in several studies, (170, 185, 186) reported good reliability (ICC = 0.75-0.93) and small variability (CV = 1-5.3%) for both the 180ºCOD and the V-cut tests. Meylan et al. (180) showed good reliability (ICC = 0.72-0.94) and acceptable variability (CV = 1.6-10.6%) for COD task, though more variation was observed in this test.

Between-COD tests variations' may be due to subjects' participation in a multi-sport activity in the Meylan's study. Of all COD tests, the 180ºCOD had the greatest reliability (ICC = 0.80-0.82, CV = 1-1.7%). However, the tendency with those studies included in current review when measuring COD performance seems to be to report intraday reliability (ICC), resulting in a flawed measure of reliability as it assesses "rank-order consistency". In team sports, like soccer, players represent a homogenous sample and it means that very small changes in performance can result in player´s rank-order, changing the next test performance. When it happens, the ICC value decreases and gives a false impression of reduced reliability. Therefore, apart from reporting ICC values, measures of variability (CV) for COD tests would need to be calculated by practitioners.

Time measurement devices included ET (60, 125, 126, 170, 179, 180, 184-186) and HHS (31, 182). Two studies (31, 182) used HHS tools and reported a high ICC (0.89-0.90) whereas the rest of studies used ET and also showed a high ICC (0.72-0.99). Hetzler et al. (188) compared those times obtained by HHS with ET during a 200 m sprint in trained runners (8 males, 10 females). It was concluded that on the basis of the absolute error between HHS and ET, when greater precision is required, ET is more reliable method than HHS because the absolute error if it is less. Therefore, it is advisable to use ET to record COD times.

It is fundamental to understand the normal growth and maturation process of female soccer players for the systematic evaluation of the potential effects of regular physical activity (189). Youth soccer, like many sports, is organized into annual age groups according to chronological age. Unfortunately, players can have an advantage or disadvantage when performing tests due to their maturity status and relative age (born earlier or later in the year) (190), as chronological age and biological maturity rarely progress at the same rate (190-192). As such, these variables should be included to better understand either those changes reported in adolescents or a greater performance achieved in some players. Furthermore, basic improvements in one physical component (e.g., speed) during the early stages of maturation and growth may enhance performance in another one (e.g., COD speed) (139, 192). However, the majority of research studies have not reported the maturity status of adolescent soccer players; there are only six studies that have taken this into account (135, 137, 170, 180, 185, 186). These studies concluded that maturity should be taken into account when interpreting explosive and COD performance of adolescent female soccer players. Thus, the disruption of motor coordination, which is usually observed before peak height velocity (193, 194), might be a consideration in terms of the reliability of physical performance measures. Test familiarization is an important point to provide an accurate assessment of reliability (174, 195, 196). In the current review, seven studies reported a familiarization period before testing with high ICC values (0.75-0.99) (60, 135, 137, 170, 180, 185, 186). On the other hand, the rest of studies did not take this into consideration; however, ICC values were also high (0.72-0.98). Thereby, there is a lack of information regarding the procedures undertaken during the familiarization period for reliability establishment in COD testing, specifically concerning adolescent female soccer players of the studies. Given the aim is to reduce the risk of intra-participant variability, it is suggested that all players conduct familiarization sessions prior to data collection, even if they have performed the test protocols on multiple occasions.

In relation with the type of surface, both artificial turf and rubber/parquet indoor surface have shown similar high ICC values (>0.70) (30, 126, 170, 180, 182, 184). Artificial turf is developed to improve performance, provide more natural field and grass characteristics and reduce injuries (197). So that, artificial turf surface characteristics are more related with soccer´s demands than rubber or parquet indoor. Moreover, the changes in surface characteristics may affect kinetic patterns of players, potentially perturbing their technical performance of skill specific activities during competition (198). Hence, it seems necessary to performance COD tests on artificial turf to reflect accurately how quickly players can actually change of direction.

Finally, some studies have shown an improvement in COD performance as the season progressed (199, 200), attributing these increases to the training and match play. In addition, COD performance also showed significant decreases during the off-season period (199, 201). These findings may indicate that soccer players are less fit at the beginning of the season which could affect the reliability values. Therefore, any changes in performance throughout the season should be accompanied by further data analysis.

The smallest worthwhile change can be calculated by multiplying the standard deviation by 0.2 (202) and if such values are used in conjunction with absolute reliability data such as the CV or standard error of the measurement, this will enable practitioners to distinguish between which changes are 'real' and changes inside the error of the test (210).

Characteristics of different cod tests

Table 5 shows the COD tests included in this review. The tests aiming to assess COD can be grouped according to the time to complete the test and the number and type of COD involved (172).

The duration and intensity of the COD tests are determined by the relative contribution of the energy system involved in performance (172). The anaerobic energy system uses phosphocreatine for the first 5-10 s of exercise (203, 204). In this regard, the pro-agility test, 180ºCOD, 5-0-5 test and the 15 m agility run test last less than 5 s. The rest of the COD tests last approximately 5-9 s or > 10 s; from then, the aerobic system starts releasing energy (203). Although the tests with duration of more than 5 s might be chosen in relation to the energetic system used in soccer, the selection of a COD test should be based on the movement patterns and requirements presented in soccer rather than in the energetic system used. Given previous research has highlighted that soccer players can change direction every 2-4 s (167), it seems prudent to suggest that COD tests should err on the side of shorter durations.

The number of COD varies among tests, from 1 to 9. Certain tests (pro-agility test,180ºCOD, 5-0-5 test, agility test, 15 m agility run) have 1, 2 or 3 directional changes, while others like the MIT includes 9 COD. Barnes et al. (36) reported that in team sports, players are mostly subjected to sharp COD (e.g., 180º turn) during sprints of 5 m, involving only one COD. As a consequence, tests including a COD with large angle changes could be considered the most appropriate. This is further supported in recent research from Dos'Santos et al. (205) who highlighted a trade-off between velocity and the angle when changing direction. It was suggested that angles < 45° require minimal braking, which enables velocity to be maintained. Thus, in order to truly test the transition from braking to propulsive force actions during COD tests, larger COD angles might be a strong consideration for test selection (156).

The sharp 90º and 135º COD require the players to adapt a sideways learning posture in order to apply enough lateral force to the ground to successfully change direction at high speed (206). Players are also likely to require adjustments to the stride pattern when decelerating and accelerating around each stick (206). In the current review, 8 studies (170, 180-196) indicated angle of directional change within a range of 45 to 180º. It is important to acknowledge that the majority of COD-runs in soccer matches occur within a range of 0 to 90º (92). Therefore, COD tests require > 90º angles which will need pre-test familiarisation to improve reliability values.

Training

Nine studies investigated training influences on COD. Five studies (31, 135, 137, 184, 186) have reported improvements in COD performance after different training programs, two studies reported a decline in COD performance (30, 185) and another one did not report any change (126). It is well known that strength and power development may have a positive impact on COD performance (207). For this reason, training programs should focus on working strength and power development. Three studies (32, 30, 185) investigated the effects of a neuromuscular training program on the 180ºCOD, the V-cut test, the MIT and the T-test. Theses training programs included core stability, balance, lower-limb strength and flexibility exercises. The only difference between them was that two studies used the program as a warm up (15 min; 11 weeks; 2 days per week) (30), while the other used to program as main sessions (90-120 min; 6 weeks; 3 days per week) (31). The warm up training protocol did not improve the MIT performance (0.4%; ES = 0.08) while the control group that did not perform the training program, improved such performance (-1.1%; ES = -0.26) (32). In relation with these results, Pardos-Mainer et al. neither showed improvements in the 180ºCOD (0-4%; ES = -0.01; -0.59) This could indicate that the neuromuscular program used like a warm up did not provide sufficient stimulus to improve COD performance. In contrast, Noyes et al. (31) found different results in the T-test duration with a neuromuscular training protocol (-6.14%; ES = 0.43). This may be due to different factors like duration, frequency and the number of training sessions per week.

Vescovi et al. (126) investigated the effects of 12 weeks of 3 days per week of the Prevent Injury Enhance Performance program in the MIT and PAT tests. They observed a decline on performance in both the experimental and the control group. Similar results were found by Lindblom et al. (30). In this regard, while the control group improved their performance, the performance of the experimental group declined. Due to these reasons, we hypothesize that these may be due to intervention programs where warm-ups were performed regularly prior to scheduled practices and has a short duration of 15-20 min.

Mathisen et al. (184), Pardos-Mainer et al. (186) and Wright et al. (135, 137) investigated the effects of speed, agility, strength and interval training with the agility test, the 180ºCOD, the V-cut test and the MTT, respectively and all reported significant improvements. The female players in the study of Mathisen et al. (184) performed speed training for 8 weeks and reported a significant improvement in the agility test (-5.2%; ES = -1.38) compared with the control group (-1.1%; ES = -0.26). Pardos-Mainer et al. (186)

performed a CSPT in 36 adolescent female soccer players. They observed improvement in the 180ºCOD (-7; -2%; ES = -0.52; -0.15) and the V-cut test (-2.4%; ES = -0.58) after 8 weeks. Against, the control group did not show positive results (-2;4%; ES = -0.28;0.23). Wright et al. (135) also reported a significant improvement in the MTT duration (-8.37%; ES = -1.45) after 8 weeks of HIIT, concretely in after-PHV players. In other study, the same author showed positive results after a strength training program in 180ºCOD (-1.9; -8.3%; ES = -2.09; -0.45) during 3 years one day per week (137). Both studies had not a control group. According to these results and previously commented, it seems to be that strength and power drills have a positive impact on COD performance.

Limitations of the present review and directions for future research

This systematic review provides some practical guidelines and considerations to be used when performing COD ability tests in adolescent female soccer players; however, there are some significant limitations that require acknowledgement.

The present review is focused in COD speed and not in agility because some scientist evidences show that many true agility tests are not actually reliable (62). Furthermore, the maturational status, the menstrual cycle, the time of the day, the training block, the period of the season and the playing position of the participants was not always reported. In relation with menstrual cycle, some studies have observed the effects of the phase of the menstrual cycle on performance (208, 209), and the findings in the literature are equivocal. There have been no studies of this review examining the impact of the menstrual cycle phase on COD performance. Therefore, this factor would be beneficial to observe to aid the understanding of whether the menstrual cycle phase significantly effects on COD performance; thus, affecting the reliability values. Then, further research should be done to evaluate COD in each soccer playing position with their specified test and the effects of the phase of the menstrual cycle on COD performance. In addition, prospective studies in adolescent female soccer players are necessary to make well-oriented recommendations to trainers and coaches. Ideally, they should include large sample sizes and report reliability values from each test used. Finally, considerations concluded in the present review are really interesting in adolescent female soccer players. Although it is possible that some of them, such us characteristics of COD tests or factors that affect test reliability, can be informative to adolescent male soccer. However, it is necessary to be very caution in using this information

CONCLUSIONS

Change of direction ability in adolescent female soccer players can be evaluated with different tests, however the 180ºCOD seems to be the most appropriate to replicate the movement patterns of soccer. The reliability of the COD ability tests depends on the instruments used such as electronic timing gates, the surface and/or the playing level of the soccer player. Test results should be interpreted with caution as they may be influenced by the period in growth and maturation, the playing position of the player and the period of the soccer season. Specifically, strength and power drills can improve change of direction ability in female soccer players whereas results on neuromuscular training need further investigation. Finally, the characteristics of an ideal test to assess the COD ability in soccer should be only one COD with a duration of less than <5 s and at a COD angle within a range <90º.

4.2. Artículo II [Manuscript II]

Reliability and sensitivity of jumping, linear sprinting and change of direction ability tests in adolescent female football players.

Pardos-Mainer E, Casajús JA, Gonzalo-Skok O. Reliability and sensitivity of jumping, linear sprinting and change of direction ability tests in adolescent female football players. Sci Med Football. 2019;3(3):183-190.

ABSTRACT

Purpose: The aim of this study was to assess the reliability, sensitivity and performance changes across the season of jumping, linear sprinting and change of direction ability (CODA) tests in adolescent female football players.

Materials and methods: Sixty female football players (U-16 and U-18) performed bilateral and unilateral countermovement jump tests, a single leg hop test, a 40-m linear speed test, and two CODA tests on 2 occasions separated by 5-7 days to assess test-retest reliability. Furthermore, test sensitivity was also calculated. Finally, fifty-two players performed each test 3 times throughout the season to analyse those performance changes.

Results: Reliability scores showed *a priori* acceptable values in U-16 (ICC= 0.76-0.94; CV= 1.0%-4.8%) and U-18 (ICC= 0.75-0.99; CV= 1.0%-3.6%) in all tests. All tests were sensitive to detect large changes at both short- and mid-term with the exception of the V-cut test (only at short-tem) in both groups. Seasonal changes were mainly produced between baseline and Test 3 in linear sprinting and jumping measurements in U-16 and U-18, respectively.

Conclusions: Jumping, linear sprinting and CODA tests are reliable and can detect moderate to large performance changes and they could be used to monitor their performance in U-16 and U-18 female football players.

Keywords: Team sports, youth, lower body, high-intensity, linear speed, change of direction.

INTRODUCTION

Women's football has increased in popularity and participation during the last decade (166). Such impact has had consequences through both a greater skill level and physical demands throughout trainings and matches (210). Given that there are between-sex differences, women's football should be analysed specifically. In this regard, it has been reported that female players cover a total distance of approximately 10 km with 1.7 km completed at high-speed (>18 km/h^{-1}) (211, 212), perform between 1350 and 1650 changes of activity such as passing, dribbling, tackling and trapping (211, 212) and carry out 5.1 and 31.2 repeated sprints and high intensity bouts, respectively (213). Despite its growing popularity, female players are exposed to greater training volumes and competition demands than ever before and, therefore, a better understanding of female players' physical performance changes is needed to design appropriated training programs.

Football players can be assessed through several physical fitness tests (i.e., vertical jump, Illinois agility test, 40-m sprint). Such tests are divided into laboratory tests and football-specific field tests (214). Even though laboratory tests are considered reliable and useful in measuring general fitness level, these tests are less affordable, too expensive and more time-consuming than football-specific field tests. On the other hand, football-specific field tests are much popular among strength and conditioning coaches, due to their simplicity, lower costs and minimal use of equipment. While the reliability and validity of several tests have been assessed in male football players (215, 216), it has been poorly investigated in females (169, 217). Furthermore, the sensitivity of a test is of key importance in outcome studies. It is defined as the ability to detect practically relevant changes or differences (14). A test can actually be a priori deemed to be reliable but if the test is unable to detect the relatively small, but meaningful, changes in response to an intervention cannot be considered as practical (96). Unfortunately, this property has been often overlooked, and information about the sensitivity of jumping, sprinting and change of direction ability (CODA) tests is scarce in female football players.

Therefore, the aims of this study were: 1) to investigate the reliability and sensitivity of jumping, linear sprinting and CODA tests, and 2) to determine short- and mid-term change across the season in a cohort of U-16 and U-18 female football players.

METHODS

Participants

A total of 68 female football players (U-16 and U-18) belonging to the same female football division club academy squad (Iberdrola Women's First Division) participated in this study. Their maturational status was assessed through age at peak height velocity (APHV) (218), but validation studies indicated several limitations in this equation such as the lack of a measurement of sitting height and a typical error of measurement of 0.5 years (219, 220). All players were training in a football club for at least 4 years. Physical sessions of different teams consisted on speed, agility and quickness training, injury prevention or coordination exercises allowing to maintenance physical fitness level. At the time of the study, all players were competing at national and regional level (i.e., Spanish Female Football National League, Aragón Female Football Territorial League). Furthermore, some players (n = 4) were also competing at international level (i.e., European Female Football Championships). Data collection for the reliability study took place in the second month of the competitive season (November) after a 2-month pre-season period (August-September) (**Table 9**) and involved 60 female football players (age: 15.7 ± 1.2 years; height: 159.1 ± 6.5 cm; body mass: 55.1 ± 8.9 kg). In the second investigation, 52 players (age: 15.9 ± 1.4 years; height: 159.4 ± 6.5 cm;

Table 9. Subject characteristics.

Group	n	Age (y)	APHV	Height (cm)	Body mass (kg)	Body mass index (kg/m^2)	Training practical (h·w^{-1})
U-16	37	14.2±1.6	-0.66±0.98	157.9±6.8	51.8±7.8	20.7±2.4	~ 4 hours (1 technical-tactical sessions + 2 physical sessions)
U-18	23	17.1±0.79	0.41±0.32	160.2±6.1	58.4±10.1	22.6±2.7	~ 4 hours (1 technical-tactical sessions + 2 physical sessions)

Values are mean ±SD. APHV: Age at peak height velocity; BMI: Body mass index body mass: 55.6 ± 8.7 kg) performed the jumping, linear sprinting and CODA tests throughout the season to determine the short- (September- November) and mid-term (September-February) changes across the season.

Participants were healthy and they did not suffer any disease or injury that could affect the results at the moment of study. Parental/guardian consents for all players involved in this investigation were obtained. The study was conducted according to the Declaration of Helsinki and was approved beforehand by the local ethics committee.

Experimental Design

Participants were assessed at baseline (test-retest reliability) and again at 12 (short-term) and 24 (mid-term) weeks on jumping, linear sprinting and CODA tests by the same group of investigators during the entire study, at the same time of the day (6 PM to 8 PM) and under the same environmental conditions (~22ºC and ~20% of humidity) in a football field. One week prior to the commencement of the study, players performed two familiarization trials (jumping, linear sprinting and CODA tests) to avoid any learning effect. Before performing the tests, a warm-up, consisting of jogging (3 min), lower-limb dynamic stretches (4 min) and high-intensity activities (4 min), was performed. Thereafter, before executing all tests, two practice trials were allowed with 30 s (jumping tests) or 2 min (linear sprint and CODA tests) of passive recovery between practice trials. Two min of passive recovery was allowed between-tests and between practice and test trials. Players wore athletic shoes (jumping tests) and football boots (linear sprint and CODA tests) in the field tests.

Bilateral countermovement jump test and unilateral countermovement jump test

Jumping height was assessed using a vertical countermovement jump (CMJ) (Optojump, Microgate, Bolzano, Italy). Elevation of the centre of the gravity was calculated for all jumps as flight time (Ft) in seconds, applying the laws of ballistics: H =

g(tv)2/8 (m); where H is the height and g is the gravitational acceleration. Each trial was validated by a visual inspection to ensure that each landing was without any leg flexion, and players were instructed to maintain their hands on their hips during CMJ. The depth of the CMJ was self-selected. CMJ was performed three times, separated by 45 s of passive recovery, and the best jump was recorded and used for analysis. The same criterion was used to assess the unilateral countermovement jump (UCMJ). Leg swing of the alternate leg was allowed. The mean between both the best left leg performance and the best right leg performance was used for the subsequent analysis.

Single leg hop test

The single leg hop test (SLH) was measured using a standard measuring tape. Each subject standing with the toes of the designated leg positioned just behind a starting line (marked with tape) and with hands relaxed at sides. When ready, each subject flexed and then rapidly extended the assessed leg, jumping as far as possible (forward distance), and landing on the same limb holding balance during 2-3 s (16, 221). When landing, players should maintain the balance position for 2-3 s. The distance jumped was measured from the tip of the foot (starting point) to the heel. Both leg swing of the alternate leg and arm swing were allowed. Each test was performed twice, separated by at least 45 s of passive recovery, and the best jump was recorded and used for analysis. The mean between both the best left leg performance and the best right leg performance was used for the subsequent analysis.

40-m speed test

Running speed was evaluated by 40-m sprint time (standing start) with 10-m, 20-m, 30-m split times. The front foot was placed 0.5 m before the first timing gate. Time was recorded with photoelectric cells (*Microgate, Bolzano, Italy*). One pair of the electronic timing system sensors mounted on tripods was set at 0.75 m above the floor and was positioned 3 m apart facing each other on either side of the starting line (222, 223). The 40-m sprint was performed twice, separated by at least three minutes of passive recovery. The best time was recorded for analysis.

180º Change of direction test

Players performed a 10-m sprint test with a 180ºCOD. 180ºCOD is a modification of the traditional 505 test (94), which has reported high levels of test-retest reliability (ICC = 0.88 and typical error 2.4%) (95) and it has been validated (223), where the front foot was placed 0.5m before the first timing gate (*Microgate, Bolzano, Italy*) and a 10-m sprint test was performed. One pair of the electronic timing system sensors mounted on tripods was set at 0.75 m above the floor and was positioned 3 m apart facing each other on either side of the starting line. Each player sprinted from the start/finish line, completely crossed the 5 m line with either right or left foot, and turned 180º to sprint back to the start/finish line. The 180ºCOD was executed twice with each leg. Between-repetitions recovery was two min. The mean time between the best time of each leg was used.

