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ESCUELA ACADÉMICO PROFESIONAL DE TECNOLOGÍA MÉDICA EN TERAPIA FÍSICA Y REHABILITACIÓN

"EFECTO DEL EJERCICIO PLIOMÉTRICO EN EL RENDIMIENTO DEPORTIVO EN JÓVENES JUGADORES MASCULINOS DE SOCCER"

TRABAJO DE REVISIÓN SISTEMÁTICA PARA OPTAR EL TÍTULO DE LICENCIADO EN TECNOLOGÍA MÉDICA EN TERAPIA FÍSICA Y REHABILITACIÓN

Presentado por:

AUTORES:

HERRERA CARAZAS, IVONNE JESSABEL

VILLENA PRESENTACIÓN, KARINA LIZ

ASESOR:

Mg. JUAN CARLOS BENITES AZABACHE

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Dedicatoria

- Este artículo lo dedicamos principalmente a Dios.

- A nuestros padres con mucho amor y cariño por todo lo brindado.

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Genoveva Margot Carazas Cueva Josefina Presentación Torres

- A nuestros esposos e hijos porque son nuestro futuro.

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Asesor:

Mg. Juan Carlos Benites Azabache

Jurado:

Presidente:

Juan Carlos Benites Azabache

Secretaria:

Marleni Rosario Aurich Quispe

Vocal:

Yolanda Reyes Jaramillo

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RESUMEN

Objetivo: El objetivo de este estudio es conocer el efecto del ejercicio pliométrico en el rendimiento deportivo en jóvenes jugadores masculinos de soccer.

Material y Métodos: Se realizó una búsqueda sistemática en las bases de datos de PubMed, EBSCOhost, PEDRO Database, SciELO-(Scientific Electronic Library Online) y Google Académico, el riesgo de selección en los estudios individuales fue realizado analizando la calidad metodológica según la escala de Pedro.

Estudios incluidos: Fueron incluidos ensayos clínicos en jóvenes jugadores masculinos de soccer que se les aplicaron programas de ejercicios pliométricos, los cuales fueron comparados con un grupo placebo, cuyos contenidos tienen como máximo 7 años de antigüedad.

Resultados: Se obtuvieron un total de 101 artículos revisados de diferentes bases de datos, los cuales por un filtro de criterios de inclusión y exclusión donde se obtuvieron 8 ensayos. Los ensayos clínicos demostraron estadísticamente que los ejercicios pliométricos comparados con el tratamiento habitual/ placebo tienen un efecto significativamente favorable en el rendimiento deportivo.

Conclusión: La calidad de la evidencia muestra que el ejercicio pliométrico tiene un efecto significativamente favorable comparado con el tratamiento habitual/placebo en el rendimiento deportivo.

Palabras clave: ejercicio pliométrico, rendimiento deportivo, jugadores de soccer, revisión sistemática

ABSTRACT

Objetive: *The objective of this study is to know the effect of plyometric exercise on sports performance in young male soccer players.*

Material and methods: *A systematic search was made in the databases of PubMed, EBSCO host, PEDRO Database, SciELO (Scientific Electronic Library Online) and Google Scholar. The risk of selection in the individual studies was carried out by analyzing the method logical quality according to Pedro's scale.*

Included studies: *Clinical trials were included in young male soccer players who were given plyometric exercise programs, which were compared to a placebo group, whose contents are at most 7 years old.*

Results: *We obtained a total of 101 articles reviewed from different databases, which by a filter of inclusion and exclusion criteria where 8 trials were obtained. Clinical trials statistically demonstrated that plyometric exercises compared with usual / placebo treatment have a significantly favorable effect on sports performance.*

Conclusion: *The quality of evidence shows that plyometric exercise has a significantly favorable effect compared to usual treatment / placebo in sports performance.*

Keywords: *Plyometric exercise, sports performance, soccer players, systematic review.*