V-cut test

Players performed a 25-m sprint with four CODs of 45º 5 m each (224). Sprint times were measured by dual beam photocell systems (Microgate, Bolzano, Italy). The front foot was placed 0.5 m before the first timing gate (Microgate, Bolzano, Italy). One pair of the electronic timing system sensors mounted on tripods was set approximately 0.75 m above the floor and was positioned 1.5 m apart facing each other on either side of the starting line. There were marks on the floor and cones, so subjects knew when to change of direction. For the trial to be valid, players had to pass the line, placed on the floor, with one foot completely at every turn. If the trial was considered a failed attempt, a new trial was allowed. The distance between each pair of cones was 0.7 m. The V-cut test was executed twice and 3 min of passive recovery was provided between repetitions. Time in the best (fastest) trial was retained.

Statistical Analyses

Data are presented as mean ± SD. The distribution of each variable was examined with the Kolmogorov-Smirnov normality test. All data were normally distributed. Relative reliability analysis was examined by the intra-class correlation coefficient (ICC). An ICC > 0,70 was considered acceptable (225, 226). To examine absolute reliability, pairwise comparisons were first applied. The significance level was set at $p \leq 0{,}05$. The magnitude of between-sessions differences was also expressed as standardized mean difference (Cohen effect sizes, ES). The criteria to interpret the magnitude of the ES's were as follows: <0.2 = trivial, 0.2-0.6 = small, 0.6-1.2 = moderate, and >1.2 = large (154). The Hopkins' spreadsheet (227) was also used to determine the change in the mean between trials and the typical error of measurement (TEM), expressed as a coefficient of variation (CV). A CV of less than 5% was set as the *a-priori* criterion for reliability. The sensitivity of the test was assessed while comparing the smallest worthwhile change (SWC) with those changes produced throughout the season. The SWC was determined by multiplying the between-subject SD by 0.2 ($SWC_{0.2}$), which corresponds to a small effect, 0.6 ($SWC_{0.6}$), which correspond to a moderate effect, and 1.2 ($SWC_{1.2}$), which corresponds to a large effect. If the changes were higher than the SWC, the test was rated as "good"; if the changes were similar to the SWC, the rating was "OK"; and if the changes were lower than the SWC, a rating of "marginal" was given (14). Furthermore, the short- and mid-term changes in jumping, linear sprinting and CODA performance between baseline (i.e. start of the season after 4 weeks of pre-season) and T1 (~ 12 weeks) and T2 (~ 24 weeks), respectively, in a cohort of U-16 and U-18 female football players during a regular competitive season during a regular competitive season were assessed.

An ANOVA of repeated measurements (3 times) was performed to know if there were significant differences between moments. A Bonferroni post-hoc analysis was carried out when it was needed (Version 19.0; SPSS Inc, Chicago, IL). Homogeneity of variance was evaluated using a Mauchly test of sphericity, and the Greenhouse-Geisser adjustment was used if assumptions of spherecity were violated. A significant effect was considered when $p < 0.05$.

RESULTS

Test-retest reliability

ICC and CV values were *"a priori"* acceptable in both U-16 (ICC= 0.76 to 0.94; CV= 1.0% to 4.8%) and U-18 (ICC= 0.75 to 0.99; CV= 1.0% to 3.6%). There were substantial between-trial differences in linear sprinting test (10-m, 20-m, 30-m and 40-m) and V-cut test in the U-16 cohort (i.e., 0.2<ES<0.6). However, there were no substantial between-trial differences in the U-18 group (i.e., ES<0.2). All the other measures of reliability of all tests are presented in **Table 10** (U-16) and **Table 11** (U-18).

Table 10. Measures of reliability in jumping, linear sprinting and CODA tests in U-16 female soccer players (n = 37)

Test	Trial 1	Trial 2	TEM (90% CL)	CV (90% CL)	ICC (90% CL)	Difference (90% CL)	ES (90% CL) (rating)	SWC $_{0.2}$ (%) (rating of usefulness)	SWC $_{0.6}$ (%) (rating of usefulness)	SWC $_{1.2}$ (%) (rating of usefulness)
CMJ	21.7 ± 3cm	21.7 ± 3cm	1.03cm (0.86 to 1.31)	4.8% (3.9 to 6.1)	0.89 (0.81 to 0.94)	-0.03cm (-0.47 to 0.41)	0 (Trivial)	0.6cm (2.8%) (Marginal)	1.8cm (8.3%) (Good)	3.6cm (16.6%) (Good)
CMJU	10.8 ± 2.5cm	11 ± 2.6cm	0.56cm (0.41 to 0.71)	4.8% (4 to 6.2)	0.95 (0.92 to 0.97)	0.11cm (-0.13 to 0.35)	0.08 (Trivial)	0.51cm (4.7%) (Marginal)	1.53cm (14%) (Good)	3.06cm (14.2%) (Good)
SLH	119.8 ± 14.1cm	120 ± 14.3cm	4.02cm (3.35 to 5.08)	3.8% (3.2 to 4.9)	0.92 (0.87 to 0.96)	0.11cm (-1.57 to 1.78)	0.01 (Trivial)	2.84cm (2.4%) (Marginal)	8.52cm (7.1%) (Good)	17.04cm (14.2%) (Good)
10m	2.05 ± 0.09s	2.09 ± 0.1s	0.05s (0.04 to 0.06)	1.8% (1.4 to 2.4)	0.75 (0.56 to 0.87)	0.04s (0.02 to 0.06)	0.42 (Small)	0.03s (0.9%) (Marginal)	0.09s (2.8%) (Good)	0.18s (5.5%) (Good)
20m	3.56 ± 0.14s	3.62 ± 0.16s	0.06s (0.05 to 0.08)	1.3% (1 to 1.7)	0.85 (0.72 to 0.92)	0.06s (0.03 to 0.09)	0.4 (Small)	0.06s (0.8%) (Marginal)	0.17s (2.5%) (Good)	0.33s (5%) (Good)
30m	5.08 ± 0.25s	5.16 ± 0.31s	0.07s (0.06 to 0.09)	1.3% (1 to 1.7)	0.94 (0.88 to 0.97)	0.07s (0.04 to 0.11)	0.29 (Small)	0.07s (1.1%) (Marginal)	0.21s (3.3%) (Good)	0.42s (6.7%) (Good)
40m	6.53 ± 0.33s	6.63 ± 0.37s	0.08s (0.06 to 0.11)	1% (0.8 to 1.4)	0.96 (0.91 to 0.98)	0.10s (0.06 to 0.14)	0.29 (Small)	0.02s (1.1%) (Good)	0.06s (3.2%) (Good)	0.13s (6.4%) (Good)
180ºCOD	3.01 ± 0.10s	3.01 ± 0.11s	0.05s (0.04 to 0.06)	1.7% (1.4 to 2.3)	0.82 (0.68 to 0.90)	-0.01s (-0.03 to 0.02)	0 (Trivial)	0.02s (0.7%) (Marginal)	0.06s (2.1%) (Good)	0.13s (4.2%) (Good)
VCUT	7.71 ± 0.37s	7.82 ± 0.47s	0.16s (0.12 to 0.23)	2.1% (1.6 to 3.0)	0.76 (0.50 to 0.89)	0.11s (0.01 to 0.21)	0.26 (Small)	0.08s (1.1%) (Marginal)	0.25s (3.3%) (Good)	0.5s (6.5%) (Good)

CMJ: countermovement jump; UCMJ: unilateral countermovement jump; SLH: single leg hop test; COD180º: average of both left and right leg in 5+5 m sprint test with a 180º change of direction; V-cut: 25-m sprint test with 4 x 45º changes of direction; cm: centimetres; s: seconds; m: meters; n= final number of participants; TEM: typical error of measurement; .CL: confidence limits; CV: coefficient of variation expressed as percentage of TEM; ICC: Intraclass correlation coefficient; Difference: difference in mean between the 2 trials; ES: effect size and ES rating (see Methods); SWC: smallest worthwhile change (0.2 x standard derivation = $SWC_{0.2}$; 0.6 x standard deviation = $SWC_{0.6}$; 1.2 x standard derivation = $SWC_{1.2}$ and rating of usefulness

Table 11. Measures of reliability in jumping, linear sprinting and change of direction ability tests in U-18 female soccer players (n = 23)

Test	Trial 1	Trial 2	TEM (90% CL)	CV (90% CL)	ICC (90% CL)	Difference (90% CL)	ES (90% CL) (rating)	SWC $_{0.2}$ (%) (rating of usefulness)	SWC $_{0.6}$ (%) (rating of usefulness)	SWC $_{1.2}$ (%) (rating of usefulness)
CMJ	22.3±4cm	22.2±3.5cm	0.75cm (0.55 to 1.19)	3.6% (2.7 to 5.8)	0.97 (0.91 to 0.99)	-0.11cm (-0.69 to 0.47)	-0.03 (Trivial)	0.75cm (3.4%) (Marginal)	2.25cm (10.1%) (Good)	4.5m (20.2%) (Good)
CMJU	12.7±3.2cm	12.2±3cm	0.44cm (0.32 to 0.72)	3.6% (2.4 to 7.6)	0.99 (0.95 to 1)	0cm (-0.36 to 0.36)	-0.16 (Trivial)	0.62cm (5%) (Marginal)	1.86cm (15.1%) (Good)	3.72cm (30.1%) (Good)
SLH	125.6±12cm	124.1±13.4cm	2.21cm (1.65 to 3.43)	1.6% (1.1 to 3)	0.98 (0.93 to 0.99)	-1.50cm (-3.12 to 0.12)	-0.12 (Trivial)	2.54cm (2%) (Marginal)	7.62cm (6.1%) (Good)	15.2cm (12.2%) (Good)
10m	2.05±0.09s	2.06±0.09s	0.04s (0.03 to 0.07)	2.2% (1.7 to 3.3)	0.79 (0.54 to 0.91)	0.01s (-0.02 to 0.04)	0.11 (Trivial)	0.03s (0.9%) (Marginal)	0.09s (2.6%) (Good)	0.11s (5.3%) (Good)
20m	3.59±0.15s	3.60±0.16s	0.07s (0.05 to 0.10)	1.8% (1.4 to 2.7)	0.85 (0.65 to 0.94)	0.02s (-0.02 to 0.06)	0.06 (Trivial)	0.03s (0.9%) (Marginal)	0.09s (2.6%) (Good)	0.19s (5.2%) (Good)
30m	5.07±0.23s	5.08±0.23s	0.08s (0.06 to 0.11)	1.5% (1.1 to 2.2)	0.91 (0.78 to 0.96)	0.01s (-0.04 to 0.06)	0.04 (Trivial)	0.05s (0.9%) (Marginal)	0.14s (2.7%) (Good)	0.28s (5.4%) (Good)
40m	6.57±0.33s	6.57±0.32s	0.11s (0.08 to 0.17)	1.7% (1.3 to 2.5)	0.90 (0.76 to 0.9)	0s (-0.08 to 0.07)	0 (Trivial)	0.07s (0.9%) (Marginal)	0.19s (2.9%) (Good)	0.39s (5.9%) (Good)
180ºCOD	2.98±0.14s	2.97±0.12s	0.06s (0.05 to 0.10)	1% (0.7 to 2.2)	0.80 (0.55 to 0.92)	-0.02s (-0.06 to 0.03)	-0.08 (Trivial)	0.03s (0.8%) (Marginal)	0.08s (2.6%) (Good)	0.16s (5.2%) (Good)
VCUT	7.74±0.26s	7.79±0.43s	0.19s (0.14 to 0.31)	2.2% (1.5 to 4.3)	0.75 (0.39 to 0.91)	0.08s (-0.07 to 0.23)	0.12 (Trivial)	0.07s (0.9%) (Marginal)	0.21s (2.7%) (Good)	0.41s (5.3%) (Good)

CMJ: countermovement jump; UCMJ: unilateral countermovement jump; SLH: single leg hop test; COD180º: average of both left and right leg in 5+5 m sprint test with a 180º change of direction; V-cut: 25-m sprint test with 4 x 45º changes of direction; cm: centimetres; s: seconds; m: meters; n= final number of participants; TEM: typical error of measurement; .CL: confidence limits; CV: coefficient of variation expressed as percentage of TEM; ICC: Intraclass correlation coefficient; Difference: difference in mean between the 2 trials; ES: effect size and ES rating (see Methods); SWC: smallest worthwhile change (0.2 x standard derivation = $SWC_{0.2}$; 0.6 x standard deviation = $SWC_{0.6}$; 1.2 x standard derivation = $SWC_{1.2}$ and rating of usefulness

Sensitivity

U-16

No test was sensitive to detect small changes at any time in the U-16 cohort group with the exception of linear sprinting measurements (10-m, 20-m, 30-m and 40-m) at both short- and mid-term.

CMJ, 180ºCOD and V-cut were sensitive to detect moderate changes at mid-term in the U-16 group. Furthermore, as ocurred with small changes, linear sprinting measurements were also sensitive at both short- and mid-term.

All measurements were sensitive to detect large changes at both short- and mid-term, with the exception of the V-cut test (only at short-term). For details check the **Table 12**.

U-18

No measurement was sensitive to detect small changes at both short- and mid-term.

While COD tests were sensitive to detect moderate changes at short-term, CMJ showed to be sensitive at mid-term. Furthermore, horizontal jumping and linear sprinting were also sensitive to detect moderate changes at short-term as well as mid-term.

All measurements were sensitive to detect large changes at both short- and mid-term, with the exception of the V-cut test (only at short-term). For details check the **Table 13**.

Table 12. Responsiveness of jumping, linear sprinting and CODA tests in U-16 female soccer players at different stages of the season (n = 30)

	Variable	Baseline	Post-	ES (CL90%)	% (CL90%)	Chances	Outcome
CMJ (cm) CV: 4.8% SWC: 2.76%	2-3	23.3±3.40cm	22.5±3.48cm	-0.11 (-0.53; 0.30)	-1.8 (.8; 4.8)	5/75/20%	Very Unlikely
	2-4	23.3±3.40cm	24.7±3.93cm	0.35 (-0.10; 0.79)	5.6 (-1.5; 13.2)	57/42/1%	Possibly
	3-4	22.5±3.48cm	24.7±3.93cm	0.51 (0.19; 0.84)	8.9 (3.2; 14.9)	89/11/0%	Likely
UCMJ (cm) CV: 4.8% SWC: 4.68%	2-3	12.5±2.59cm	12.3±2.5cm	0.03 (-0.19; 0.25)	0.7 (-4.2; 5.8)	9/88/3%	Very Unlikely
	2-4	12.5±2.59cm	13.7±2.68cm	0.40 (0.11; 0.69)	9.6 (2.6; 17)	87/13/0%	Likely
	3-4	12.3±2.5cm	13.7±2.68cm	0.48 (0.25; 0.70)	11.2 (5.8; 16.9)	97/3/0%	Very likely
SLH (cm) CV: 3.8% SWC: 2.6%	2-3	126.5±13cm	122.5±17cm	-0.19 (-0.46; 0.09)	-2 (-4.9; 1)	0/85/15%	Very Unlikely
	2-4	125.9±17.6cm	133.7±16.8cm	0.49 (0.24; 0.74)	5.5 (2.7; 8.4)	84/16/0%	Likely
	3-4	124.8±22.5cm	133.7±16.8cm	0.55 (0.31; 0.78)	8.7 (4.9; 12.6)	98/2/0%	Very likely
10m (s) CV: 1.8% SWC: 0.92%	2-3	2.06±0.12s	2.01±0.09s	-0.34 (-1.02; 0.34)	-2 (-5.8; 2.1)	6/41/53%	Possibly
	2-4	2.06±0.12s	2±0.09s	-0.52 (-0.93; -0.1)	-3 (-5.3; -0.6)	0/19/81%	Likely
	3-4	2.01±0.09s	2±0.09s	-0.16(-0.85; 0.52)	-0.8 (-4; 2.5)	9/61/29%	Unclear
20m (s) CV: 1.3% SWC: 0.84%	2-3	3.58±0.18s	3.49±0.13s	-0.33 (-0.83; 0.16)	-1.8 (-4.3; 0.9)	3/35/62%	Possibly
	2-4	3.58±0.18s	3.45±0.13s	-0.67 (-0.93; -0.4)	-3.5 (-4.8; -2.1)	0/1/99%	Very Likely
	3-4	3.49±0.13s	3.45±0.13s	-0.33 (-0.88; 0.22)	-1.2 (-3.3; 0.8)	3/50/48%	Possibly
30m (s) CV: 1.3% SWC: 1.09%	2-3	5.05±0.26s	4.89±0.16s	-0.44 (-0.93; 0.04)	-2.3 (-4.8; 0.2)	1/23/76%	Likely
	2-4	5.05±0.26s	4.84±0.19s	-0.77 (-1.04; -0.51)	-4 (-5.4; -2.7)	0/0/100%	Almost certain
	3-4	4.89±0.16s	4.84±0.19s	-0.33 (-0.88; 0.21)	-1.2 (-3.1; 0.7)	2/53/45%	Possibly
40m (s) CV: 1% SWC: 1.06%	2-3	6.52±0.33s	6.32±0.21s	-0.47 (-0.91; -0.04)	-2.5 (-4.7; -0.2)	1/12/87%	Very Likely
	2-4	6.52±0.33s	6.26±0.25s	-0.77 (-1.01; -0.54)	-4 (-5.2; -2.8)	0/0/100%	Almost certain
	3-4	6.32±0.21s	6.26±0.25s	-0.28 (-0.78; 0.21)	-1 (-2.7; 0.8)	3/47/49%	Possibly
180ºCOD (s) CV: 1.7% SWC: 0.73%	2-3	2.97±0.12s	2.91±0.12s	-0.42 (-0.77; -0.06)	-1.8 (-3.3; -0.3)	0/17/83%	Likely
	2-4	2.97±0.12s	2.89±0.16s	-0.64 (-0.98; 0.29)	-2.8 (-4.3; -1.3)	0/2/98%	Very Likely
	3-4	2.91±0.12s	2.89±0.16s	-0.27 (-0.68; 0.13)	-1.2 (-3; 0.6)	1/76/23%	Unlikely
V-cut (s) CV: 2.1% SWC: 1.08%	2-3	7.95±0.33s	8.11±0.42s	0.61 (0.18; 1.04)	2.7 (0.8; 4.6)	70/30/0%	Likely harmful
	2-4	7.95±0.33s	7.98±0.36s	0.08 (-0.23; 0.39)	0.3 (-1; 1.7)	2/98/0%	Very Unlikely
	3-4	8.11±0.42s	7.98±0.36s	-0.38 (-0.69; -0.07)	-2 (-3.6; -0.3)	0/54/46%	Possibly

CMJ: countermovement jump; UCMJ: unilateral countermovement jump; SLH: single leg hop test; COD180º: average of both left and right leg in 5+5 m sprint test with a 180º change of direction; V-cut: 25-m sprint test with 4 x 45º changes of direction; cm: centimetres; s: seconds; m: meters; n= final number of participants; Values (mean ± standard derivation [SD]) represent the standardized difference (ES) (90%CL). the percentage of change (%) (90 % CL). percentage chance of having better/trivial/poor values than other stage and qualitative outcome resulting from chances. Each stage represented 8 weeks. 2: September; 3: November; 4: February; CV: coefficient of variation; SWC: smallest worthwhile change

Table 13. Responsiveness of jumping, linear sprinting and CODA tests in U-18 female soccer players at different stages of the season (n = 22)

	Variable	Baseline	Post	ES (CL90%)	% (CL90%)	Chances	Outcome
CMJ (cm) CV: 3.6% SWC: 4.14%	2-3	23.3±3.72cm	22.4±3.1cm	-0.05 (-0.37; 0.26)	-0.9 (-6; 4.5)	8/74/18%	Unclear
	2-4	23.3±3.72cm	25.1±3.53cm	0.35 (-0.07; 0.74)	6 (-0.7; 13.2)	73/26/1%	Possibly
	3-4	22.4±3.1cm	25.1±3.53cm	0.63 (0.33; 0.93)	10.2 (5.3; 15.4)	98/2/0%	Very likely
UCMJ (cm) CV: 3.6% SWC: 4.76%	2-3	12.3±2.57cm	12.2±2.73cm	0.32 (-0.08; 0.73)	7.9 (-1.8; 18.5)	78/19/3%	Likely
	2-4	12.3±2.57cm	14.5±2.38cm	0.79 (0.48; 1.10)	19 (11.1; 27.4)	100/0/0%	Almost certain
	3-4	12.2±2.73cm	14.5±2.38cm	0.58 (0.23; 0.92)	14.4 (5.4; 24.1)	97/2/0%	Very likely
SLH (cm) CV: 1.6% SWC: 2.27%	2-3	126.8±13.9cm	124.5±15cm	-0.08 (-0.4; 0.25)	-0.8 (-4.1; 2.6)	11/55/34%	Unclear
	2-4	126.8±13.9cm	130.1±12.3cm	0.37 (0.11; 0.62)	3.9 (1.2; 6.7)	92/8/0%	Very likely
	3-4	124.5±15cm	130.1±12.3cm	0.45 (0.06; 0.83)	5.9 (0.8; 11.2)	92/7/1%	Very likely
10m (s) CV: 2.2% SWC: 1.5%	2-3	2.05±0.08s	2.02±0.10s	-0.42 (-1.1; 0.22)	-1.7 (-4.3; 0.9)	1/61/38%	Possibly
	2-4	2.05±0.08s	1.98±0.09s	-0.92 (-1.64; -0.19)	-3.8 (-6.6; -0.8)	0/18/82%	Likely
	3-4	2.02±0.10s	1.98±0.09s	-0.46 (-1; 0.08)	-2.5 (-5.4; 0.4)	1/42/57%	Possibly
20m (s) CV: 1.8% SWC: 1.5%	2-3	3.58±0.14s	3.53±0.16s	-0.42 (-1; 0.17)	-1.7 (-4.1; 0.7)	1/51/48%	Possibly
	2-4	3.58±0.14s	3.46±0.14s	-0.82 (-1.49; -0.16)	-3.4 (-6; -0.7)	0/16/84%	Likely
	3-4	3.53±0.16s	3.46±0.14s	-0.18 (-0.51; 0.16)	-0.6 (-1.7; 0.5)	0/96/4%	Very Unlikely
30m (s) CV: 1.5% SWC: 1.5%	2-3	5.04±0.20s	4.97±0.23s	-0.38 (-0.96; 0.2)	-1.6 (-3.9; 0.8)	2/45/53%	Possibly
	2-4	5.04±0.20s	4.88±0.20s	-0.8 (-1.40; -0.2)	-3.3 (-5.7; -0.8)	0/11/89%	Likely
	3-4	4.97±0.23s	4.88±0.20s	-2.1 (-4.2; 0.1)	-0.41 (-0.84; 0.03)	1/32/68%	Likely
40m (s) CV: 1.7% SWC: 1.5%	2-3	6.53±0.29s	6.43±0.29s	-0.35 (-0.89; 0.19)	-1.6 (4.1; 0.9)	2/50/48%	Possibly
	2-4	6.53±0.29s	6.3±0.27s	-0.75 (-1.29; -0.22)	-3.5 (-5.9; -1)	0/11/89%	Likely
	3-4	6.43±0.29s	6.3±0.27s	-0.45 (-0.87; -0.02)	-2.2 (-4.2; -0.1)	0/34/66%	Likely
180ºCOD (s) CV: 1% SWC: 0.67%	2-3	2.96±0.13s	2.91±0.09s	-0.25 (-1.02; 0.51)	-1.2 (-4.6; 2.4)	14/32/54%	Unclear
	2-4	2.96±0.13s	2.85±0.14s	-0.66 (-1.32; 0)	-3 (-6; 0)	2/10/88%	Likely
	3-4	2.91±0.09s	2.85±0.14s	-0.43 (-1.01; 0.16)	-1.4 (-3.2; 0.5)	2/34/64%	Possibly
V-cut (s) CV: 2.2% SWC: 1.51%	2-3	7.73±0.39s	7.97±0.37s	0.76 (0.17; 1.35)	4.3 (0.9; 7.8)	86/14/0%	Likely harmful
	2-4	7.73±0.39s	7.74±0.28s	0.2 (-0.16; 0.56)	1.1 (-0.9; 3.2)	17/82/1%	Possible trivial
	3-4	7.97±0.37s	7.74±0.28s	-0.5 (-0.9; -0.1)	-2.5 (-4.5; -0.5)	0/39/61%	Possibly

CMJ: countermovement jump; UCMJ: unilateral countermovement jump; SLH: single leg hop test; COD180º: average of both left and right leg in 5+5 m sprint test with a 180º change of direction; V-cut: 25-m sprint test with 4 x 45º changes of direction; cm: centimetres; s: seconds; m: meters; n= final number of participants; Values (mean ± standard derivation [SD]) represent the standardized difference (ES) (90%CL). the percentage of change (%) (90 % CL). percentage chance of having better/trivial/poor values than other stage and qualitative outcome resulting from chances. Each stage represented 8 weeks. 2: September; 3: November; 4: February; CV: coefficient of variation; SWC: smallest worthwhile change

Performance changes across the season

Descriptive data and significant differences across the season are shown in **Table 14 and 15**.

U-16

Significant changes were shown in all linear sprinting measurements and horizontal jumping from baseline to T3. Furthermore, horizontal jumping and unilateral vertical jumping were significantly improved between T2 to T3. No significant differences were found for the rest of variables and moments. For details check the **Table 14**.

U-18

All jumping measurements were significantly improved from baseline to T3. In addition, CMJ also showed significant improvements between T2 and T3. No significant differences were found for the rest of variables and moments. For details check the **Table 15**.

Table 14. Season changes of jumping, linear sprinting and CODA tests in U-16 female soccer players at different stages of the soccer season (n = 30).

Variable	Baseline	Test 2	Test 3	*F*	*p*
CMJ (cm)	22.3 ± 3.40	22.5 ± 3.48	24.7 ± 3.93	3.323	NS
UCMJ (cm)	12.5 ± 2.59	12.3 ± 2.5	13.7 ± 2.68$^{\$}$	7.047	0.01
SLH (cm)	126.5 ± 13	122.5 ± 17	133.7 ± 16.8$^{\#,\$}$	12.606	<0.01
10m (s)	2.06 ± 0.12	2.01 ± 0.09	2± 0.09	1.178	NS
20m (s)	3.58 ± 0.18	3.49 ± 0.13	3.45 ± 0.13$^{\#}$	3.299	0.05
30m (s)	5.05 ± 0.26	4.89 ± 0.16	4.84 ± 0.19$^{\#}$	4.933	0.03
40m (s)	6.52 ± 0.33	6.32 ± 0.21	6.26 ± 0.25$^{\#}$	6.359	0.01
180ºCOD (s)	2.97 ± 0.12	2.91 ± 0.12	2.89 ± 0.16$^{\#}$	5.340	0.01
V-cut (s)	7.95 ± 0.33	8.11 ± 0.42	7.98 ± 0.36	4.221	NS

NS: Nonsignificant p > 0.05; CMJ: countermovement jump; UCMJ: unilateral countermovement jump; SLH: single leg hop test; 180ºCOD: average of both left and right leg in 5+5 m sprint test with a 180º change of direction; V-cut: 25-m sprint test with 4 x 45º changes of direction;

§ Significant difference from the moment baseline and T2, at $p < 0.05$

$^{\$}$ Significant difference from the moment T2 and T3, at $p < 0.05$

$^{\#}$ Significant difference from the moment baseline and T3, at $p < 0.05$

Table 15. Seasonal changes of the jumping, linear sprinting and CODA tests in U-18 female soccer players at different stages of the soccer season (n = 22).

Variable	Baseline	Test 2	Test 3	*F*	*p*
CMJ (cm)	23.3 ± 3.72	22.4 ± 3.1	25.1 ± 3.53[#,$]	7.544	0.01
UCMJ (cm)	12.3 ± 2.57	12.2 ± 2.73	14.5 ± 2.38[#]	8.742	0.01
SLH (cm)	126.8 ± 13.9	124.5 ± 15	130.1 ± 12.3[#]	4.060	0.03
10m (s)	2.05 ± 0.08	2.02 ± 0.10	1.98 ± 0.09	3.422	NS
20m (s)	3.58 ± 0.14	3.53 ± 0.16	3.46 ± 0.14	3.432	NS
30m (s)	5.04 ± 0.20	4.97 ± 0.23	4.88 ± 0.20	3.585	NS
40m (s)	6.53 ± 0.29	6.43 ± 0.29	6.3 ± 0.27	3.849	NS
180ºCOD (s)	2.96 ± 0.13	2.91 ± 0.09	2.85 ± 0.14	0.760	NS
V-cut (s)	7.73 ± 0.39	7.97 ± 0.37	7.74 ± 0.28	5.234	NS

NS: Nonsignificant; CMJ: countermovement jump; UCMJ: unilateral countermovement jump; SLH: single leg hop test; 180ºCOD: average of both left and right leg in 5+5 m sprint test with a 180º change of direction; V-cut: 25-m sprint test with 4 x 45º changes of direction;

[§] Significant difference from the moment baseline and T2, at $p < 0.05$

[$] Significant difference from the moment T2 and T3, at $p < 0.05$

[#] Significant difference from the moment baseline and T3, at $p < 0.05$

DISCUSSION

The aims of the present study were to investigate the reliability and sensitivity of jumping, linear sprinting and change of direction ability tests, and to determine short- and mid-term change across a season in a cohort of U-16 and U-18 female football players. The main findings were that 1) U-18 players showed more reliable and sensitive results in all tests analysed compared to their U-16 counterparts, 2) all tests were sensitive to detect large changes at both short- and mid-term in both U-16 and U-18 cohort groups, and 3) seasonal changes were mainly produced between baseline and T3 in linear sprinting and jumping measurements in U-16 and U-18, respectively.

Reliability, usefulness and responsiveness of jumping tests

The reliability of the jumping tests was declared as "good" due to the absence of any systematic bias (i.e., between-sessions differences were rated as "trivial" based on ES), the low CV (<5%) and the high relative reliability (>0.70) in U-16 and U-18 female football players. Between-sessions differences were rated as "trivial" based on ES in almost all tests. The high ICC values of CMJ (0.89-0.97), UCMJ (0.95-0.99) and SLHU (0.92-0.98) were similar to those previously reported in adult health participants for the CMJ (0.91-0.95) (195, 228) vertical hop test (0.92) (229) and horizontal bilateral jump test (0.87-0.89) (236). The CV for CMJ height (3.6%-4.8%) was somehow greater than the 2.6% measured in healthy women (21.0 ± 2.1 yr.) on a force plate (230), while a poorer reliability of the highest jump of CMJ (6%) was reported in physically active women (21.0 ± 2.1 yr.) (195).

Between-studies differences might be due to different measurement devices used, training background or fitness level. The CV for unilateral jumping tests [(UCMJ: 3.6% to 4.8%; SLHU: 1.6 to 3.8%)] was similar to the range (1.9 to 4.1%) observed in 18 athletic male players aged between 20-30 years (236). Interestingly, in both studies, the horizontal test had greater within-trials reproducibility than the vertical test. Thus, the speculation that vertical jump assessment is more reliable in this type of assessment seems unfounded (228).

Furthermore, previous research studies have suggested that jumping height variability in the CMJ is greater in younger participants and it decreases with growth and maturation (231, 232), if so, this may be one of the reasons why the CV in jumping tests is smaller in U-18 group than U-16 group. From a practical point of view, to decrease absolute reliability and, consequently, improve repeated jumping performance, it would be necessary jumping-specific motor control adaptations through training (i.e. jumping expertise).

Differences between the SWC and those changes produced between moments show as CMJ is the most sensitive measurement in both U-16 and U-18. It seems that the current differences with unilateral jumping tests (horizontal and vertical) might be due to neural coordination or other factors related with between-limbs coordination. In this regard, such age (i.e., U-16 and U-18) were hormonal differences help to improve strength and, consequently, jumping performance, mainly influence in bilateral jumping rather than unilateral jumping. Therefore, it should be recommended to use bilateral jumping as a variable to monitor those “real” changes produced throughout the season.

Reliability and sensitivity of linear sprinting test

The reliability of the linear sprinting test was declared as “good” due to the low CV value (<5%) and the high relative reliability (>0.70) in U-16 and U-18 female football players. Between-sessions differences were rated as “trivial” based on ES in U-18 female soccer players. Conversely, a small difference was detected in U-16 female soccer players. Between-groups differences’ might be due to a lower experience in performing such test, greater between-subjects variability or an altered locomotive function during adolescence. It might be possible that between-age reliability differences could be normalised through a regular and intense training to stabilise locomotive function (233). The 40-m speed test showed an ICC ranged from 0.75 to 0.96 and it agrees with the data reported in the same test in youth male and female population (0.88 to 0.96) (234). With respect to the CV range value observed (1.0-2.2%), it is in the same line with those values generally reported for 40-m sprints in young male football players (233, 234). Therefore, these results are similar to male studies though more female football players' studies are necessary.

Those changes occurred throughout the season were greater than the SWC (moderate and large changes) in both groups. However, the U-16 was also able to detect small changes. It is hypothesized that those locomotive changes (i.e., technique disruption) produced close to growth spurt (i.e., peak height velocity, skeletal system) seem to affect acceleration and maximal sprinting performance. In accordance with our hypothesis, Meyers et al. confirm that the period of peak height velocity improve sprint performance in male youth players (235, 236). Thus, the linear sprinting test might have good sensitivity, as it was able to detect those practically relevant changes occurring in the examined cohort (U-16 and U-18).

Reliability and sensitivity of change of direction tests

The reliability of CODA tests was declared as "good" due to the low CV values (<5%) and the high relative reliability (>0.70). Between-sessions differences' were rated as "trivial", while the V-cut test ES magnitude was small (0.23) in the U-16 group. It should be possible that those changes related with adolescence, as commented previously in linear sprinting, might be the reasons to this small difference. The ability to repeatedly perform CODs is mainly dependent on technique that might be disturbed during the adolescence period. The relative reliability value of 180ºCOD test (0.80-0.82) was similar to those values reported for the Illinois (0.83), L-Run (0.88), Pro-Agility (0.82), T-test (0.83) and 505 (0.81) tests in male junior team sports players (95), while the ICC found for the V-cut (0.75-0.76) is lower than the ICC reported (0.92) in young basketball players (96). The absolute reliability of 180ºCOD (1-1.7%) and V-cut (2.1-2.2%) is in line with some previous research that found good reliability for measures of CODA performance in other tests, like Illinois (1.64%), L-Run (1.63%), Pro-Agility (1.81%), T-test (2.29%) and 505 (1.92%) tests in male junior team sports players (95). Hence, the current results are supported with previous investigations, though more studies in female soccer players are necessary to establish stronger conclusions.

Single COD test seems to be more sensitive to detect “real” changes than the V-cut test. It is possible that 180ºCOD might has greater similarities to linear sprinting than the V-cut test and, thus, those improvements in linear sprinting are closely related to those found in 180ºCOD. As such, some training methodologies as resistance training or eccentric overload training should be included to maintain or even improve multiple COD performance (224, 237). Hence, single COD test (i.e., 180ºCOD) might be used as a CODA assessment tool, whereas the V-cut test results must be interpreted with caution. In this regard, V-cut test should also be used with caution to assess CODA in female soccer players as total distance, time to completion such test or its technical features might be contributing factors and can modify CODA analysis.

Several limitations could be identified in this study. Adolescent females soccer players have particular characteristics (e.g. anthropometry) and, consequently, our results cannot be directly extrapolated to other sports. No playing position differences were considered because of the limited number of players present in each of the playing role.

Therefore, further studies with larger sample sizes, differences based on playing positions and different populations are needed.

PRACTICAL IMPLICATIONS

The current findings have provided evidence and guidelines for the meaningful detection of the jumping, linear sprinting and CODA tests performance changes. Such information will aid sports coaches and trainers in selecting jumping, linear sprinting and CODA tests for future testing batteries. It is worth noting that when female football players are close to the APHV some training strategies such as eccentric overload training, resistance training, plyometrics, sled-towing and/or technique training should be included to avoid a multidirectional sprinting decrement. Finally, coaches are encouraged to accustom their players with testing procedures to ensure the most valid results.

CONCLUSION

This study has shown that jumping, linear sprinting and CODA tests may be reliable and sensitive to those training-induced changes typically observed during the short and mid-term competitive season in U-16 and U-18 female soccer players. Finally, better reliability results are found as the age participants increases.

4.3. Artículo III [Manuscript III]

Adolescent female soccer players' soccer-specific warm-up effects on performance and inter-limb asymmetries

Pardos-Mainer E, Casajús JA, Gonzalo-Skok O. Adolescent female soccer players' soccer-specific warm-up effects on performance and inter-limb asymmetries. Biol Sport. 2019;36(3):199-207.

ABSTRACT

No studies have assessed whether changes in physical performance and inter-limb asymmetries (ILA) can be achieved with the FIFA 11+ prevention programme in adolescent female soccer players. The aim of this study was to assess the effect of the FIFA 11+ programme compared with a standard warm-up on physical performance and ILA in adolescent female soccer players. Thirty-six adolescent female soccer players were randomly assigned to an experimental (EG; n = 19) or a control group (CG; n = 17). Unilateral/bilateral countermovement jump (CMJ), drop jump (DJ) and horizontal jump tests, two different change of direction tests, an ankle dorsiflexion test, the Y-Balance test (YBT) and inter-limb asymmetries were measured before and after 10 weeks of training. The results revealed no significant group-by-time interactions in the vast majority of variables (p>0.05). Paired t-test revealed significant improvements of the right [effect size (ES):0.56] and left (ES:0.49) CMJ, right (ES:0.74) and left (ES:0.54) DJ (ES:0.74), right (ES:1.27) and left (ES:1.26) posteromedial direction and right (ES:0.89) and left (ES:0.84) posterolateral direction in the YBT in the EG (p < 0.05). Right anterior direction in the YBT and V-cut test were significantly improved in both groups (p<0.05). For inter-limb asymmetry variables, no significant group-by-time interactions (ES:0 to 0.93) and an improvement between pre- and post-tests (ES:-0.76 to 0.49) were observed. Therefore, the FIFA 11+ programme led to improved unilateral jumping, dynamic balance and reduced lower extremity symmetries of several tests in adolescent female soccer players.

Keywords: Lower extremity asymmetries, change of direction, strength, intervention, football, females

INTRODUCTION

Soccer has become increasingly popular among females worldwide and according to the Women´s Football Survey of the Fédération Internationale de Football Association (FIFA), there were more than 30 million registered women soccer players in 2014 (157). Soccer is considered a contact sport and demands a wide variety of skills at different intensities. In this regard, soccer players are mainly running throughout the soccer game, while other high-intensity activities such as sprinting, jumping, kicking and changing direction are also important performance factors that require both maximal strength and anaerobic power of the neuromuscular system (238, 239). Some of the physical demands for adolescent female soccer players during matches have been reported (19) with total distances covered 6-9 km and sprinting with top speeds reaching over 27 km/h^{-1}, but more information is necessary about change of activity such as passing, dribbling, tackling and trapping, repeated sprinting or high intensity bouts in this population.

At youth standards, popularity is increasing at a rapid rate. There has been almost a 4% increase in participation in the last 5 years in youth female soccer players (158). During the last decade, there has been a high number of injuries in young soccer players (6). Quadriceps strains and severe knee (e.g., anterior cruciate ligament) ligament injuries are the most frequent in female soccer players in comparison to their male counterparts (7).

Different multifaceted neuromuscular warm-up programmes to reduce the risk of injury and/or to improve soccer specific variables have been developed such as, Sportsmetrics Warm-Up for Injury Prevention and Performance training programme, the Harmoknee injury prevention programme and the FIFA 11+ programme (9, 240-244). In this regard, the FIFA 11+ is one of the most commonly used injury prevention warm-up programmes in young soccer players (242, 245). It was developed by a group of FIFA experts (246) as a structured warm-up programme aimed at minimizing the injury risk of the most common injuries in soccer (i.e. ankle and knee sprains, adductor and hamstring strains). Some studies (242-244) have reported on the use of the FIFA 11+ programme in adolescent males and females soccer players (aged 13-19 years), with injury reductions ranging from 21% to 32%. Therefore, different exercises or factors may have been responsible for efficacy of the FIFA 11+ to prevent injuries.

Exercise used in prevention protocols, such as the FIFA 11+, have also been shown to have performance effects among youth soccer players (aged 9-18 years), such as agility (244), jumping height (247) or functional balance (146) improvements. In addition, a meta-analysis concluded that FIFA 11+ was effective in increasing dynamic balance and exercises performance in soccer players (248). However, Steffen et al. (9), after FIFA 11+, did not detect improved performance. The most likely explanation is that the training volume and intensity for each of the exercises were too low to result in performance improvements. Limited and conflicting data are currently available and more studies are necessary.

Recently, lower extremity asymmetries have been included in test batteries performed by different soccer clubs due to their relation to lower-limb injuries and physical performance (78, 249). In this regard, female athletes with a single-leg hop asymmetries greater than 10% have a 4-fold in lower-extremity injuries (111). Furthermore, an asymmetry greater than 4 cm in the anterior direction during the Y balance test (YBT), is associated with increase in lower-limb injury risk (250). In addition, Rey et al. (249) studied the effects of two different eccentric hamstring training exercises, the Nordic hamstring exercises and the Russian belt exercises. Both exercises decreased inter-limb asymmetry in the single leg hamstring bridge in junior soccer players. As such, this scarce information makes it challenging to provide solid, evidence-based recommendations. In addition, to the authors´ knowledge, no studies have analysed the effects of the FIFA 11+ on inter-limb asymmetries in female soccer players, hence, more studies for this population are warranted.