CAPÍTULO I: EL PROBLEMA

1.1. Planteamiento del problema

Yuri Verhoshansky es el investigador más destacado en pliometría y que eventualmente jugó un gran papel en la popularización de esta forma de entrenamiento. “El entrenamiento pliométrico produce resultados evidentes en deportes que requieren saltar y tener agilidad. La URSS y el Bloque Oriental han estado empleando ejercicios pliométricos desde 1960, sólo fue después de 15 o 20 años después que el mundo occidental escucho del tema. Esto se debía en parte a la actitud discreta del bloque Oriental hacia sus métodos de entrenamiento. Algunos atletas aún evitan comentar su entrenamiento, ya que de alguna manera ellos trabajaban en un proyecto militar clasificado” (1).

Un partido de soccer consta de 90 minutos, los cuales requieren de un alto rendimiento aeróbico asociados a la potencia para un éxito en su performance(2), El soccer es un deporte que requiere habilidades específicas que implican movimientos explosivos y la acción muscular en diferentes velocidades como la capacidad de salto y agilidad (3), si analizamos la secuencia de movimiento típico durante el fútbol (paradas bruscas, intercambio de gestión, sprints rápidos, bola de patadas y golpes explosivos) se observa que depende del ciclo de estiramiento y acortamiento característico de los músculos implicados (4). Por ello, es importante que los jugadores de soccer profesionales y amateur desarrollen dicha habilidad, con ayuda del entrenamiento adecuado para tener un buen rendimiento durante el desarrollo del juego/deporte del fútbol.

En la actualidad el entrenamiento de los jugadores de soccer consta en las adaptaciones músculo-esqueléticas frente a los cambios de postura para ello poder mantener el equilibrio y balance postural en múltiples direcciones y finalmente evita una caída, donde la actividad deportiva el balance postural es requeridos para mantener la estabilidad durante el juego, donde también son importantes, como la fuerza, flexibilidad, coordinación y técnicas deportivas (5).

El entrenamiento de los jugadores de soccer se basa en utilizar máquinas y pesos libres para la actividad orientadas a la mejora de las cualidades relacionadas con la fuerza, consiguiendo los máximos grados de la especialidad con actividades muy sencillas que se realizan en el propio terreno de juego, utilizando barras y pesos que aumentan la fuerza a realizar por parte del jugador (6).

La polimetría es un método de desarrollo de la fuerza reactiva (fuerza elástico explosiva y reflejo-elástico-explosiva) que utiliza el Ciclo de Estiramiento Acortamiento (CEA) para aumentar la fuerza producida por el sistema músculo-esquelético (7). Esto sucede, cuando una acción excéntrica precede a una concéntrica, la fuerza resultante de la acción concéntrica aumenta, ésa es la esencia del CEA (7). Los ejercicios polimétricos, se dividen en dos, la de bajo impacto y la de alto impacto, donde se diferencian entre sí porque después de realizar el salto, tienen la finalidad de enlazarla o no a alguna acción (7). De esta forma podemos expresar de forma general que la polimetría, mediante sus dos variantes, pretende optimizar la capacidad del deportista de aumentar la cantidad de fuerza producida en la fase concéntrica mediante la implementación del aprovechamiento de las propiedades elásticas de los componentes elásticos musculares en serie y en paralelo, así como mejorando el uso del reflejo miotático (7).

Los ejercicios pliométricos permiten que sus músculos respondan más rápidamente y completamente al estimular el sistema neuro-muscular, para hacer más eficiente el uso de los estiramientos reflejo y la elasticidad, se deben ejercer sobre un músculo de forma rápida contracciones concéntricas y excéntricas. Lo que esto significa es que se producirá más fuerza cuando los músculos se contraen justo después de haber sido estirados (1).

Para que un ejercicio sea verdaderamente pliométrico debe consistir en un movimiento precedido por una contracción excéntrica, esto produce no solo la estimulación de los propioceptores sensibles al estiramiento rápido, sino también la carga de los componentes elásticos seriados (los tendones y los puentes cruzados entre las fibras musculares) con la fuerza de tensión desde la que puede rebotar (8).