Therefore, the aims of the present study were 1) to evaluate the effects of the FIFA 11+ in physical performance in adolescent female soccer players; and 2) to observe whether lower extremity inter-limb asymmetries are decreased in different tests, in a group of adolescent female soccer players. The hypothesis of this study was that there would be an improvement in both physical performance and inter-limb asymmetries from pre-intervention to post-intervention in performance tests.

MATERIAL AND METHODS

Subjects

Thirty-six adolescent female soccer players (age: 12.7 ± 0.6 years; height: 156.3 ± 7.0 cm; body mass: 52.5 ± 8.3 kg; body mass index: 21.4 ± 0.4 kg/m^2) voluntarily agreed to participate in this study and written informed consent was obtained from both the players and their parents before beginning the investigation. Data collection took place during the seventh month, out of nine, of the competitive season (**Table 16**). Afterwards, players were randomly assigned (ABBA distribution) to a control group (CG, =17) or experimental group (EG, n=19) based on their ranked physical performance. The study was carried out in conformity with the ethical standards of the Declaration of Helsinki and has been approved by the Ethics Committee of Clinical Research from the Government of Aragón (CP19/039, CEICA, Spain).

Table 16. Descriptive Data of the Participants, Mean ± SD.

	Age (y)	Height (cm)	Body mass (kg)	BMI (kg/m^2)
Experimental group	12.5 ± 0.4	153.7 ± 6.9	51.2 ± 7.7	21.2 ± 2.2
Control group	13.1 ± 0.3	160.8 ± 4.9	55.9 ± 8.2	21.6 ± 2.8

BMI: Body- mass index

Design

Players in the CG performed their habitual warm-up consisting of a combination of running exercises (4-5 min at light intensity), followed by 4-5 min of dynamic mobility emphasizing the lower-extremity muscle groups (gastrocnemius, quadriceps, hip flexors, adductors, hamstrings and gluteals) and technical exercises with the soccer ball (4-5 min). EG players carried out an additional injury prevention programme (FIFA 11+) twice per week for 10 weeks at the beginning of each training session, replacing the habitual warm-up (**Figure 10**). Both teams were managed by the same coach and participated in a similar weekly soccer training volume and methodology (2 sessions/week of 90 minutes and 1 match/week). Athletes belonged to the same female soccer division club academy squad (Iberdrola Women´s Spanish First Division) and all players were training in a soccer club for at least 4 years. Two weeks prior to the commencement of intervention, four familiarization sessions were executed in the EG to learn the exercises included in the FIFA 11+. Furthermore, two weeks (test) and one week (re-test) before the start of the training intervention, players performed the same testing battery and test-retest reliability was assessed. One week after the end of the training intervention, the tests were repeated to examine the effects of the FIFA 11+. The duration of the warm-up was equal for both groups and lasted approximately 15 min. Four players (experimental 2; control 2) did not perform in post-test the 180º change of direction test (180º COD) and the V-cut test (V-cut) due to injury, muscle fatigue or other commitments.

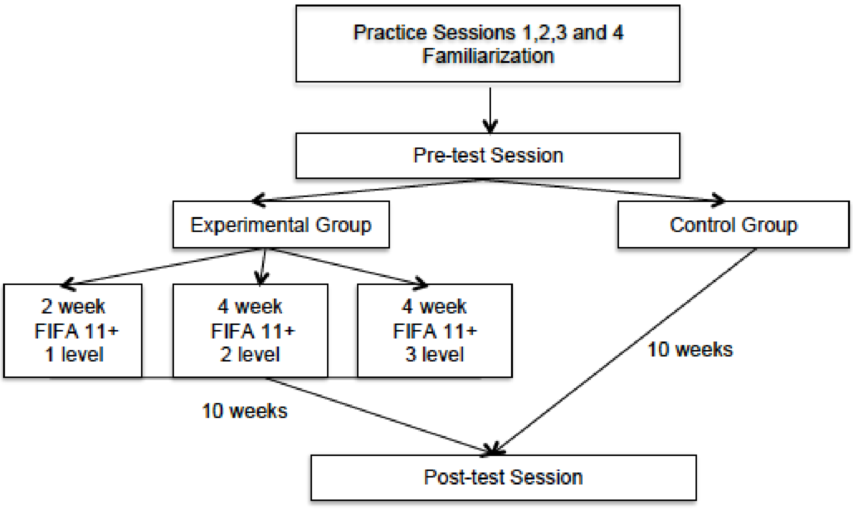


Figure 10. Project design timeline

The FIFA 11+ programme combined cardiovascular activation and preventive neuromuscular exercises and consisted of 3 parts. Part one: six running exercises at slow velocity combined with active stretching and controlled contacts; part two: six exercises focusing on trunk and lower extremities' strength, balance, plyometric and agility components (each exercise had three progression levels); and part three: three running exercises at both moderate and high speed combined with changes of direction (COD). For more details see the manual and instructions freely available on the official website (http://www.fifa.com/development/medical/index.html).

Procedures

Performance tests were completed in 2 hours. These tests were performed on the soccer field. Players wore athletic shoes (jumping tests) and soccer boots (COD tests) in the field/gym tests, whilst balance tests were conducted barefoot. Participants were familiarized with all study tests as they had completed these as part of an assessment battery between 4-8 times prior to the study. The allowed practice trials are described in the specific test description. Two trial for jumping and COD tests and 3 trials for musculoskeletal tests were allowed.

Standing broad jump (SBJ) test. The SBJ indirectly measured horizontal power. This test was measured using a standard measuring tape *(30m M13; Stanley, New Britain, EEUU)* and was assessed as described elsewhere (251). The variables used in the analyses were: Single-legged left horizontal jump (SLHL) and single-legged right horizontal jump (SLHR). Each test was performed twice, separated by at least 45 seconds of passive recovery, and the best jump was recorded and used for analysis.

Single leg hop (SLH) test. The SLH indirectly measured unilateral horizontal power. This test was measured using a standard measuring tape *(30m M13; Stanley, New Britain, EEUU)* and was assessed as described elsewhere (178). The variables used in analyses were: 1-legged left horizontal jump (SLHL) and 1-legged right horizontal jump (SLHR). Each test was performed twice, separated by at least 45 seconds of passive recovery, and the best jump was recorded and used for analysis.

Bilateral countermovement jump test and unilateral countermovement jump test. Jumping height was assessed using a vertical countermovement jump (CMJ) (reported in centimetres) with flight time measured by the Optojump (*Optojump, Microgate, Bolzano, Italy*) and is described elsewhere (170). Each test was performed 3 times, separated by 45 seconds of passive recovery, and the best jump was recorded and used for analysis. The same criterion was used to assess unilateral CMJ (UCMJ). The variables used for analyses were: 1-legged left CMJ (CMJL) and 1-legged right CMJ (CMJR).

Drop jump test and unilateral drop jump (UDJ) test. Players started at the top of a 31.5 cm high box. Flight time was measured by the Optojump (*Optojump, Microgate, Bolzano, Italy*) and the protocol is described elsewhere (252). Each test was performed 3 times, separated by 45 seconds of passive recovery, and the best jump was recorded and used for the analysis. The same criterion was used to assess UDJ, however, players stepped forward from the high box 831.5 cm) to the Optojump from the contralateral limb to the test limb. The variables used for analyses were: 1-legged left DJ (DJL) and 1-legged right DJ (DJR).

Weight- bearing dorsiflexion test. Ankle dorsiflexion was evaluated through the LegMotion system *(LegMotion, your Motion, Albacete, Spain)* and the test is described elsewhere (253). Three trials were allowed with each ankle (i.e., left and right) with 10 seconds of passive recovery between trials. The third value in each ankle was selected for subsequent analysis of weight-bearing dorsiflexion (WB-DF).

Y-Balance test. Dynamic balance was assessed by using the OctoBalance device *(OctoBalance, Check your MOtion, Albacete, Spain)*, which analyzed three lower limb excursion directions: anterior (YBT-A), posteromedial (YBT-PM) and posterolateral (YBT-PL). The test is described elsewhere (253). Three trials were allowed with each leg with 10 seconds of passive recovery between trials. The mean result of the three trials in each leg was selected for subsequent analysis (253).

V-cut test. Players performed a 25-m sprint with four CODs of 45º 5 m each, as described elsewhere (170). Sprint times were measured by dual beam photocell systems (*Microgate, Bolzano, Italy*). The V-cut test was executed twice and 3 min of passive recovery was provided between repetitions. Time in the best (fastest) trial was retained.

180º Change of direction (COD) test. Players performed a 10-m sprint test with a180ºCOD. The front foot was placed 0.5 m before the first timing gate (*Microgate, Bolzano, Italy*), a 10-m sprint test was performed and is described elsewhere (170). The180ºCOD was repeated twice with right (CODR) and left (CODL) changes and 2 min of between-repetition recovery was allowed. The best time with each 180º-COD was recorded to calculate the mean time that was used for subsequent analyses.

Statistical analysis

Statistical analyses were performed with SPSS for MAC (Version 19.0; SPSS Inc, Chicago, IL). Data are presented as mean ± standard deviation (SD). Normality and equal variance assumptions were checked using the Shapiro-Wilk test and Levene test, respectively. Statistical significance was inferred from $p < 0.05$. A 2 (group) x 2 (time) repeated measures of analysis of variance (ANOVA) was calculated for each parameter. The standardized difference or effect size [ES, 90% confidence limit (CL)] in the selected variables was calculated using the pooled SD (pre- and post-test). Threshold values for Cohen ES statistics were >0.2 (small), >0.6 (moderate), and >1.2 (large) (154). Only players who participated in >85% of all training sessions were included in the final analyses. Consequently, 4 of the 36 players were excluded due to injury, muscle fatigue or other commitments. As a result, 32 players were included in the final analyses. The final sample sizes for the different groups were n = 15 for CG and n = 17 for EG.

Inter-limb asymmetry was calculated using the following formula (156):

Inter-limb symmetry (%) = (stronger limb-weaker limb/stronger limb) x 100.

Relative reliability analysis was examined using the ICC. The typical error of measurement (TEM) was used to examine the absolute reliability. The spreadsheet of Hopkins (Reliability from consecutive pair of trials, xrely.xls (2015)) was used to determine both ICC and TEM, expressed as a coefficient of variation (CV).

RESULTS

ICC and CV results of this study were from 0.83 to 0.93 and ranged 1.5% to 5.3%, respectively. These results indicate good reliability (ICC > 0.67) and acceptable variability (CV < 10%) (195).

Summary results of all tests performed in CG and EG are shown in **Table 17.**

Table 17. Summary results of all tests performed in Control Group and Experimental Group. Mean ± SD

	Control Group				Experimental Group			
Variable	**Pretest**	**Posttest**	***p***	**ES (90 CL)**	**Pretest**	**Posttest**	***p***	**ES (90 CL)**
SBJ (m)[$]	1.52 ± 0.22	1.63 ± 0.18*	.033	0.30 (0.07; 0.53)	1.48 ± 0.16	1.49 ± 0.13	.708	0.07 (-0.19; 0.33)
SLH$_R$ (m)	1.23 ± 0.20	1.32 ± 0.19	.153	0.28 (-0.3; 0.60)	1.23 ± 0.16	1.29 ± 0.12*	.017	0.40 (0.15; 0.66)
SLH$_L$ (m)	1.29 ± 0.18	1.36 ± 0.16	.153	0.30 (-0.04; 0.65)	1.25 ± 0.18	1.32 ± 0.14*	.016	0.34 (0.11; 0.58)
% As SLH	91.9 ± 6.37	93.5 ± 5.31[¢]	.653	0.15 (-0.45; 0.74)	92.9 ± 4.74	94.3 ± 5.09[¢]	.453	0.26 (-0.35; 0.87)
CMJ (cm)	22.8 ± 3.12	23.1 ± 6.28	.917	-0.11 (-1.16; 0.94)	20 ± 3.68	22.1 ± 3.39*	.014	0.48 (0.14; 0.82)
CMJ$_R$ (cm)	11.3 ± 1.96	12.3 ± 2.42	.329	0.34 (-0.30; 0.99)	10.5 ± 1.98	11.1 ± 2.37	.446	0.56 (0.30; 0.82)
CMJ$_L$ (cm)	11.4 ± 2.36	11.6 ± 2.68	.810	0.07 (-0.43; 0.57)	10.4 ± 2.36	11.8 ± 2.37*	.004	0.54 (0.25; 0.83)
% As UCMJ	93.1 ± 4.35	91.3 ± 6.87	.179	-0.76 (-1.72; 0.20)	90 ± 5.46	87.3 ± 8.67	.154	-0.62 (-1.32; 0.08)
DJ (cm)	23.3 ± 4.86	24.7 ± 4.55	.309	0.38 (-0.22; 0.97)	21.2 ± 3.44	23.3 ± 3.50*	.007	0.61 (0.24; 0.99)
DJ$_R$ (cm)	13.4 ± 3.48	13.6 ± 3.49	.637	-0.12 (-0.81; 0.56)	11.3 ± 2.25	13.2 ± 2.86*	.002	0.74 (0.39; 1.08)
DJ$_L$ (cm)	13.3 ± 2.94	14.03 ± 3.46	.827	0.05 (-0.45; 0.55)	11.7 ± 2.93	13.4 ± 2.63*	.002	0.54 (0.27; 0.81)
% As UDJ	90.7 ± 5.94	88.5 ± 8.96	.766	-0.29 (-1.89; 1.31)	87.1 ± 9.73	92.5 ± 5.33[¢]	.070	0.47 (0.06; 0.89)
WB-DF$_R$ (cm)	12.4 ± 2.23	12.7 ± 2.97	.261	0.20 (-0.22; 0.61)	12.2 ± 2.17	12.7 ± 2.51	.307	0.20 (-0.20; 0.61)
WB-DF$_L$ (cm)	12.6 ± 2.24	12.9 ± 2.72	.220	0.29 (-0.19; 0.76)	12.3 ± 1.97	12.8 ± 2.26	.217	0.26 (-0.14; 0.65)
% As WB-DF	92.9 ± 4.94	87.3 ± 7.28*	.015	-1.19 (-1.93; -0.45)	91.4 ± 5.65	87.5 ± 10.7	.182	-0.76 (-1.68; 0.15)
YBT-A$_R$ (cm)	58.1 ± 5.67	60 ± 4.05*	.046	0.45 (0.09; 0.81)	56.4 ± 6.22	59.2 ± 5.09*	.026	0.42 (0.12; 0.72)
YBT-A$_L$ (cm)	57.6 ± 5.08	60.1 ± 3.21	.303	0.56 (0.05; 1.08)	56.1 ± 5.45	58.4 ± 5.90	.194	0.40 (-0.05. 0.85)
% As YBT-A	96.1 ± 3.03	94.6 ± 3.29	.164	-0.43 (-0.94; 0.09)	95.3 ± 4.65	94.6 ± 5.12	.601	-0.15 (-6; 0.31)
YBT-PM$_R$ (cm)	74.2 ± 12.8	70.8 ± 16.3	.202	-0.37 (-0.81; 0.08)	61.1 ± 6.39	70.4 ± 7.12*	.000	1.27 (0.90; 1.64)
YBT-PM$_L$ (cm)	68.2 ± 11.3	72.3 ± 12.7	.185	0.40 (-0.12; 0.92)	62.3 ± 6.88	71.9 ± 5.21*	.000	1.26 (0.99; 1.54)
% As YBT-PM	89.8 ± 8.44	90.3 ± 8.37[¢]	.239	0.27 (-0.44; 0.99)	92.3 ± 7.48	93.6 ± 3.50[¢]	.524	0.18 (-0.24; 0.59)
YBT-PL$_R$ (cm)	64.2 ± 12.4	68.9 ± 15.1	.171	0.38 (-0.13; 0.89)	62.3 ± 6.98	69.2 ± 6.40*	.001	0.89 (0.47; 1.30)
YBT-PL$_L$ (cm)	68 ± 13.5	70.5 ± 14.1	.621	0.14 (0.36; 0.65)	59.9 ± 9.50	68.2 ± 5.98*	.001	0.84 (0.49; 1.18)
% As YBT-PL	90.4 ± 6.13	92.2 ± 6.39[¢]	.239	0.4 (0; 0.8)	93.1 ± 5.53	95 ± 4.34[¢]	.273	0.33 (-0.17; 0.82)
V-cut (s)	7.85 ± 0.39	8.16 ± 0.31*	.011	0.70 (0.30; 1.09)	7.89 ± 0.33	8.09 ± 0.33*	.006	0.59 (0.26; 0.93)
180ºCOD$_R$ (s)	2.96 ± 0.13	3.05 ± 0.13	.133	0.53 (-0.06; 1.11)	3.02 ± 0.13	3.06 ± 0.10	.200	0.32 (-0.10; 0.73)
180ºCOD$_L$ (s)	2.96 ± 0.13	3.01 ± 0.11	.271	0.28 (-0.16: 0.71)	3.04 ± 0.14	3.04 ± 0.13	.959	-0.01 (-0.43; 0.41)
% As COD	97.7 ± 2.13	96.2 ± 2.36	.148	-0.44 (-1.23; 0.36)	96.8 ± 1.84	97.7 ± 1.79[¢]	.112	0.49 (-0.02; 1)

R: Right; L: Left; CMJ: countermovement jump; UCMJ: unilateral countermovement jump; CMJ$_R$: one- egged vertical right jump; CMJ$_L$: one-legged vertical left jump; UDJ: unilateral drop jump; DJ$_R$: one-legged drop right jump; DJ$_L$: one-legged drop left jump; SBJ: Standing broad jump; SLH: single leg hop test; SLH$_R$: one-legged horizontal right jump; SLH$_L$: one-legged horizontal left jump; WB-DF: weight- bearing dorsiflexion; YBT: Y-Balance test; YBT-A: anterior direction; YBT-PM: posteromedial direction; YBT-PL: posterolateral direction; 180ºCOD: 5+5 m sprint test with a 180º change of direction; V-cut: 25-m sprint test with 4 x 45º changes of direction; SD: standard deviation; As: asymmetry; cm: centimetres; s: seconds; m: meters; CL: confidence limits; ES: Effect Size

* Significant difference between the pre-test and post-test ($p < .05$)

[$] Significant group by time interaction ($p < .05$)

[¢] Decrease limb symmetry index

Strength tests

ANOVA showed significant group by time interactions for the SBJ ($p < 0.05$). Paired t-tests revealed significant improvement of the SBJ ($p = 0.033$; ES = 0.30) in the CG but no improvement in the EG ($p > 0.05$). Although the right SLH, left SLH, CMJ, left CMJ, DJ, right DJ and left DJ did not show a significant group-by-time interaction, paired *t*-tests revealed significant improvement between pre-test and post-test in the EG ($p < 0.05$). For the right CMJ, SLH asymmetry, UCMJ asymmetry, and UDJ asymmetry no significant group-by-time interaction and an improvement between pre- and post-tests were observed. Strength results from between-groups analysis are illustrated in **Figure 11A**.

Musculoskeletal tests

ANOVA showed significant group-by-time interactions for the right YBT-PM ($p < 0.01$). Paired *t*-tests revealed significant improvement of the right YBT-PM (ES = 1.27) in the EG but no improvement in the CG ($p > 0.05$). However, the left YBT-PM, right YBT-PL and left YBT-PL did not show a significant group-by-time interaction. Paired *t*-tests revealed significant improvement between pre-test and post-test in the EG ($p < 0.05$). Right YBT-A improved significantly in both the CG and EG ($p < 0.05$), but no significant group-by-time interactions were observed. For the left YBT-A, YBT-A asymmetry, YBT-PM asymmetry and YBT-PL asymmetry no significant group-by-time interaction or improvement between pre- and post-tests was observed.