La revisión sistemática se justifica en la necesidad de integrar la evidencia actual del efecto de los ejercicios pliométricos en el rendimiento deportivo de jugadores de soccer.

1.2. Formulación del problema

La formulación del problema en términos de pregunta es la siguiente:

¿El efecto del ejercicio pliométrico es favorable en el rendimiento deportivo en jóvenes jugadores masculinos de soccer?

1.3. Justificación

La siguiente revisión sistemática es viable y factible, ya que la universidad nos proporciona la base de datos EBSCO y tenemos el acceso a diversas alternativas de búsqueda, lo cual hace que la revisión sistemática se lleve a cabo con éxito y con imparcialidad.

A nivel práctico la revisión sistemática, pondrá a disposición a los fisioterapeutas nueva evidencia en el trabajo diario.

Esta revisión sistemática, da un aporte a la universidad en el aspecto de actividad física, lo cual lo realizamos para que los alumnos, y personal educativo, sepan la importancia de la misma, no sólo en cuanto a personas que realicen alguna actividad como hobbie, sino también para aquellos que realizan ejercicios de élite, donde necesitan un incremento del rendimiento deportivo, el cual se puede proporcionar mediante los ejercicios pliométricos.

1.4. Objetivo

Tiene como objetivo:

Verificar mediante la revisión sistemática, el efecto del ejercicio pliométrico en el rendimiento deportivo en jóvenes jugadores masculinos de soccer.

CAPÍTULO II: MÉTODOS

Para la elaboración de esta revisión sistemática fueron utilizadas las directrices propuestas por el PRISMA (9) y sus extensiones. (9)(10)

PRISMA es un conjunto mínimo de elementos basado en evidencia para escribir y publicar revisiones sistemáticas y metanálisis, consta de 27 ítemsterminología, formulación de la pregunta de investigación, identificación de los estudios y extracción de datos, calidad de los estudios y riesgo de sesgo, cuando combinar datos, meta análisis y análisis de la consistencia, y sesgo de publicación selectiva de estudios o resultados (10).

Así mismo se han hecho modificaciones tales como: introducción, objetivos, problema y discusión; adaptándolos al instructivo de tesis.

2.1. Criterios de Elegibilidad.

Se utilizaron como criterios de elegibilidad conforme a la estructura Población, Intervención, Comparación y Outcome (PICO):

- Población : jóvenes jugadores masculinos de soccer
- Intervención : ejercicios pliométricos
- Comparación : ejercicio habitual/placebo
- Outcome(resultados) : rendimiento deportivo
- Además, se incluyeron otros criterios de elegibilidad
- Publicaciones en todos los idiomas.

2.2. Fuentes de Información.

Se realizó una revisión sistemática de la literatura para cumplir el objetivo de la revisión. Se realizó la búsqueda de las bases de datos y buscadores especializados hasta el 29 Octubredel 2016: PubMed, EBSCOhost, PEDRO Database, SciELO-Scientific Electronic Library Online y Google Académico, los cuales se muestran en la **tabla 1.**

Tabla 1FUENTE DE INFORMACIÓN

FUENTE DE INFORMACIÓN	ENLACE WEB	TIPO	ACCESIBILIDAD	PROPIETARIO/ ADMINISTRADOR
PUBMED	http://www.ncbi.nlm.nih.gov/pubmed	Motor de búsqueda y Base de Datos	Libre	Biblioteca Nacional de Medicina de los Estados Unidos
PEDRO Database	http://www.pedro.org.au/spanish/	Motor de búsqueda y Base de Datos especializada en fisioterapia	Libre	Centro de Fisioterapia Basada en la Evidencia en el George Institute for Global Health
EBSCOhost	https://www.ebscohost.com/	Base de datos multidisciplinaria, académica y de investigación, contiene:SPORTDiscus MedicLatina Academic Search Premier	Suscripción	Elton B. Stephens Company