For the flexibility data, no significant group-by-time interaction or improvement between pre- and post-tests was observed. Musculoskeletal results from between-groups analysis are illustrated in **Figure 11B.**

Change of direction tests

There were no significant group-by-time interactions of all COD tests. For within-group change from pre-test to post-test, significant impairment was revealed in the V-cut test in the CG (ES: 0.70) and the EG (ES = 0.59). COD results from between-group analysis are illustrated in **Figure 11C.**

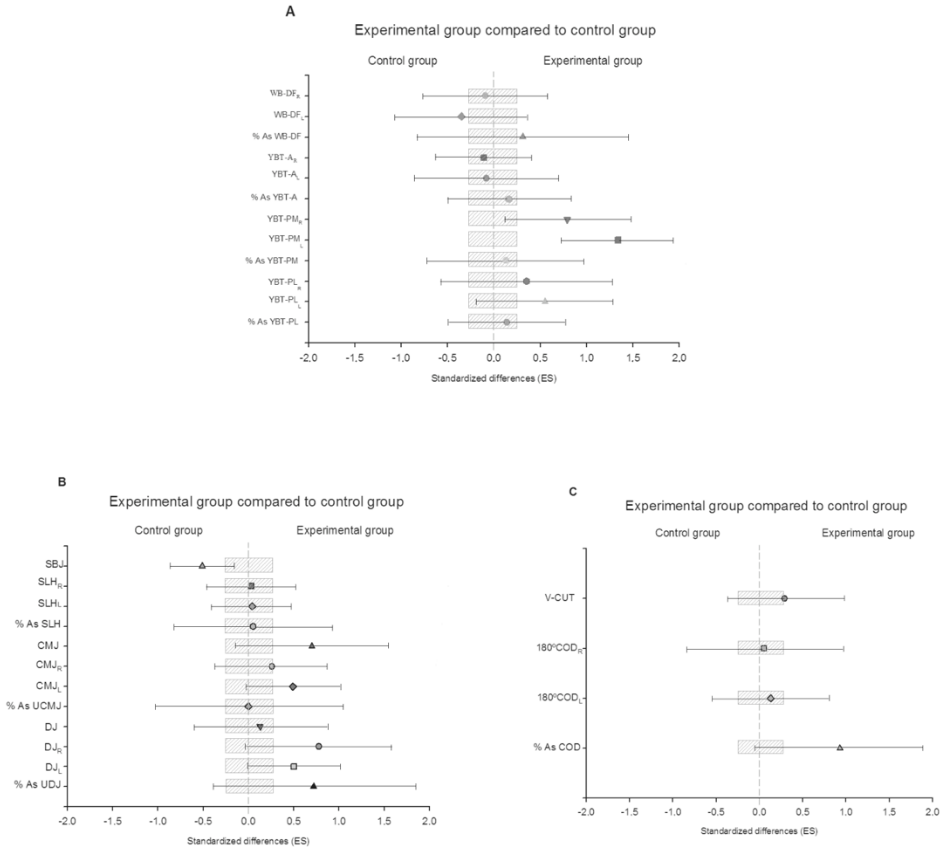


Figure 11. Efficiency of training group in comparison with control group to improve jumping, agility, balance and flexibility variables. Bars indicate uncertainty in the true mean changes with 90% confidence intervals.

R: Right; L: Left; WB-DF: weight-bearing dorsiflexion; YBT: Y-Balance test; YBT-A: anterior direction; YBT-PM: posteromedial direction; YBT-PL: posterolateral direction; As: asymmetry; CMJ: countermovement jump; CMJR: one-legged vertical right jump; CMJL: one-legged vertical left jump; UDJ: unilateral drop jump; DJR: one-legged drop right jump; DJL: one-legged drop left jump; SLHR: one-legged horizontal right jump; SLHL: one-legged horizontal left jump; As: asymmetry;180ºCOD: 5+5 m sprint test with a 180º; V-cut test: 25-m sprint test with 4 x 45º changes of direction.

DISCUSSION

The aims of the present study were to assess the effects of 10-week FIFA 11+ implementation on physical performance and to evaluate asymmetry reduction in skill-related physical fitness tests in adolescent female soccer players.

The main finding was the improvement in dynamic balance and unilateral jumping through the current injury prevention programme. Conversely, no improvements were found in the rest of the performance tests in this cohort of adolescent female soccer players. Furthermore, in 5 out of 8 tests in the EG, asymmetries were decreased (Table 16).

Previously, it has been suggested that the FIFA 11+ provides positive effects on the variables analysed in the present study (jumping ability, range of motion [ROM] or COD) in adolescent females (146, 247). Similar results were found within our study, with significant improvement in CMJ (6%), 3-step jump (3.4%), Illinois agility test (2%) and 5 out of 6 for reach in the SEBT (4-7%) in the EG. No significant differences were found in the EG in comparison to the CG. Indeed, Steffen et al. (9) analysed whether the FIFA 11+ could improve fitness performance in U-18 female soccer players and there was no difference between the intervention and control groups in the change in performance from the pre- to post-test for any of the tests used. As occurred in our study, no significant differences were reported between the FIFA 11+ group and CG (this group carried out their usual soccer warm-up).

In the EG, the magnitude of change found in jumping power of the vertical, horizontal and drop jumps (ES: 0.07 to 0.74) opposes that of previous studies (ES: -0.22 to 0.37) after a similar injury prevention programme (9, 30, 126, 254, 255). Substantial improvements observed in all jumping variables, while CG achieved trivial changes in

CMJ (ES: -0.11) and DJ with right leg (ES: -0.12). As a result, the between-group analyses showed substantial differences in vertical jumps (CMJ and DJ) at post-test, whereas there were no differences in horizontal jumping. This result might be explained by having fewer drills in the horizontal direction than the vertical direction in the FIFA 11+, and it is similar to the results of the study of Ozbar et al. (256). In this regard, controversy still exists regarding the effect of these programmes on the jumping ability of adolescent female soccer players with results showing both positive (254, 255) and unclear effects (9, 126). However, it is worth noting that the main aim of this programme is to reduce injury risk and not improve performance. Therefore, further studies are needed to explore whether the FIFA 11+ can elicit positive neuromuscular adaptations in adolescent female soccer players.

COD ability is one of the most important components in soccer (27). Its improvement has become a focus of training programmes in adolescent female soccer players (135, 184). However, trivial results (ES: -0.01 to 0.32) were found in the EG in all COD tests after the FIFA 11+ programme in this study. Similarly, several studies have also shown trivial improvements (ES: -0.8 to 0.27) in different COD tests (e.g., Illinois test, dribbling test, Pro-Agility test) (9, 126). It is worth noting that COD ability mainly depends on several determinants such as technique, anthropometry, straight sprinting and strength (164). As such, it might be possible that these determinants were not sufficiently stimulated through the current injury prevention programme and, thus a greater and more specific training stimulus may be needed to develop this complex ability.

Following the FIFA 11+, the YBT directions scores were significantly improved in the EG compared to the CG. Specifically, no significant between-group differences were found in the anterior direction while the EG significantly improved in the posterolateral (ES: 0.84 to 0.89) and posteromedial (ES: 1.26 to 1.27) distances compared to CG. Similar results using this test have been observed following an eight-week neuromuscular training programme (ES: 0.69 to 0.91) (147) and a four-month study performing the FIFA 11+ (ES: 0.61 to 1.09) (146). It has been reported that posterolateral and posteromedial direction improvements might be the result of both better neuromuscular control and dynamic balance rather than greater lower-limb strength in female collegiate soccer athletes (249). As such, it is worth noting that part 2 of the FIFA 11+ consists of several progressive plyometric, balance, and core exercises which can improve with greater neuromuscular control. Thus, the current results might be related to those exercises performed during the intervention. On the other hand, the absence of improvements in the anterior direction after performing the FIFA 11+ was expected because the ankle dorsiflexion ROM also showed no between-group differences. The ankle dorsiflexion ROM improvements may have cancelled out any notable differences between groups in the anterior direction and therefore a specific group of exercises to enhance ankle ROM needs to be included in warm-up programmes.

WB-DF improved in both groups after the intervention. Therefore, it seems that the training programme performed was ineffective to induce ROM evidence. It has been reported that a static stretching intervention prompted ankle dorsiflexion improvements (ES: 0.30) and even more when including an elastic band within the stretches (ES: 0.85) (258). Thus, it seems necessary to use a specific intervention if one´s goal is to enhance ankle dorsiflexion ROM. Furthermore, a low ROM might be considered as a risk factor to develop a patellar tendinopathy (258). Consequently, those players who have a low ankle dorsiflexion might be likely to suffer a tendon injury and, thus, it might be reasonable to include specific exercises within soccer training routines in these particular players.

Side- to-side asymmetry is a current measurement from different clinical tests (259, 260) and it is an important variable to assess the injury risk (250, 261, 262). Previous investigations have reported that collegiate Division I athletes (208) and high school basketball players (262) who showed more than 4 cm of side-to-side asymmetry in the anterior directions were 2.2 times and 2.5 times more prone to suffer a lower-limb injury, respectively. Within our sample, 26.7% of our adolescent female soccer players would be more likely to sustain a non-contact lower-limb injury. In this regard, the current neuromuscular programme reduced the asymmetry in the posteromedial and posterolateral YBT direction (ES: 0.18 to 0.33). It might be possible that this improvement could be obtained through the inclusion of unilateral exercises performed during the intervention. It appears that the FIFA 11+ was effective at reducing the DJ asymmetry, whilst the CG became more asymmetrical. In contrast, the EG become more asymmetrical in the CMJ test. These changes in vertical jump should be interpreted with caution. Practitioners should consider the individual nature of asymmetries when interpreting data relative to these side-to-side differences, and an individualized approach to monitoring asymmetry might be considered to optimize physical performance and reduce the risk of future injury of each female soccer player (263).

However, direct comparisons with adolescent female soccer players are not available and, therefore, further studies are required to allow further exploration.

There are several limitations are presented of the current study: the small number of adolescent female soccer players, between-age differences, maturational status of the participants, differences in players' position demands during the matches were not assessed, and data cannot be extrapolated to other populations such as men's soccer or other sports. Cumulative fatigue during the season may impact the results because the intervention was performed at the later stage of the season. Some exercises of the current programme (e.g., plank and side plank) might be difficult for adolescent female soccer players to carry out; therefore these exercises should be modified to increase participation percentage (e.g., set knees on the ground).

CONCLUSIONS

The FIFA 11+ programme carried out during a 10-week intervention period could be a stimulus sufficient enough to improve different performance variables and reduce inter-limb asymmetries in adolescent female soccer players. This programme significantly improves unilateral explosive and muscular power as well as dynamic and functional balance, which are believed to aid in the prevention of lower limb injuries. The FIFA 11+ also reduces inter-limb asymmetries of skill-related physical tests, which therefore minimizes injury risks. However, COD showed no improvements. It may be of interest to incorporate other explosive and technical training methods (e.g., straight sprints) to optimize COD adaptations.

4.4. Artículo IV [Manuscript IV]

Effects of combined strength and power training on physical performance and inter-limb asymmetries in adolescent female soccer players

Pardos-Mainer E, Casajús JA, Bishop C, Gonzalo-Skok O. Effects of combined strength and power training on physical performance and inter-limb asymmetries in adolescent female soccer players. **Int J Sports Phsyiol Perform.** *Accepted for publication.*

ABSTRACT

Purpose: This study examined the effects of an 8-week combined strength and power training (CSPT) intervention on physical performance and inter-limb asymmetries in adolescent female soccer players. **Methods:** Thirty-seven adolescent female soccer players (age: 16.1±1.1 yrs) were randomly assigned to a control (CG, n = 18) and experimental group (EG, n = 19). EG performed CSPT twice a week, which consisted of strength and power exercises that trained the major muscles of the lower body and trunk musculature. Pre- and post-intervention tests included unilateral and bilateral horizontal and countermovement jump tests, a 40-m sprint test (10 and 30-m split times), a 10-m sprint with a 180º change of direction (COD) test and a multiple COD test (V-cut test). Asymmetries were also analyzed in the unilateral tests. **Results:** Significant group by time interaction of the improvement between pre and post-tests were observed for speed (Effect size (ES): -1.30 to -1.16) and COD tests (ES: -0.62 to -0.61) but not in jumping (ES: -0.09 to 0.28) and inter-limb asymmetries tests (ES: -0.13 to 0.57). **Conclusions:** The short-term in-season CSPT program induced greater speed and COD performance improvements compared to soccer training alone in adolescent female soccer players.

Keywords: strength, change of direction, intervention, female

INTRODUCTION

Soccer is considered a contact sport, demanding a wide variety of skills at different intensities. In this regard, soccer players predominately run throughout the game, while other high intensity activities like sprinting, jumping, kicking and changing direction are also important performance factors that require both maximal strength and anaerobic power of the neuromuscular system (264, 265). Given the importance of high intensity activities for soccer performance, training strategies that ensure their optimal development are continuously being investigated and also, in recent years is having a great importance in youth soccer players (11, 185).

In order to design an appropriate training program, it is important to consider both the players´ age, stage of biological maturation, and their movement competence. The aim of training before peak height velocity (PHV) should be to increase neuromuscular strength, fundamental movement skills, and speed (266). Players circa-PHV could suffer a reduction in coordination and joint range of motion, whilst concurrently experiencing increases in physiological stress during match play (267). Finally, research highlights that post-pubertal players should prioritise improvements in strength and power, due to the natural increase in lean muscle mass associated with maturation (267). Therefore, training programs in youth female soccer players should take into consideration the athlete's physical capability (fundamental movement skills and soccer specific fitness), biological maturation, individual needs, and acute readiness to train (122).

Different training methods to improve soccer specific variables have been developed such as, high-intensity interval training, resisted sprint training, strength training or plyometric training (5, 12, 122, 269, 270). A previous study of female college soccer players showed that high-intensity interval training, performed twice per week for 5-weeks, significantly improved the Yo-Yo Intermittent Recovery 1 test distance (Effect size (ES): 0.44) (270). Shalfawi et al. (12) compared the effects of resisted agility and resisted sprint training with strength training on highly-trained (e.g., second division standard in Norway, top 3 in this division at the time of the study and 4-7 training sessions a week) female soccer players. They reported that 10-weeks of resisted sprint training (performed twice per week) improved maximal oxygen uptake during the incremental 20-m beep-test (ES: 0.85) and the squat jump (SJ) (ES: 0.42), while strength training significantly increased the beep-test performance (ES: 0.92) and the SJ (ES: 0.59). Ramirez-Campillo et al. (5) developed a 6-week plyometric training program with 38 female COD time (ES: 0.85) improvements in comparison to the control group. Whilst individual training interventions have been shown to produce enhancements in measures of athletic performance for soccer players (118, 269-271), there is a lack of studies looking at the effectiveness of strength and power training specifically on performance measures in youth female soccer populations.

Inter-limb asymmetries have been a common source of investigation in recent years and refers to the concept of comparing the function of one limb in respect to the other (15). Between-limb imbalance in strength and power, assessed as the limb symmetry index, has been considered as a valid and useful tool to detect players at high injury risk (e.g., 4-fold in players with >10% asymmetry) of lower extremity injury (16). Additionally, inter-limb asymmetries might also play a role in performance (e.g., greater symmetrical team-sports players seem to be faster that their asymmetrical counterparts) (17, 272). In this regard, strength training is amongst the most frequently used strategies to improve soccer performance and high-intensity actions, as well as to decrease asymmetries (12, 118, 194, 273, 274). Therefore, training programs should focus on combined bilateral and unilateral strength training to decrease inter-limb asymmetries and to increase performance during competition. However, relatively few studies have addressed this issue in young soccer players (249, 274). In addition, to the authors´ knowledge, no studies have analyzed the effect of an intervention on inter-limb asymmetry in youth female soccer players, hence, more studies for this population are warranted.

Therefore, the aims of the present study were 1) to evaluate the effects of combined strength and power training (CSPT) in physical performance and, 2) to observe if inter-limb asymmetries decreased as a result of the training intervention in a group of adolescent female soccer players. The hypothesis of this study was that there would be an improvement in both physical performance and inter-limb asymmetries from pre-intervention to post-intervention.

METHODS

Subjects

A total of 37 adolescent female soccer players (age: 16.1 ± 1.1 y; height: 159.7 ± 7.1 cm; body mass: 55 ± 7.1 kg) belonging to the same female soccer division club academy squad (Iberdrola Women´s First Division) participated in this study. Their maturational status was assessed through age at PHV (219), but validation studies indicated several limitations in this equation such as the lack of a measurement of sitting height and a typical error of measurement of 0.5 years (220, 221). Data collection took place during the sixth month out of 9 during the competitive season (**Table 18**). All players were training in a soccer club for at least 4 years. None of the players had any background in regular strength and power training. At the time of the study, all players were competing at national and regional standard (e.g., Spanish Female Soccer National League, Aragón Female Football Territorial League). Furthermore, some players (n = 4) were also competing at international standard (e.g., European Female Soccer

Championship). Participants were healthy and they did not suffer any disease or injury that could affect the results of the study. Written informed consent was obtained from both the players and their parents before beginning the investigation. The study was carried out in conformity with the ethical standards of the Declaration of Helsinki and has been approved by the Ethics Committee of Clinical Research from the Government of Aragón (CP19/039, CEICA, Spain).

Table 18. Descriptive Data of the Participants. Mean ± SD.

	Age (y)	**APHV**	**Height (cm)**	**Body mass (kg)**	**BMI (kg/m^2)**
Experimental group	16.2 ± 0.9	1.20 ± 0.55	159.8 ± 5.4	55.9 ± 5.5	21.8 ± 2.1
Control group	15.6 ± 0.9	0.73 ± 0.51	159.7 ± 4.9	54.1 ± 8.8	21.2 ± 2.9

BMI: Body- mass index; APHV: Age at peak height velocity;

Study Design

Using a pre-test matched-pairs study design (ABBA distribution), players from 2 different teams were divided into an experimental group (EG: *n* = 19) and a CG (CG: *n* = 18) based on their COD speed performance. Players were classified using a points system across all COD speed tests, from the first to the last position. Thereafter, each player was positioned in a global classification. From this point, the first player, that is, the player who had the most points was allocated in the EG, the second and the third players were allocated into the CG, and the fourth player in the EG. Both teams were involved in a similar weekly soccer training volume and methodology (3 sessions/week of 90 minutes and 1 match/week). EG players carried out an additional CSPT program twice per week for 8-weeks after the habitual warm-up. Players in the CG performed their habitual training that consisted on 15-min warm-up, 30-min technical training, 30-min tactical training, 40-min small-sided games and 5-min cool-down. Both groups performed the same training volume on the pitch. Tests were performed 2 weeks and 1 week (reliability analysis) before training and 1 week after the training period. Furthermore, 2 weeks before the commencement of intervention, four familiarization sessions were executed in the EG to thoroughly learn the exercises included in the CSPT program (**Figure 12**). The same researchers supervised every training session.

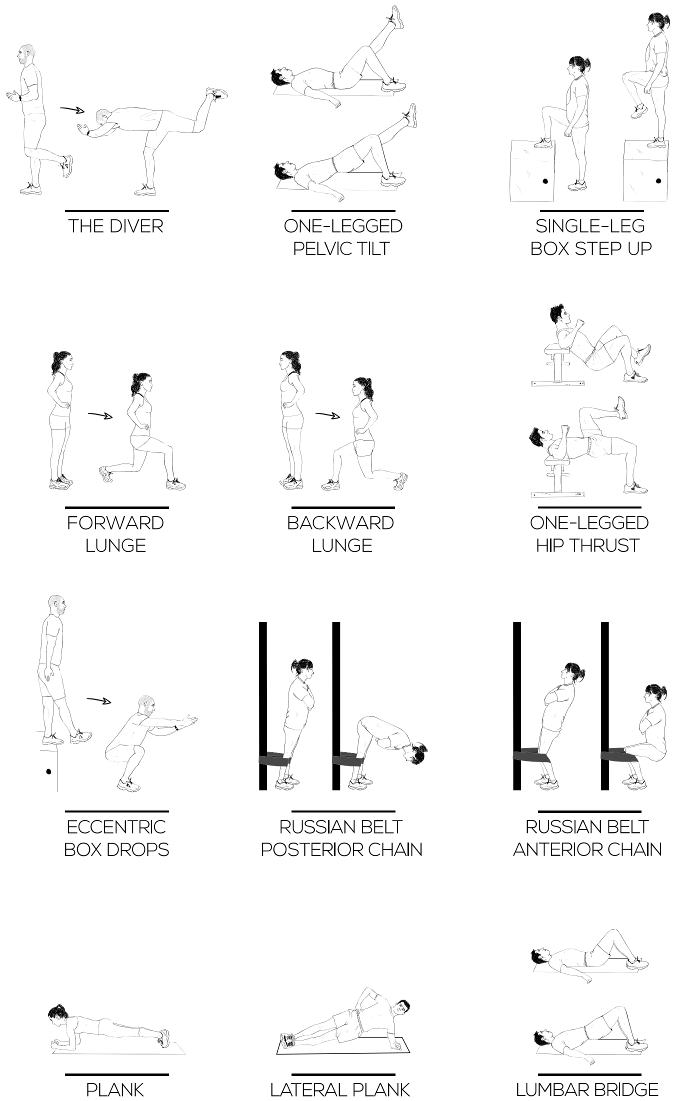


Figure 12. Exercises of combined strength and power training program

Procedures

Combined Strength and Power Training Program.

The CSPT was completed during the mid-portion of the competition period. The EG performed 2 sessions (~35 minutes) per week at the same time interspersed by 48-72 hours during an 8-week period. **Table 19** shows in detail the characteristics the training program. Exercises were performed in the same order in which they appear in the table (e.g. in session 2, training exercises were performed in the following order: diver, forward lunge, backward lunge, plank and lumbar bridge), and all exercises repetitions had to be completed before the following training set. Approximately 3-min rest periods were allowed between each set and each exercise. Box to single-leg box step up and eccentric box drops had a 30 cm height. All exercises were body weight resistance with the exception of the diver, forward lunge and backward lunge exercises. In all sessions, the warm up consisted of 5 minutes jogging and 5 minutes of joint mobilization exercises. Then, participants performed 2 sets of 6 to 10 repetitions (separated by 3-min rests) of 5 to 6 exercises in each session. Two experienced strength and conditioning coaches controlled every training session, providing verbal encouragement to each participant.