FUENTE DE INFORMACIÓN	ENLACE WEB	TIPO	ACCESIBILIDAD	PROPIETARIO/ ADMINISTRADOR
SciELO - Scientific Electronic Library Online	http://www.scielo.org/	Biblioteca electrónica publicación electrónica de ediciones completas de las revistas científicas	Libre	FAPESP (http://www.fapesp.br) - la Fundación de Apoyo a la Investigación del Estado de São Paulo, BIREME (http://www.bireme.br) - Centro Latinoamericano y del Caribe de Información en Ciencias de la Salud
Google académico	https://scholar.google.com/	Buscador especializado en literatura científica-académica	Libre	Google Inc.

2.3. Búsqueda.

Los términos de búsqueda que se utilizaron tuvieron en un primer momento la identificación como terminología MESH (Medical Subject Headings) y DeCS (Descriptores en Ciencias de la Salud) bajo desambiguación en español e inglés, de no ubicarse se aproximó la terminología a su denominación técnica más común.

Tabla 2BUSQUEDA TERMINOLOGÍA MESH/DESH

Búsqueda de TerminologíaMesh/Desh		
	Término 1	**Término 2**
Término Español	**PLIOMETRICO**	**Rendimiento Deportivo**
DeCS	**si**	**SI**
Término Inglés	***Plyometric***	***Athletic Performance***
MESH	**si**	**SI**
Sinónimos	***Exercise, Plyometric*** ***Exercises, Plyometric*** ***Plyometric Exercises*** ***Plyometric Drill*** ***Drill, Plyometric*** ***Drills, Plyometric*** ***Plyometric Drills*** ***Plyometric Training*** ***Plyometric Trainings*** ***Training, Plyometric*** ***Trainings, Plyometric*** ***Stretch-Shortening Exercise*** ***Exercise, Stretch-Shortening*** ***Exercises, Stretch-Shortening*** ***Stretch Shortening Exercise*** ***Stretch-Shortening Exercises*** ***Stretch-Shortening Drill*** ***Drill, Stretch-Shortening*** ***Drills, Stretch-Shortening*** ***Stretch Shortening Drill*** ***Stretch-Shortening Drills*** ***Stretch-Shortening Cycle Exercise*** ***Cycle Exercise, Stretch-Shortening*** ***Cycle Exercises, Stretch-Shortening*** ***Exercise, Stretch-Shortening Cycle*** ***Exercises, Stretch-Shortening Cycle*** ***Stretch Shortening Cycle Exercise*** ***Stretch-Shortening Cycle Exercises***	***Athletic Performances*** ***Performance, Athletic*** ***Performances, Athletic*** ***Sports Performance*** ***Performance, Sports*** ***Performances, Sports*** ***Sports Performances***

Se realizó la estrategia de búsqueda en las bases de datos: *PubMed, EBSCO,* Pedro *database, Scielo Scientific Electronic Library Online*, y *Google* Académico. Los artículos fueron seleccionados para su inclusión en base a sus títulos; siguiendo los resúmenes y finalmente las copias del texto completo que se analizaron para determinar la elegibilidad de acuerdo a los criterios de inclusión y exclusión.