Table 19. Combined Strength and Power Training Program*

Exercise	Week 1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7		Week 8	
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
The Diver		2 x 6R		2 x 6R		2 x 8R		2 x 8R		2 x 6R (10% BM)		2 x 6R (10% BM)		2 x 8R (10% BM)		2 x 8R (10% BM)
One-legged pelvic tilt	2 x 6R		2 x 6R													
Single-leg box step up							2 x 6R		2 x 6R		2 x 8R		2 x 8R		2 x 10R	
Forward lunge		2 x 6R		2 x 6R		2 x 8R		2 x 8R		2 x 6R (10% BM)		2 x 6R (10% BM)		2 x 8R (10% BM)		2 x 8R (10% BM)
Backward lunge		2 x 6R		2 x 6R		2 x 8R		2 x 8R		2 x 6R (10% BM)		2 x 6R (10% BM)		2 x 8R (10% BM)		2 x 8R (10% BM)
One-legged hip thrust					2 x 6R		2 x 6R		2 x 8R		2 x 8R		2 x 10R		2 x 10R	
Eccentric box drops								2 x 6R		2 x 6R		2 x 8R		2 x 8R		2 x 10R
Russian Belt posterior chain	2 x 6R		2 x 6R		2 x 7R		2 x 7R		2 x 8R		2 x 8R		2 x 10R		2 x 10R	
Russian Belt anterior chain	2 x 6R		2 x 6R		2 x 7R		2 x 7R		2 x 8R		2 x 8R		2 x 10R		2 x 10R	
Plank	2 x 15"	2 x 15"	2 x 15"	2 x 15"	2 x 15"	2 x 15"	2 x 15"	2 x 20"	2 x 20"	2 x 20"	2 x 20"	2 x 20"	2 x 20"	2 x 20"	2 x 20"	2 x 20"
Lateral plank	2 x 15"		2 x 15"		2 x 15"		2 x 15"		2 x 20"		2 x 20"		2 x 20"		2 x 20"	
Lumbar bridge		2 x 15"		2 x 15"		2 x 15"		2 x 20"		2 x 20"		2 x 20"		2 x 20"		2 x 20"

*Recovery between sets = 3 minutes; R: Reps; BM: Body mass

Performance Tests

Participants were assessed at baseline and 8 weeks post-intervention on jumping, linear sprinting and change of direction ability (CODA) tests by the same group of investigators during the entire study, at the same time of the day (18:00-20:00) and under the same environmental conditions (~22ºC and ~20% of humidity) on a soccer field. Performance tests were completed in 2 hours on the soccer field. Before all testing, a warm-up standardized during 10 minutes was completed by participants. This consisted of running at 60-70% of the maximum heart rate, dynamic stretches such as multi-planar lunges, inchworms and spiderman exercises before progressing into practice jumps, sprints and CODs at 60, 80 and 100% of perceived maximum effort. A 3-minute rest was prescribed between the warm-up and the first test. Players wore athletic shoes (for jump tests) and soccer boots (for linear sprint and COD tests).

Standing broad jump test

The standing broad jump test indirectly measured horizontal power. This test was measured using a standard measuring tape *(30m M13; Stanley, New Britain, USA)* and was assessed as described elsewhere (251). Each test was performed three times, separated by at least 30 seconds of passive recovery, and the best jump was recorded and used for analysis.

Single-leg horizontal jump test

The single-leg horizontal jump test indirectly measured unilateral horizontal power. This test was measured using a standard measuring tape *(30m M13; Stanley, New Britain, USA)* and was assessed as described elsewhere (170). Leg swing of the alternate leg flexed to 90º at the hip and knee was allowed. The variables used in analyzes were: 1-legged left horizontal jump and 1-legged right horizontal jump. Each test was performed three times, separated by at least 30 seconds of passive recovery, and the best jump was recorded and used for analysis.

Bilateral and unilateral countermovement jump test

Vertical jumping ability was assessed using a vertical countermovement (CMJ) jump test (reported in centimeters) with flight time measured by the Optojump (*Optojump, Microgate, Bolzano, Italy*) to calculate jump height and is described elsewhere (170). Each test was performed three times, separated by 30 seconds of passive recovery, and the best jump was recorded and used for analysis. The same criterion was used to assess unilateral CMJ test. Leg swing of the alternate leg flexed to 90º at the hip and knee was allowed. Furthermore, subjects were instructed to perform a controlled, balanced landing and to stick the landing for 2-3 s with the same assessed leg.

40-m speed test

Running speed was evaluated by a 40-m sprint time (standing start) with 10-m, 20-m, 30-m split times. Time was recorded with dual beam photocell systems (*Witty, Microgate, Bolzano, Italy*) and is described elsewhere (170). The 40-m sprint was performed twice, separated by at least three minutes of passive recovery. The best time was recorded for analysis.

180º Change of direction test.

Players performed a 10-m sprint test with one180ºCOD. Sprint times were measured by dual beam photocell systems (*Microgate, Bolzano, Italy*) a 10-m sprint test was performed and is described elsewhere (170). The180ºCOD was repeated twice with right and left and 2-min of between-repetitions recovery was allowed. The best time with each180ºCOD was retained.

V-cut test

Players performed a 25-m sprint with 4 CODs of 45º 5-m each and is described elsewhere (170). Sprint times were measured by dual beam photocell systems (*Microgate, Bolzano, Italy*). The V-cut test was executed twice and 3 min of passive recovery was provided between repetitions. Time in the best (fastest) trial was recorded for analysis

Statistical Analysis

Statistical analysis was performed with SPSS for MAC (Version 19.0; SPSS Inc, Chicago, IL). Data are presented as mean ± standard deviation (SD). Normality and equal variance assumptions were checked using the Shapiro-Wilk test and Levene test, respectively. Statistical significant was inferred from $p < 0.05$. Relative reliability analysis was examined by the intra-class correlation coefficient ($ICC_{3,1}$). To examine the absolute reliability, the typical error of measurement was used. The spreadsheet of Hopkins (227) was used to determine both ICC and typical error of measurement, expressed as a coefficient of variation. A repeated measures ANOVA with Bonferroni post-hoc analysis was conducted to determine systematic bias between time points, with an alpha level of $p < 0.05$. Within-group comparisons (Student paired *t*-test) were carried out to detect significant differences between the pre-test and post-test in all variable in both groups. In addition, an ANCOVA (general linear model) was used to detect any significant between-group difference at post-test using the pre-test as covariates. The standardized difference or effect size (ES, 90% confidence limit) in the selected variables were calculated using the pre-training SD. Threshold values for Cohen ES statistics were >0.2 (small), >0.6 (moderate), and >1.2 (large) (154).

Inter-limb asymmetry was calculated using the following formula (155) :

Inter-limb asymmetry = 100/Max Value (right and left)*Min Value (right and left)*-1+100.

RESULTS

Only players who participated in 85% of the training sessions were included in the final analyses. No participant was excluded due to injury, illness or lack of interest, and as a result, all players were included in the final analyses. No significant between-group differences were found at pre-test for any of the variables analysed. Reliability of all tests performed in CG and EG is shown in **Table 20**.

Table 20. Reliability data for each test (n= 37).

Variable	***p***	**ICC (CL90%)**	**CV (CL90%)**
CMJ	0.70	0.89 (0.80; 0.93)	6% (4.9; 8)
CMJ_R	0.25	0.93 (0.87; 0,97)	3% (2.5; 4.1)
CMJ_L	0.98	0.91 (0.77; 0.95)	4.8% (4; 6.3)
SBJ	0.80	0.91 (0.77; 0.96)	1.8% (1.4; 2.6)
SLH_R	0.82	0.85 (0.71; 0.92)	4.3% (3.5; 5.3)
SLH_L	0.58	0.80 (0.58; 0,93)	5.5% (4.5; 6.8)
10m	0.01	0.82 (0.58; 0.92)	4.2% (3.5; 5.4)
20m	0.01	0.85 (0.65; 0,94)	3.6% (2.4; 7.5)
30m	0.01	0.88 (0.81; 0.93)	2.2% (1.7; 3.3)
40m	0.01	0.89 (0.76; 0.90)	2.3% (1.8; 3.3)
180ºCOD_R	0.51	0.85 (0.71; 0.92)	2.5% (1.9; 3.5)
180ºCOD_L	0.59	0.86 (0.65; 0.93)	2.4% (1.6; 4.2)
V-cut	0.34	0.80 (0.57; 0.93)	2.5% (1.6; 3.6)

ICC: Intra-class correlation coefficient; CV: Coefficient of variation; R: Right; L: Left; SBJ: Standing broad jump; SLH_R: one-legged horizontal right jump; SLH_L: one-legged horizontal left jump; CMJ: countermovement jump; CMJ_R: one-legged vertical right jump; CMJ_L: one-legged vertical left jump; 180ºCOD: 5+5 m sprint test with a 180º change of direction; R: right; L: left; V-cut: 25-m sprint test with 4 x 45º changes of direction.

Table 21. Summary results of all tests performed in Control Group and Experimental Group. Mean ± SD

	Control Group				Experimental Group				Interaction #	
Variable	**Pre-test**	**Post-test**	**p**	**ES (90 CL)**	**Pre-test**	**Post-test**	**p**	**ES (90 CL)**	**p**	**ES (90 CL)**
SBJ (m)	1.41 ± 0.18	1.46 ± 0.20	0.12	0.22 (-0.02; 0.46)	1.74 ± 0.15	1.78 ± 0.16*	0.01	0.29 (0.12; 0.46)	0.70	-0.03 (-0.26; 0.20)
SLH$_R$ (m)	1.20 ± 0.14	1.25 ± 0.14*	0.01	0.32 (0.17; 0.47)	1.32 ± 0.15	1.37 ± 0.19	0.09	0.25 (-0.14; 0.54)	0.88	-0.09 (-0.37; 0.20)
SLH$_L$ (m)	1.25 ± 0.13	1.28 ± 0.14	0.10	0.22 (0; 0.44)	1.29 ± 0.11	1.36 ± 0.16*	0.01	0.58 (0.24; 0.92)	0.18	0.28 (-0.07; 0.63)
% As SLH	4.09 ± 3.93	4.48 ± 3.33	0.64	0.07 (-0.33; 0.47)	6.32 ± 5.41	5.26 ± 5.08	0.43	-0.26 (-0.85; 0.33)	0.78	-0.13 (-0.67; 0.41)
CMJ (cm)	23 ± 3.73	23.9 ± 4.35	0.22	0.23 (-0.10; 0.57)	23.5 ± 3.30	25.6 ± 3.65*	0.01	0.55 (0.25; 0.85)	0.24	0.28 (-0.16; 0.71)
CMJ$_R$ (cm)	12.1 ± 2.77	13.1 ± 2.65	0.06	0.36 (0.07; 0.66)	12.9 ± 1.95	14.3 ± 2.44*	0.02	0.58 (0.18; 0.98)	0.53	0 (-0.47; 0.46)
CMJ$_L$ (cm)	11.7 ± 2.36	12.8 ± 3.16	0.09	0.40 (-0.03; 0.83)	12.9 ± 3.1	13.9 ± 3.1	0.08	0.31 (-0.02; 0.63)	0.84	-0.01 (-0.51; 0.50)
% As UCMJ	12.5 ± 10.2	15.7 ± 10.1	0.29	0.22 (-0.23; 0.67)	11.5 ± 8.99	11.5 ± 11.3	0.97	-0.21 (-0.77; 0.35)	0.34	-0.04 (-0.70; 0,61)
10m (s)	2.1 ± 0.11	1.99 ± 0.10*	0.01	-0.98 (-1.55; -0.41)	2.08 ± 0.07	1.99 ± 0.09*	0.01	-1.29 (-1.99; -0.59)	0.98	0.16 (-0.66; 0.98)
20m (s)	3.42 ± 0.10	3.46 ± 0.14	0.12	0.33 (-0.04; 0.69)	3.6 ± 0.12	3.45 ± 0.13*	0.01	-1.21 (-1.60; -0.83)	0.01#	-1.30 (1.73; 0.87)
30m (s)	4.81 ± 0.15	4.85 ± 0.19	0.15	0.23 (-0.05; 0.42)	5.05 ± 0.18	4.85 ± 0.19*	0.01	-1.11 (-1.45; -0.76)	0.01#	-1.20 (1.57; -0.82)
40m (s)	6.24 ± 0.21	6.29 ± 0.25	0.17	0.19 (-0.05; 0.42)	6.51 ± 0.26	6.24 ± 0.25*	0.01	-1.02 (-1.27; -0.77)	0.01#	-1.16 (-1.47; -0.85)
180ºCOD$_R$ (s)	2.89 ± 0.11	2.93 ± 0.12	0.58	0.23 (-0.14; 0.60)	2.87 ± 0.16	2.85 ± 0.18	0.44	-0.15 (-0.49; 0.18)	0.47	-0.19 (-0.67; 0.29)
180ºCOD$_L$ (s)	2.93 ± 0.15	2.91 ± 0.11	0.86	-0.18 (-0.45: 0.09)	2.96 ± 0.16	2.89 ± 0.18*	0.03	-0.52 (-0.89: -0.14)	0.03#	-0.61 (-1.03; -0.20)
% As COD	2.62 ± 2.29	2.14 ± 1.55	0.49	-0.07 (-0.55; 0.41)	4.42 ± 3.14	2.55 ± 1.93	0.08	-0.30 (-0.96; 0.36)	0.39	-0.57 (-1.56; 0.41)
V-cut (s)	7.98 ± 0.38	7.97 ± 0.39	0.24	-0.02 (-0.26; 0.21)	8.05 ± 0.38	7.81 ± 0.27*	0.01	-0.58 (-0.90; -0.27)	0.01#	-0.62 (-1.05; -0.20)

R: Right; L: Left; CMJ: countermovement jump; UCMJ: unilateral countermovement jump; CMJ: countermovement jump; CMJ$_R$: one- egged vertical right jump; CMJ$_L$: one-legged vertical left jump; SBJ: Standing broad jump; SLH: single leg hop test; SLH$_R$: one-legged horizontal right jump; SLH$_L$: one-legged horizontal left jump; 180ºCOD: 5+5 m sprint test with a 180º change of direction; V-cut: 25-m sprint test with 4 x 45º changes of direction; SD: standard deviation; As: asymmetry; cm: centimetres; s: seconds; m: meters; CL: confidence limits; ES: Effect Size

* Significant difference between the pre-test and post-test ($p < 0.05$)

#Significant group by time interaction including pre-test as covariate ($p < 0.05$)

Performances in jump, linear sprinting and COD tests are shown in **Table 21**. No significant group by time interaction of the improvement between pre and post-tests were observed for jump and inter-limb asymmetries tests. ANCOVA showed significant group by time interactions for the 20-m (*p* = 0.01; ES: 1.30 (90% confidence limit [CL]: 0.87; 1.73)), 30-m (*p* = 0.01; ES: 1.20 (90% CL: 0.82; 1.57)), 40-m (*p* = 0.01; ES: 1.16 (90% CL: 0.85; 1.47)), the left180ºCOD (*p* = 0.03; ES: 0.61 (90% CL: 0.20; 1.03)) and the V-cut test (*p* = 0.01; ES: 0.62 (90% CL: 0.20; 1.05)) in favour of the EG

DISCUSSION

The aims of the present study were to evaluate the effects of a CSPT program on physical performance and to examine such effects on inter-limb asymmetries in several unilateral tests, in a group of adolescent female soccer players. The main finding of this study was that a CSPT induced improvements in speed and COD parameters in adolescent female soccer players but, did not improve jump and asymmetry parameters. Therefore, these results provide relevant evidence to support the need for adding strength and power training within the soccer training program to obtain further development of the speed and COD performance of adolescent female soccer players.

The between group analyses did not show significant differences in any jump variables at post-testing, which was in agreement with the previous studies on adolescent soccer players using strength training (12, 275). However, other studies have shown improvements in jump ability after similar training programmes have been performed (5, 276, 277). These previous studies have all programmed exercises where the speed of movements is performed at high velocity. In contrast, the current CSPT program seems to have been less effective in making positive during jump testing, than other programs using explosive plyometric and strength exercises. These results suggest that the speed of movement (rather than the resistance of load) is more likely to positively affect jump performance in adolescent female soccer players.

The CSPT approach employed in the present study was an effective training strategy to enhance sprinting and COD performance. A recent study with similar training methods also reported significant changes in these physical qualities, in female soccer players (137). This study speculated that strength and power training was important in developing sprint physical qualities but could not prove this within the limitations of a single-arm quasi-experimental design. In contrast, the present study used both a CG and EG, and showed that the selected exercises were effective at improving sprint and COD performance (ES: -0.61 to -1.30). According to this study, it is appears that strength and power training may be consistent training methods to drive the neuromuscular adaptations (eg, increase in neural drive, coordination or improved fundamental movement skills) that likely improving acceleration, deceleration, peak velocity and/or COD speed.

Regarding sprint time, the training program resulted in significant 20-, 30- and 40-m improvements for EG compared to CG. Given the inherent differences often employed between study methodologies, true comparisons between different studies is challenging. However, others studies have found similar significant increases in sprint performance after a plyometric program in female soccer players (3, 5). It is well acknowledged that horizontal force production has an important application in sprint acceleration performance (278). Both plyometric training discussed previously and the current training program incorporated horizontal stimulus and this may have increased the chances to gain adaptations. However, Shalwafi et al. (12) have shown that during the in-season period and after a strength program, female soccer players did not improve sprint performance. It has been observed that soccer players experience a reduction in performance during the competitive period (279) and strength training should be used with caution during mid-season. Findings of the present study suggest that CSPT was effective in improving acceleration (eg, 20-m sprint-time) performance after 8-weeks of training (**Table 20**). It should be noted that a meaningful portion of the CSPT exercises (eg, eccentric box drops, forward and backward lunges and single-leg box step up) in the current intervention have been shown improve muscular power in the hip, knee and ankle extension, which are highly related to short-distance sprints (280, 281). Hence, these results highlight the importance of developing both lower body strength and power which may enhance linear sprinting performance (282). Further research is warranted to observe what exercise order and training scheduling is better to improve linear sprinting performance in adolescent female soccer players.

Current results indicated significant improvements in COD performance after the CSPT program. Our findings and others (31, 137) have observed significant improvements in CODA in adolescent female soccer players. It has been described that to achieve the fastest performance during a COD test; larger contributions of isometric and eccentric strength, higher braking and propulsive forces and lower contact times, are all required (283). The utilization of different exercises such as forward and backward lunges, Russian belt posterior and anterior chain, and single-leg box step ups may have induced higher isometric contractions; thus, facilitating improved technique and body alignment during COD tests. The isometric strength seems to be decisive to optimize the triple extension during180ºCOD test, as a result of permitting the correct alignment of the lower limbs to then subsequently, reaccelerate thereafter (283). Thus, the CSPT intervention was again, effective at improving key movement patterns (180º directional change) which are common movements in soccer.

Despite the apparent critical relevance of between-limb imbalance for protection against injury and performance (16, 17), to the best of our knowledge, this is one of the first study to assess the impact of a training intervention on lower- extremity asymmetries in adolescent female soccer players (185). Nevertheless, the current CSPT program did not make any meaningful changes in inter-limb asymmetries. Pardos-Mainer et al. (185) reported that a neuromuscular training program was effective at reducing the drop jump (ES: 0.72) and COD (ES: 0.93) asymmetries. When viewing the asymmetry results in **Table 21**, it is evident that the SD is quite large relative to the mean value; more so than for other test metrics. In turn, this may be a reason as to why no significant differences in asymmetry were present post-intervention. Furthermore, practitioners should be somewhat mindful of assessing relationships between an asymmetry index and additional fitness test scores. Asymmetry is a ratio (ie, made up of 2 composite parts); thus, it is probable that biased or inflated correlations may be reported when the relationship between asymmetry and its composite parts are assessed. Thus, it is suggested that practitioners consider interpreting changes in asymmetry rather than associative analysis, and on an individual basis, which is in line with recent empirical suggestions on the topic (282).

In addition, a previous study evaluated the effect of three different unilateral strength training strategies in young soccer players (96). Interestingly, all training strategies decreased CMJ asymmetry (ES: 0.08 to 0.23) but did not decrease single-leg horizontal jump asymmetry (ES: -0.58 to 0.06). Thus, it is not currently clear what the best training strategy is to decrease between-limb differences.

A possible limitation of the present study is that exercise intensity (eg, session rating of perceived exertion) was not measured. The use of such a non-invasive method to quantify the internal training load in each training session could be useful in future study designs. Second, analysis asymmetry was calculated using the group mean value, which showed the variable nature of asymmetry, as represented by the large SD. As previously suggested, it is suggested that monitoring changes in asymmetry is done on an individual basis. In addition, in order to determine whether a change in asymmetry is meaningful, it is suggested that this change must be greater than the test variability score (263, 284), which is in line with recent suggestions on the topic. Furthermore, adolescent female soccer players have particular characteristics and, our results cannot be directly extrapolated to other sports. In this way, we cannot establish the influence of maturation through PHV as all players are substantially above PHV. Consequently, further studies should be done taking into account maturity offset (ie, with pre-, mid- and post-PHV) to determine the possible influence of maturation on performance adaptations. Finally, to try to achieve similar results in a similar sample a proper execution is required to develop the expecting adaptations and, in consequence, experienced coaches should be involved.

CONCLUSIONS

For our adolescent female soccer players, the addition of strength and power training in the short-term (ie, 8 weeks) during the in-season period, induced greater speed and COD performance improvements compared to soccer training alone. However, inter-limb asymmetries did not decrease; thus, it should be interesting to incorporate other training methods (eg, plyometric training) or strategies (eg, start the session with the weaker leg) to minimize injury risk and to improve performance.

PRACTICAL APPLICATIONS

The findings of this study are that a CSPT during the in-season period in adolescent female soccer players can improve speed and COD performance. These adaptations can be achieved in a few weeks and may potentially increase competitive performance and minimize the risk of injury. It is worth noting that simple interventions can produce significant improvements in an adolescent population that is relatively untrained in strength and power. Therefore, our data support the notion that strength and power training can elicit sprint related performance improvements in-season.

4.5. Artículo V [Manuscript V]

Age-related differences in acceleration and maximal sprinting speed in adolescent female soccer players.

<u>Pardos-Mainer E</u>, Casajús JA, Gonzalo-Skok O. Age-related differences in acceleration and maximal sprinting speed in adolescent female soccer players. **Kinesiology.** *Submitted.*

ABSTRACT

This study investigated age-related differences in acceleration and maximal sprinting speed (MSS) in 80 adolescent female soccer players (Under 14, n = 20; Under 16, n = 37; Under 18, n = 23). Also, it examined the possible influence of anthropometry (body mass) and biological maturation (age at peak height velocity (APHV)) on in such sprint-running qualities. And finally, it analysed the location of the fastest 10-m split time ($Split_{best}$) over a 40-m sprint in relation to age and MSS in 160 independent player sprints. Players were tested for 10-m sprint (acceleration) and 40-m sprint (each 10-m split times). The maximal sprint speed was defined as the average running speed during the $Split_{best}$. There were age-based differences both in absolute performance in all split times (Under 18 > Under 16 > Under 14; $p < 0.05$) and when APHV were statistically controlled ($p > 0.05$). In contrast, all between-group differences disappeared after body mass adjustment ($p < 0.05$). The distribution of the distance associated with the $Split_{best}$ was not statistically affected by age, though the older players showed a greater proportion of 30 to 40 m $Split_{best}$. Within a single age-group in the present players' sample, body mass had a significant impact on running speed qualities. In addition, 10-m intervals are still required to guarantee an accurate evaluation of MSS in adolescent female soccer players using timing gates. Coaches may need to consider players' maturity status when assess and train running speed qualities.

Keywords: peak height velocity, velocity, peak running, football

INTRODUCTION

Women's soccer has increased in popularity and participation during the last decade (166). In its last report, FIFA estimates that there is close to one million of U-18 players in Europe, having increased the number of licenses in just one year by more than 10% (158). So, today, the growth of this sport at early ages is a reality and this causes the increase of studies and research in this population.

Soccer is considered a contact sport and demands a wide variety of skills at different intensities (13, 277). The ability to perform high-speed actions is an important prerequisite to successfully perform different actions in soccer (90). Several studies with soccer players have shown that the improvement of high-speed components such as acceleration (286, 287) and maximal sprinting speed (MSS) (27, 288) are related to match performance. Specifically, maximal sprinting speed is the maximum speed, instantaneous or average, reached after a segmental or global acceleration, and acyclical or cyclical (289). Usually, this quality is associated with a successful performance on soccer match play (56). However, during competition, players rarely covers the minimum distance to reach their maximum speed (56), so the ability to accelerate, defined as the rate of change of speed (57), is more important to achieve MSS and for this reason, coaches should take into account the development of this ability (290).

The ability to accelerate is a skill that manifests itself in short distances (89), specifically, it is divided into 2 phases: the initial acceleration in the first 5 to 10 m (291) and the maximal sprinting speed likely reached after 20 to 40 m (64, 292). Wong et al. (293) have detected that each player performs on average a maximum or close to maximum acceleration of 10-30 m every 90 seconds. Thus, the greater ability to run short distances in less time, the greater the player's success.

Biological maturation is a gradual process over time in which modifications are presented at the anatomical and physiological level. Hormones are stimulated during the period of puberty until full maturity is reached (294). Any inappropriate stimulus could cause some alteration in the development of the adolescent and that is why, the training loads should adapt to the speed of subject's maturation (295). Several studies have observed the contribution of chronological age, biological maturation and anthropometric characteristics to sprinting performance in young soccer players (189, 293, 296). For example, Malina et al. (189) showed that height, body mass and maturity status are determinants of sprint-running performance. However, there are no studies that have analysed the contribution of these characteristics to acceleration and MSS in adolescent female soccer players.

Thus, the aims of this study were: 1) to investigate the relationship between acceleration and MSS in different age-groups of female young soccer players (U-14 to U-18), 2) to examine the influence of body mass and biological maturation on acceleration and MSS, and 3) to locate the fastest 10-m split time ($Split_{best}$) over a 40-m sprint in relation to age and MSS in adolescent female soccer players (U-14 to U-18).

METHODS

Subjects

Eighty female soccer players (U-14, U-16 and U-18) belonging to the same female soccer division club academy squad (Iberdrola Women's First Division) participated in this study (age: 14.9 ± 1.5 years; height: 158.6 ± 6.7 cm; body mass: 53.3 ± 7.8 kg) (**Table 22**). All players were training in a soccer club for at least 4 years. Physical sessions of different teams consisted on speed, agility and quickness training, injury prevention or coordination exercises allowing to maintenance physical fitness level. At the time of the study, all players were competing at national and regional level (i.e., Spanish Female

Soccer National League, Aragón Female Soccer Territorial League). Furthermore, some players (n=4) were also competing at international level (i.e. European Female Soccer Championships).

Participants were healthy and they did not suffer any disease or injury that could affect the results at the moment of study. Parental/guardian consents for all players involved in this investigation were obtained. The study was conducted according to the Declaration of Helsinki (2013) and was approved beforehand by the Ethics Committee of Clinical Research from the Government of Aragón (CP19/039, CEICA, Spain).

Table 22. Subject characteristics.

Group	n	Age (y)	APHV	Height (cm)	Body mass (kg)	Training practical ($h \cdot w^{-1}$)
U-14	20	13.1 ± 0.45	0.36 ± 0.58	154.1 ± 7.6	48.8 ± 7.8	~ 3 hours (1 technical-tactical sessions + 1 physical sessions)
U-16	37	14.2 ± 1.6	2.01 ± 0.98	157.9 ± 6.8	51.8 ± 7.8	~ 4 hours (1 technical-tactical sessions + 2 physical sessions)
U-18	23	17.1 ± 0.79	2.74 ± 0.48	160.2 ± 6.1	56.1 ± 6.5	~ 4 hours (1 technical-tactical sessions + 2 physical sessions)

Values are mean ±SD. APHV: Age at peak height velocity

Maturity status

Pubertal timing was estimated according to the biological age of maturity of each individual as described by Mirwald et al. (219). The age of peak linear growth (age at peak height velocity) is an indicator of somatic maturity representing the time of maximum growth in stature during adolescence. Biological age of maturity (years) was calculated by subtracting the chronological age at the time of measurement from the chronological peak-velocity age (297). Thus, a maturity age of -1.0 indicates that the player was measured 1 year before this peak velocity; a maturity of 0 indicates that the participant was measured 1 year after this peak velocity.

Sprint Testing

Player´s acceleration was defined as their first 10-m sprint time (dual-beam electronic timing gates set at 10-m intervals (*Witty, Microgate, Bolzano, Italy)* (298). MSS (km/h^{-1}) was defined as the fastest 10-m split time measured during each 40-m sprint (292). Split time were measured to the nearest 0.01 s. Players commenced each sprint from a standing start with their front foot 0.5 m behind the first timing gate. Players started when ready, thus eliminating reaction time. Two trials were separated by al least 3 min of recovery with the best performance used as the final result.

Statistical analyses

Descriptive statistics (means ± standard deviations) are reported.

For the first part of this study, all analyses of variance (ANOVA) were performed on log-transformed data; for the sake of clarity, however, they are reported non-transformed. Between-group differences in acceleration and MSS performance were assessed using analysis of covariance (one-way ANCOVA). Body mass and APHV was used as a covariate in the present study (299). The magnitude of the differences of each covariate effect was assessed (pairwise comparisons) using standardized mean differences (Cohen effect size, ES) on the adjusted means (least squared means) provided by the ANCOVA. The criteria to interpret the magnitude of the effect size were: >0.2 (small), >0.6 (moderate), >1.2 (large), and >2.0 (very large) (154).

In the second part of this study, analyses were performed on 160 independent player sprints. The average number of test per player was 2. The distribution of the distance associated with $Split_{best}$ as a function of age was analysed with the chi-square statistic. The effect of age on average $Split_{best}$ distance (ie, 10, 20, 30 and 40 m were used for 0-10, 10-20, 20-30 or 30-40- splits) was further analysed with a one-way ANOVA.

RESULTS

U18 and U16 players had significantly ($p < 0.01$) faster 10-m, 20-m, 30-m and 40-m times than U14 players (**Table 23**).

Age differences (U18 > U16 > U14) in all split times still persisted when body mass was statistically controlled for (**Table 24**). However, after adjustment for APHV, all between-group differences disappeared.

The younger players showing the greater representation of 20-to-30-m $Split_{best}$ while the older showing it in 30-to-40-m $Split_{best}$. In addition, no significant differences within-age group X^2_3 value were found then, the distribution of the distance associated with $Split_{best}$ was not affected by age (**Figure 13**). Acceleration (10-m) and MSS were associated with age (Table 4).

Table 23. Times for 10-m, 20-m, 30-m and 40-m sprint for the U14, U16 y U18 soccer players (mean ± *s*), together with effect size differences ^.

Variables	Age groups			U16 vs. U14 ES (magnitude of difference)	U18 vs. U14 ES (magnitude of difference)	U18 vs. U16 ES (magnitude of difference)
	U14 (n = 14)	U16 (n = 24)	U18 (n = 18)			
10-m sprint (s)	2.12 ± 0.10	2.04 ± 0.09*	2.02 ± 0.12$	0.89 (Moderate)	0.93 (Moderate)	0.03 (Trivial)
20-m sprint (s)	3.67 ± 0.14	3.55 ± 0.15*	3.52 ± 0.18$	0.69 (Moderate)	0.93 (Moderate)	0.09 (Trivial)
30-m sprint (s)	5.18 ± 0.19	5.02 ± 0.24*	4.96 ± 0.26$	0.64 (Moderate)	0.92 (Moderate)	0.11 (Trivial)
40-m sprint (s)	6.84 ± 0.27	6.54 ± 0.34*	6.41 ± 0.34$	0.85 (Moderate)	1.33 (Large)	0.17 (Trivial)

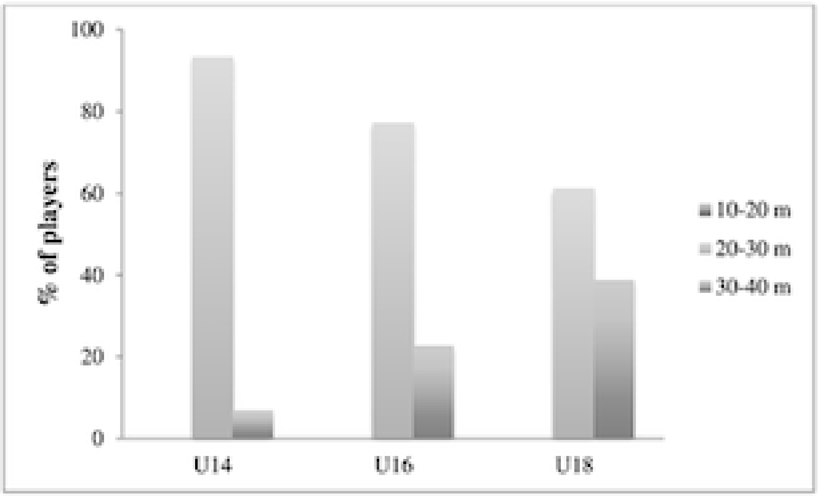
*Significant difference ($p < 0.05$) between U16 and U14 players. $ Significant difference ($p < 0.05$) between U18 and U14 players.
^ES = effect size differences. Thresholds for magnitude of difference are: ≤ 0.2 trivial. > 0.2-0.6 small, > 0.6-1.2 moderate, >1.2-2.0 large, >2.0-4.0 very large.

Table 24. 10-m, 20-m, 30-m and 40-m sprint including estimated biological maturity status (APHV = age at peak height velocity) and body mass as covariates.

	U16 vs U14		U18 vs U14	
Variables	APHV	Body mass (kg)	APHV	Body mass (kg)
10-m sprint (s)	<0.01*	0.38	<0.01*	0.18
20-m sprint (s)	<0.01*	0.36	0.09	0.21
30-m sprint (s)	<0.01*	0.28	<0.01*	0.19
40-m sprint (s)	<0.01*	0.23	<0.01*	0.69

* Significant $p < 0.05$

Figure 13. Fastest 10-m split time distribution as a function age in adolescent female soccer players.



DISCUSSION

The primary aim of this investigation was to determine the relationship among different speed qualities relevant for soccer performance at different ages and to examine what possible factors determining it in adolescent female soccer players. A secondary aim was to observe the fastest 10 m split time in relation to age and MSS. The present results showed that the disappearance of between-group differences in sprint running performances when adjusted for estimated biological maturity (i.e., APHV) suggest that high-speed running in adolescent female soccer players may be considered a general quality, which is likely to be related to qualitative muscular adaptations that occur with maturation. In addition, the current results provided that the distance associated with $Split_{best}$ within each age group vary in younger players (20 m) compared to older players (30 m). These observations are lacking on the literature for adolescent female soccer players.

Sprint performance is believed to be a significant predictor of match physical performance in soccer players (287, 288). The development of sprinting speed in the age range investigated in the present study (12-17 years) is influenced by growth and maturation (189). Growth refers to the increase in body size, both weight and stature: it refers to muscular quantitative factors (189). Otherwise, maturation refers to the timing and tempo of progress toward the mature biological (189); it refers to muscular qualitative factors (299). Growth and maturation are closely related and are unified processes (189). Previous studies have evaluated the possible role of both quantitative and qualitative muscular factors on different running speed qualities relevant to soccer performance in young male soccer players (299) but this is the first study to analyse it in adolescent female soccer players. Mendez-Villanueva et al. (299) showed that maturation explained a greater proportion of age-related differences in speed capacities than body dimensions in young male soccer players. This finding is in line with the current study, while between-group differences in acceleration and maximum running speed were clear with no adjustment (i.e. effect size rated as moderate, **Table 23**), significant results were observed when body mass was entered as covariate (**Table 24**). However, the inclusion of the estimation of maturity status (i.e., APHV) as a covariate is not significant. This suggests that the age-related differences in sprint running performance in the present study were more related to differences in anthropometric rather than differences in maturation factors *per se*.

On the other hand, sprint performance advantages associated with advanced skeletal maturity were less apparent against older female players (i.e. U16 vs. U18) than male counterparts (299). This observation was inconsistent with limited comparative data for adolescent female tennis players (300). In this study of U10 to U16 female tennis players, sprinting performance (5-m, 10-m and 20-m) did not differ between maturity groups (300). This discrepancy in observations for female athletes is likely related in part with early maturing measure used. Skeletal age estimated maturity was used with female tennis players, while APHV was used in the present study. The use of the Mirwald equation to assess maturity status has been previously questioned due to its potential associated error of ± 6 months (301). Therefore, caution may be taken into account when comparing both methods.

The present study revealed that female younger players reached the fastest 10-m split in 20-to-30-m $Split_{best}$ while older players reached in 30-to-40-m $Split_{best}$ (**Figure 13**), then older players reached MSS later than younger players. These findings might be likely related to the fact that older players have greater strength (hormonal differences) and, consequently, achieve greater MSS. Similar results showed Buchheit et al. (292) where male soccer players with greater acceleration achieved MSS later in the 40-m sprint compared with players with a lower acceleration (292). This suggests that the better acceleration of the female older players did not allow them to reach MSS after a shorter running distance than their younger (and slowest) counterparts. However, intermediate splits are still required to guarantee an accurate evaluation of all female players when using timing gates over a 40-m sprint.

To conclude, we suggest that the age effects on running speed qualities during growth in the current cohort of adolescent female soccer players are likely related with anthropometric factors (i.e., body mass) rather than biological maturation per se. However, it is worth noting that within the calculation of biological maturation is body mass and, thus, both factors are closely related. Furthermore, when comparing acceleration and MSS in adolescent female players, it should be interesting to take into account body mass. Finally, as female players are older, a longer distance seems to be required to achieve MSS. Consequently, 10-m intervals are still required to guarantee an accurate evaluation of MSS in adolescent female soccer players when using timing gates.

Capítulo 5. Conclusiones y Aportaciones principales

Nuestra recompensa se encuentra en el esfuerzo y no en el resultado. Un esfuerzo total es una victoria completada.
Mahatma Gandhi

Conclusiones

I. La habilidad del CD en jugadoras de fútbol adolescentes se puede evaluar con diferentes pruebas, sin embargo, el test del CD180º parece ser el más apropiado para replicar los patrones de movimiento del fútbol. La fiabilidad de los test de CD depende de los instrumentos utilizados, la superficie o el nivel de las jugadoras de fútbol. Además, los resultados de las pruebas de CD deben interpretarse con precaución, ya que pueden estar influenciados por el periodo de crecimiento y la maduración del sujeto, la posición de la jugadora y el momento de la temporada.

II. Los test de salto (CMJ y salto horizontal), de velocidad lineal y de CD (180ºCD y test V-cut) parecen ser fiables y sensibles a los cambios inducidos por el entrenamiento a corto y medio plazo en jugadoras de fútbol adolescentes, mostrando una mayor fiabilidad a medida que las jugadoras son de mayor edad.

III. Un programa de entrenamiento neuromuscular durante 10 semanas, produce efecto beneficioso para la mejora de la fuerza explosiva unilateral, la potencia, el equilibrio dinámico y funcional y la reducción de las asimetrías entre extremidades inferiores, aunque no logra ningún efecto beneficioso para el CD.

IV. Un programa combinado de fuerza y potencia durante 8 semanas, produce un efecto beneficioso para la mejora de la velocidad lineal y el CD, sin embargo, no reduce la asimetría entre extremidades inferiores de jugadoras de fútbol adolescentes.

V. Los factores antropométricos (p.ej. peso corporal) muestran relaciones significativas con el rendimiento de la velocidad de sprint en jugadoras de fútbol adolescentes, alcanzándose la velocidad pico en una distancia superior conforme aumenta la edad de dichas jugadoras.

Conclusions

I. The change in direction ability of adolescent female soccer players can be evaluated with different tests. However, the 180ºCOD seems to be the most appropriate to replicate the movement patterns of soccer. The reliability of the COD ability tests depends on the instruments used such as electronic timing gates and the surface and/or the playing level of the soccer player. Test results should be interpreted with caution as they may be influenced by the period in growth and maturation, the playing position of the player and the period of the soccer season.

II. Jumping (CMJ and standing broad jump), linear sprinting and COD tests may be reliable and sensitive to training-induced changes during the short and mid-term competitive season in adolescent female soccer players showing higher reliability as the age of the soccer players increases.

III. A neuromuscular training program during 10 weeks has positive effects on unilateral explosive strength, power, dynamic and functional balance and reduces lower interlimb asymmetries. Contrastly, this program has no effects on COD.

IV. An 8 weeks combined power and strength training program has positive effects on linear speed and COD however it does not reduce lower interlimb asymmetries in adolescent female soccer players.

V. Anthropometric factors (e.g. body mass) show significative relations with sprint performance in adolescent female soccer players, reaching maximal sprinting speed in a higher distances as the age of the soccer players increases.