Tabla 3ESTRATEGIA DE BÚSQUEDA

Base de datos/ fuentes	Estrategia	Entrada
PubMed	En la búsqueda avanzada se realizó la búsqueda según la construcción de tres términos: A, B y C utilizando el enlace "AND" filtrando luego de la búsqueda sólo ensayos clínicos "*Clinical Trial*"	*(("plyometric exercise"[MeSH Terms] OR ("plyometric"[All Fields] AND "exercise"[All Fields]) OR "plyometric exercise"[All Fields]) AND ("athletic performance"[MeSH Terms] OR ("athletic"[All Fields] AND "performance"[All Fields]) OR "athletic performance"[All Fields])) AND (("soccer"[MeSH Terms] OR "soccer"[All Fields]) AND players[All Fields]) AND Clinical Trial[ptyp]*
EBSCOhost	Se realizó una búsqueda avanzada, colocando *plyometric exercise*, publicaciones académicas,	*plyometric exercise, Tipos de fuentes: Publicaciones académicas Materia: physical training & condi..., muscle strength, plyometrics, exercise therapy, rugby football players, muscles, physical fitness*
PEDRO *database*	*En pedro se realizó una búsqueda simple, colocando "plyometric exercise"*	*"plyometric exercise"*
SciELO - Scientific Electronic Library Online	Se realizó una búsqueda simple colocando las palabras "*plyometric exercise"*	*"plyometric exercise"*
Google Académico	Se realizó una búsqueda avanzada, colocando palabras que deben y no deben estar expuestas en el texto.	*plyometric exercises soccer "plyometric exercise" -volleyball*

2.4 Selección de los estudios.

El proceso de selección de estudios tuvo las siguientes etapas:

- Registro de salidas a las estrategias de búsqueda: A las salidas (listado de estudios) determinadas por las estrategias de búsqueda establecidas en los buscadores y bases de datos consultadas, se incluyó el dato de fecha de búsqueda y número de estudios identificados. El tratamiento de este listado se realizó en una base de datos que consignaba a cada artículo según título, autor, *journal*, fecha, volumen y número.
- Fase eliminación de duplicados: se procedió a depurar los resultados, eliminando los estudios duplicados e integrándolos en una base de datos preladas alfabéticamente según el título.
- Fase de análisis y selección: Una vez obtenida la lista de estudios no duplicados se procedió a ordenar la base de datos según autor y año y título, se analizaron los artículos en base a sus títulos y resúmenes, finalmente las copias del texto completo para determinar la elegibilidad de acuerdo a los criterios de inclusión y exclusión. Se clasificaron según la elegibilidad de los estudios, en tres categorías: estudios incluidos, estudios eliminados por no cumplir algún criterio de inclusión y estudios eliminados por cumplir algún criterio de exclusión. Esta fase culminó cuando se obtuvo un listado de estudios seleccionados los cuales fueron ordenados por Autor (año) y título.

2.5. Riesgo de sesgo en los estudios individuales.

El riesgo de selección en los estudios individuales fue realizado analizando la calidad metodológica según la escala de Pedro (11) (12) (13) que contiene 11 criterios de los cuales él Nº1 no se puntúa.

La puntuación total va del 0 al 10, según los siguientes criterios

Tabla 4ITEMS

ITEMS	
1	Los criterios de elección (no se suma a la puntuación total): Nota sobre la administración: Este criterio se cumple si el artículo describe la fuente de obtención de los sujetos y un listado de los criterios que tienen que cumplir para que puedan ser incluidos en el estudio.
2	Asignación aleatoria Los sujetos fueron asignados al azar a los grupos (en un estudio cruzado, los sujetos fueron distribuidos aleatoriamente a medida que recibían los tratamientos): Nota sobre la administración: Se considera que un estudio ha usado una designación al azar si el artículo aporta que la asignación fue aleatoria. El método preciso de aleatorización no precisa ser especificado. Procedimientos tales como lanzar monedas y tirar los dados,deberían ser considerados aleatorios. Procedimientos de asignación cuasi-aleatorios, tales como la asignación por el número de registro del hospital o la fecha de nacimiento, o la alternancia, no cumplen este criterio.
3	La asignación fue oculta: Nota sobre la administración: La asignación oculta (enmascaramiento) significa que la persona que determina si un sujeto es susceptible de ser incluido en un estudio, desconocía a que grupo iba a ser asignado cuando se tomó esta decisión. Se puntúa este criterio incluso si no se aporta que la asignación fue oculta, cuando el artículo aporta que la asignación fue por sobres opacos sellados o que la distribución fue realizada por el encargado de organizar la distribución, quien estaba fuera o aislado del resto del equipo de investigadores.
4	Comparabilidad inicial: Los grupos fueron similares al inicio en relación a los indicadores de pronóstico más importantes. Nota sobre la administración: Como mínimo, en estudios de intervenciones terapéuticas, el artículo debe describir al menos una medida de la severidad de la condición tratada y al menos una medida (diferente) del resultado clave al inicio. El evaluador debe asegurarse de que los resultados de los grupos no difieran en la línea base, en una cantidad clínicamente significativa. El criterio se cumple incluso si sólo se presentan los datos iniciales de los sujetos que finalizaron el estudio.