Aportaciones principales de la Tesis Doctoral

- Con la revisión sistemática (**artículo I**), se describieron los test de CD que se llevan a cabo en jugadoras de fútbol adolescentes revelando que el test del CD180º, por sus características, parece ser el más apropiado para replicar los patrones de movimiento del fútbol. Además, se analizó qué factores podían afectar a la fiabilidad de los test observando que podían afectar el tipo de instrumento utilizado, la superficie o el nivel de las jugadoras. Aunque se deducen diversas conclusiones de este trabajo, se destaca qué ejercicios de fuerza y potencia mejoran el rendimiento del CD en jugadoras de fútbol adolescentes. Sin embargo, esta revisión pone de manifiesto la necesidad de realizar más estudios en esta población, dada la escasa evidencia científica con datos longitudinales.
- Los test de salto, de fuerza y de CD a lo largo de la temporada (**artículo II**) mostraron ser fiables y sensibles a los cambios inducidos por el entrenamiento a corto y medio plazo en jugadoras de fútbol adolescentes.
- Mediante los artículos longitudinales (**artículo III y IV**), se concluyó que 10 semanas de un entrenamiento neuromuscular, produce efectos significativos en la fuerza, la potencia, el equilibrio funcional y reduce las asimetrías entre extremidades inferiores. Mientras, 8 semanas de un entrenamiento combinado de fuerza y potencia produce efectos significativos en la velocidad lineal y el CD pero no mejora la asimetrías entre extremidades inferiores.
- Con el estudio transversal (**artículo V**) se determinó que los factores antropométricos se asocian positivamente al rendimiento de la velocidad de sprint en jugadoras de fútbol adolescentes. Además, la velocidad pico se alcanza a mayores distancias conforme aumenta la edad.

Main contributions of the Thesis

- With the systematic review (**Manuscript I**), we described the COD tests in adolescent female soccer players. This manuscript revealed that 180ºCOD test, due to its characteristics, seems to be the most appropriate to replicate soccer movement patterns. In addition, it was analysed the factors which could affect the reliability of tests like the instruments used such as electronic timing gates and the surface and/or the playing level of the soccer player. Although different conclusions are drawn from this study, it is highlighted which strength and power exercises improve the COD performance in adolescent female soccer players. However, there is an urgent need to perform more studies in this population given the limited research including longitudinal data.
- Jumping, linear sprinting and COD tests during season (**Manuscript II**) showed to be reliable and sensitive to training-induced changes during the short and mid-term competitive season in adolescent female soccer players
- The longitudinal studies (**Manuscript III and IV**), concluded that at 10 weeks of neuromuscular training, elicit significant effects on strength, power, functional balance performance and reduce inter-limb asymmetries between lower body. Meanwhile, 8 weeks of combined strength and power training elicit significant effects on linear speed and COD however the asymmetries between lower body did not improve.
- From the cross-sectional study (**Manuscript V**), we determined that anthropometric factors were associated with sprint speed performance in adolescent female soccer players. In addition, as female players get older, longer distance seems to be required to achieve maximal sprinting speed.

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Y al fin, te encuentras en ese momento que cuando comienzas tu Tesis Doctoral ni te planteas que jamás pueda llegar y es escribir este apartado, los agradecimientos.
Es ahora cuando pienso en lo que he vivido en estos cuatro años, en la de gente que ha entrado y salido en mi vida, en quienes han participado de manera directa e indirecta en esta Tesis, en quienes han estado siempre conmigo, en quienes me han apoyado hasta el final... me viene a la cabeza tantos quebraderos de cabeza para recoger datos, problemas de última hora con las fotocélulas Witty, el Optogait o la plataforma de fuerza, tantas peleas con las Hojas de Hopkins o con el SPSS, varias decepciones porque te rechazan por segunda, tercera, cuarta, u...octava vez un artículo, esperas interminables para recibir "minor or major comments or rejected" o momentos de máxima alegría, en el que quieres saltar, gritar y llorar de felicidad, cuando llega de manera inesperada ese preciado email con "I am pleased to inform you that your manuscript entitled XXX received by the editorial office of XXX has been accepted for publication". En definitiva, infinitos momentos de trabajo diurnos y nocturnos con mi querido Mac, mi compañero más fiel en estos cuatros años.

Curiosamente, acabo este periodo con una pandemia mundial y una situación muy peculiar que jamás me hubiese imaginado. Es ahora, cuando te das cuenta de que la vida es hermosa cuando se tiene libertad, de lo afortunados que somos de vivir en un país desarrollado con un estado de bienestar jamás antes conocido, de lo extraordinario que es viajar y conocer lugares o simplemente de lo bonito que es salir a la calle, poder respirar aire puro y pasear. Que difícil está siendo para todos esta situación, pero como se suele decir "lo que no puede contigo te hace más fuerte", así que nos toca reinventarnos y ser más creativos que nunca para superar este crítico periodo, ante todo ser positivos y creer en nuestra grandeza como seres humanos, seres racionales, y aún cuando somos capaces

de lo peor, también de lo mejor. Debemos de creer en nosotros mismos y en nuestra capacidad de unión y solidaridad para superar esta crisis todos juntos.

Me gustaría titular a mi Tesis Doctoral como la "Tesis nómada". Recopilando me doy cuenta que esta Tesis ha viajado a varios países no sólo de Europa sino también de América. Ha pasado por Francia, Grecia, República Checa, EEUU, Chile y Ecuador. Y qué suerte que haya recorrido estos países porque significa que he tenido la oportunidad de viajar y disfrutar. Y que hablar de las ciudades que ha recorrido en España, desde Madrid hasta Barcelona, pasando por Tenerife, Sevilla, Málaga, Albacete, Valencia, Bilbao, San Sebastián y por último Logroño donde prácticamente he acabado mi Tesis. En este caso la suerte viene porque el arbitraje me está dando la oportunidad de conocer multitud de ciudades y la verdad que me siento afortunada por ello.

Todo comenzó en ese último año de prácticas de CCAFD, gracias a la labor docente de mis profesores, me empezó a llamar la atención todo aquello relacionado con la investigación y el deporte. Tuve la suerte de poder elegir de las primeras de mi promoción y tenía claro que quería hacer las prácticas en el grupo de investigación GENUD. Durante varios meses pude conocer como se trabaja en un grupo de investigación, qué labores se realizan y el esfuerzo que supone escribir un artículo. Al finalizar mi periodo de prácticas hablé con José Antonio y Germán para poder quedarme en el grupo y seguir trabajando con ellos, así como intentar optar a una beca para investigar durante cuatro años. No tuve la suerte de poder recibirla por unas centésimas, la noticia fue dura pero la vida es así y hay que buscar otras alternativas, quizás fue el destino o que simplemente se alinearon los astros, pero al no recibir la beca y dedicarme a enviar currículums para poder trabajar, a la vez que realizar mi Tesis, me llamaron de la Universidad San Jorge y con 24 años empecé a impartir docencia, dónde actualmente sigo trabajando.

Primero quiero agradecer a mi director de Tesis, **José Antonio Casajús**, la inestimable ayuda que me has ofrecido a lo largo de estos cuatro años, sumando además los de la carrera, contando que ya nos encontramos en la asignatura de “Anatomía” en Magisterio, hace ya 10 años, y quién nos iba a decir en ese momento que acabarías siendo mi director de Tesis. También me tuviste en cuenta, junto a Jorge Marín, cuando hubo financiación en GENUD para contratar un investigador, lo cual nos proporcionó sustento económico para seguir trabajando durante varios meses. Además, me pusiste en contacto con Oliver para que fuese codirector en mi Tesis y todos sabemos el plus de calidad con el que he contado. Y por supuesto, te estaré eternamente agradecida por ser tú la persona que me diste la descabellada idea de introducirme en el mundo del arbitraje y lo que al final está suponiendo para mi, una forma de vida la cual me encanta y no solo me reporta alegrías y retos en mi día a día, sino que me ha hecho madurar como persona. Admiro tu capacidad de liderazgo y decisión, estoy segura que seguiremos viéndonos durante varios años en este mundo del arbitraje. Muchas gracias por haber sabido elegir las palabras y acciones en el lugar y momento adecuado y por haber creído en mi hasta el final.

También quería agradecer de una forma especial a **Oliver Gonzalo**. No solo has sido mi cotutor sino también mi compañero de trabajo y amigo. Innumerables llamadas para que me explicases la estadística, para resolver dudas de los comentarios que nos hacían los revisores, para pensar una nueva revista tras ser rechazado un artículo o simplemente para hablar de nosotros. Cuanto han cambiado nuestras vidas desde que nos conocimos hasta este momento, solo espero que las decisiones que hayamos tomado sean las correctas, el tiempo nos dirá. Gracias por “presentarme” a **Chris Bishop** o al menos tener un contacto con él vía email, creo que ha sido la persona clave en el momento preciso para que nos entrasen los últimos tres artículos de la Tesis. Gracias por la paciencia eterna que has tenido conmigo, por todo lo que me has enseñado en el mundo

de la estadística, has conseguido que le coja hasta cariño y que ahora la gente me llame para resolver dudas de las ininteligibles hojas Hopkins, por sacar tiempo de debajo de las piedras para revisar la multitud de comentarios que hemos tenido de los artículos y por saber contestar a ese revisor "agradable" lo que él quería leer. Me has hecho madurar a nivel científico y eso no tiene precio. Te deseo lo mejor en esos proyectos arriesgados que te embarcas pero que al final superas con creces, admiro el conocimiento que tienes en tu campo. Gracias por todo.

Agradecer a la **Universidad San Jorge** el apoyo que he recibido siempre de ella para conseguir mis objetivos y ante todo mi Tesis Doctoral. No puedo olvidarme de mis compañeros **Alberto Roso, Marina Mejías** y **Lucía Sagarra**, los cuales os habéis convertido en muy buenos y generosos amigos. Quiero daros las gracias a los tres por haberme defendido siempre desde el principio, entré muy joven a la Universidad y la verdad que he tenido momentos difíciles y vosotros siempre habéis estado conmigo apoyándome y haciéndome ver que todo no es tan grave como parece y que al final el tiempo pone a cada uno en su lugar. Gracias de corazón a los tres.

Gracias a **Antonio Monroy** por ponerme en contacto con **Santiago Calero** y poder cumplir mi sueño de hacer una estancia doctoral con autofinanciación y ayuda de mis padres y mi tío **Juan Pardos** (se que allí donde estés sacarás una gran sonrisa por verme llegar hasta el final). Gracias Santiago por acogerme en ese espectacular país que es Ecuador y darme a conocer como trabajáis en vuestra Universidad. No puedo olvidarme de mi buen y fiel amigo chileno, **Claudio Nieto**, cuantas veces hemos hecho Skype hablando de nuestros quebraderos de cabeza con nuestras respectivas Tesis y al final aquí estamos tú ya Doctor y yo en proceso. Gracias por contar conmigo para tus estudios, por enseñarme tu hermoso país y por brindarme tu amistad.

Olatz tu has llegado en la recta final de mi Tesis y has sabido estar a la altura para que al final logre depositar. Has soportado mis penurias porque se me ha borrado todo lo que había escrito de la Tesis ese día, porque no encontraba un documento o simplemente porque no me llega la firma de alguien. Has tenido la capacidad para calmarme y evadirme del estrés del final y para poder maquetarme el documento con la multitud de cambios en los encabezados, el análisis de las hojas par e impar y crear unos gráficos que casi ni tú entiendes pero que con mucha paciencia y según mis complicadas indicaciones has hecho a la perfección. Te animo totalmente a que te embarques en el duro camino de una Tesis Doctoral porque llegar hasta el final es el mayor reconocimiento autopersonal que puedes conseguir. Eskerrik asko. GTM.

Mi familia ha tenido un papel muy importante, no solo en la Tesis sino en mi vida. Gracias a mi **familia Pardos** (Pilar, Felipe, Marcos y Claudia) por acompañarme desde pequeña y estar apoyándome en todo momento. Gracias a mi tía **Pilar** de Suecia y su pareja **Ignacio** por haber sido mis traductores oficiales y porque a pesar de que no os gustaba en absoluto este tema habéis tenido la paciencia y la constancia de corregirme todo a la perfección. Pronto os llegará un regalo "made in Spain" por esas tierras frías donde estáis perdidos. Gracias a mi tía **Rosa** y a los que considero algo más que mis primos, mis casi hermanos **Alejandro** y **Natalia**, con vosotros es con los que he tenido un contacto más directo desde que soy pequeña y los que me habéis enseñado diferentes aspectos de la vida. Me habéis visto crecer y me habéis apoyado no solo en mis mejores momentos sino en los peores y es ahí donde de verdad se ve la gente que te quiere, solo me queda daros las gracias por estar ahí, por defenderme, por haber sido siempre fieles a mi y por jamás haberme fallado. Por último, gracias a mis abuelos maternos, **Andrés** y **Dolores,** hace ya muchos años que os fuisteis, pero os aseguro que no me olvido de vosotros. Me habéis criado y me habéis enseñado que la vida no es fácil, que hay que

trabajar duro y ser constante para conseguir los retos que te propongas, vosotros lo hicisteis y eso estoy haciendo yo.

No quiero olvidarme de **Paula**, de lo que has supuesto para mi tres años y medio y de lo que hemos sufrido juntas con tu oposición y mi Tesis Doctoral. Siempre has tenido palabras de apoyo en mis malos momentos con la Tesis, has sabido respectar mi espacio para escribir y has estado ayudándome al máximo en todo lo que has podido. Solo tengo palabras buenas para ti porque me has tratado espectacular, te deseo lo mejor en tu camino. De verdad, muchas gracias.

Para acabar y cerrar esta etapa de mi vida, tengo que agradecerles no solo esta Tesis Doctoral sino todo a las dos personas que más quiero, **Ángel** y **Laura**.

Sinceramente no tengo palabras para agradecerte todo lo que supones cada día para mi **Mamá**. Me admira tu capacidad de trabajo, tu capacidad de autosuperación o esa manera para sacar lo mejor de ti sin esperar nada a cambio. Me has enseñado valores como la constancia o la perseverancia de manera indirecta que yo he observado en ti desde que soy pequeña y que hoy están siendo claves en mi vida. Gracias por apoyarme en mis momentos más difíciles, por sacarme una sonrisa con tu humor sarcástico y por formarme no solo a nivel académico sino a nivel personal. Lo que ves hoy en mi es gracias a ti. Eternamente agradecida.

Y en especial estos cuatro duros años de Tesis Doctoral te los quiero dedicar a ti **Papá**. Has sido la persona que más me has apoyado a nivel académico, que siempre has creído en mi capacidad de estudio, intentando sacar lo mejor de mi. Gracias por enseñarme a estudiar, sé que no era tarea fácil y más con el “bicho” que era de pequeña. Admiro la paciencia infinita que has tenido conmigo, me has enseñado que “todo esfuerzo tiene su recompensa” y que “don perfecto hace mucho tiempo que murió”, que nunca hay que agachar la cabeza y que siempre hay que mirar hacia delante, que si has tocado fondo

pues peor no puedes estar así que venga levántate y sigue hacia delante. Frases que, aunque no lo pienses han sido claves para que yo llegue hasta aquí, logrando además que ame la historia y la literatura. Creo que no te haces la idea de lo que has conseguido en mi, pero a nivel académico has sido la persona que has sacado mi mejor versión y por ello te dedico con ilusión y cariño la culminación de mis estudios. Gracias, de corazón, por haber creído siempre en mi.

Anexos [Annexes]

Anexo I.

Características de las revistas científicas [Characteristics of the scientific journals]

A continuación, se muestra el factor de impacto y ranking de cada revista en "*ISI Web of Knlowledge*" – Journal Citation Reports" y "*Scopus*" dentro de sus áreas correspondientes.

[*Impact factor and ranking of each journal in "ISI Web of Knowledge – Journal Citation Reports" and "Scopus" within their subject categories*]

Artículos publicados, aceptados o sometidos [*Published, accepted or submitted manuscripts*]

Artículo/ Manuscript	**Revista/ Journal**	**Factor de impacto/ Impact Factor**
I	**Journal of Sports Medicine and Physical Fitness** ß Ranking in 2018 ISI – JCR (Sport Sciences): 63/83 Q4	**1.302**
II	**Science and Medicine in Football** ô Ranking in 2018 Scopus: (Medicine)	**2.34**
III	**Biology of Sport** ô Ranking in 2018 ISI – JCR (Sport Sciences): 33/83 Q2	**2.202**
IV	**International Journal of Sports Physiology and Performance** ß Ranking in 2018 ISI – JCR (Sport Sciences): 8/83 Q1	**3.979**
V	**Kinesiology** † Ranking in 2018 ISI – JCR (Sport Sciences): 63/83 Q4	**1.383**

ß Artículo aceptado [*Accepted manuscript*]. Anexo III y IV. *Carta de aceptación* [*Acceptance letter*]

ô Artículo publicado [*Published manuscript*]

† Artículo sometido [*Submitted manuscript*]

Anexo II

GOBIERNO DE ARAGON
Departamento de Sanidad

Informe Dictamen Favorable
Trabajos académicos

C.P. - C.I. PI19/039

27 de febrero de 2019

Dña. María González Hinjos, Secretaria del CEIC Aragón (CEICA)

CERTIFICA

1º. Que del Trabajo:

Título: EVALUACIÓN DEL RENDIMIENTO FÍSICO Y ASIMETRÍAS FUNCIONALES EN EL FÚTBOL FEMENINO

Alumna: Elena Pardos Mainer
Directores: José Antonio Casajús Mallén y Oliver Gonzalo Skok

Versión protocolo: Versión 1.0, de fecha 1/2/2019
Versión documento de información y consentimiento: Versión 2.0, de fecha 21/2/2019

2º. Considera que

- El proyecto se plantea siguiendo los requisitos de la Ley 14/2007, de 3 de julio, de Investigación Biomédica y los principios éticos aplicables.
- El Tutor/Director garantiza la confidencialidad de la información, la correcta obtención del consentimiento informado, el adecuado tratamiento de los datos en cumplimiento de la legislación vigente y la correcta utilización de los recursos materiales necesarios para su realización.

3º. Por lo que este CEIC emite **DICTAMEN FAVORABLE a la realización del proyecto**.

Lo que firmo en Zaragoza

GONZALEZ HINJOS MARIA - DNI 03857456B

Firmado digitalmente por GONZALEZ HINJOS MARIA - DNI 03857456B
Fecha: 2019.03.01 13:44:33 +01'00'

María González Hinjos
Secretaria del CEIC Aragón (CEICA)

Página 1 de 1

Tel. 976 71 5836 Fax. 976 71 55 54 Correo electrónico mgonzalezh.ceic@aragon.es

Anexo III

International Journal of Sports Physiology and Performance 2 de diciembre de 2019, 10:13

International Journal of Sports Physiology and Performance - Decision on Manuscript ID IJSPP.2019-0265.R4

Para: Elena Pardos Mainer

02-Dec-2019

Dear Miss PARDOS MAINER,

It is a pleasure to accept your manuscript entitled "EFFECTS OF COMBINED STRENGTH AND POWER TRAINING ON PHYSICAL PERFORMANCE AND INTER-LIMB ASYMMETRIES IN ADOLESCENT FEMALE SOCCER PLAYERS" in its current form for publication in the International Journal of Sports Physiology and Performance. The comments of the reviewer(s) who reviewed your manuscript are included at the foot of this letter.

We anticipate that your paper will be published in print in approximately eight to ten months. The In Press and MedLine listings should be available well before that.

Thank you for your fine contribution. On behalf of the Editors of the International Journal of Sports Physiology and Performance, we look forward to your continued contributions to the Journal.

Yours sincerely,

Dr Sabrina Skorski
Associate Editor, International Journal of Sports Physiology and Performance
s.skorski@mx.uni-saarland.de

Anexo IV

journals6.dept@minervamedicaonlinesubmission.it 8:34 J

Manuscript no. J Sports Med Phys Fitness-10178 - The Journal of Sports Medicine and Physical Fitness

Para: Elena Pardos Mainer

Dear Ms. ELENA PARDOS MAINER,

I am pleased to inform you that your manuscript entitled

DETERMINING THE RELIABILITY AND USABILITY OF CHANGE OF DIRECTION SPEED TESTS IN ADOLESCENT FEMALE SOCCER PLAYERS: A SYSTEMATIC REVIEW

received by the editorial office of The Journal of Sports Medicine and Physical Fitness and registered under no. J Sports Med Phys Fitness-10178 has been accepted for publication as Review Article.

Before preparation of the proofs, the manuscript will undergo copy-editing to align it with the journal's editorial standards. You will be contacted by the editorial staff should any questions arise.

From now on, any request for substantial changes in content (changes of title and authorship, new results and corrected values, changes in figures and tables) will be subject to a completely new peer-review process.

Thank you for considering the journal The Journal of Sports Medicine and Physical Fitness for publication of your paper.

Sincerely,

Prof. Alberto Oliaro
Managing Editor
The Journal of Sports Medicine and Physical Fitness
....
Edizioni Minerva Medica
Corso Bramante 83-85
10126 Torino, Italy
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