ITEMS	
5	Todos los sujetos fueron cegados: Nota sobre la administración: Cegado significa que la persona en cuestión (sujeto, terapeuta o evaluador) no conocía a qué grupo había sido asignado el sujeto. Además, los sujetos o terapeutas solo se consideran "cegados" si se puede considerar que no han distinguido entre los tratamientos aplicados a diferentes grupos. En los estudios en los que los resultados clave sean auto administrados (ej. escala visual analógica, diario del dolor), el evaluador es considerado cegado si el sujeto fue cegado.
6	Todos los terapeutas fueron cegados: Nota sobre la administración: Cegado significa que la persona en cuestión (sujeto, terapeuta o evaluador) no conocía a que grupo había sido asignado el sujeto. Además, los sujetos o terapeutas solo se consideran "cegados" si se puede considerar que no han distinguido entre los tratamientos aplicados a diferentes grupos. En los estudios en los que los resultados clave sean auto administrados (ej. escala visual analógica, diario del dolor), el evaluador es considerado cegado si el sujeto fue cegado.
7	Todos los evaluadores fueron cegados: Nota sobre la administración: Cegado significa que la persona en cuestión (sujeto, terapeuta o evaluador) no conocía a qué grupo había sido asignado el sujeto. Además, los sujetos o terapeutas solo se consideran "cegados" si se puede considerar que no han distinguido entre los tratamientos aplicados a diferentes grupos. En los estudios en los que los resultados clave sean auto administrados (ej. escala visual analógica, diario del dolor), el evaluador es considerado cegado si el sujeto fue cegado.
8	Seguimiento adecuado:Las medidas de al menos uno de los resultados clave fueron obtenidas de más del 85% de los sujetos inicialmente asignados a los grupos.Nota sobre la administración: Este criterio sólo se cumple si el artículo aporta explícitamente tanto el número de sujetos inicialmente asignados a los grupos como el número de sujetos de los que se obtuvieron las medidas de resultado clave. En los estudios en los que los resultados se han medido en diferentes momentos en el tiempo, un resultado clave debe haber sido medido en más del 85% de los sujetos en alguno de estos momentos.
9	Análisis de intención de tratar:Se presentaron resultados de todos los sujetos que recibieron tratamiento o fueron asignados al grupo control, o cuando esto no pudo ser, los datos para al menos un resultado clave fueron analizados por "intención de tratar"Nota sobre la administración: El análisis por intención de tratar significa que, donde los sujetos no recibieron tratamiento (o la condición de control) según fueron asignados, y donde las medidas de los resultados estuvieron disponibles, el análisis se realizó como si los sujetos recibieran el tratamiento (o la condición de control) al que fueron asignados. Este criterio se cumple, incluso si no hay mención de análisis por intención de tratar, si el informe establece explícitamente que todos los sujetos recibieron el tratamiento o la condición de control según fueron asignados.

ITEMS	
10	Entre el grupo de las comparaciones: Los resultados de comparaciones estadísticas entre grupos fueron informados para al menos un resultado clave.Nota sobre la administración: Una comparación estadística entre grupos implica la comparación estadística de un grupo con otro. Dependiendo del diseño del estudio, puede implicar la comparación de dos o más tratamientos, o la comparación de un tratamiento con una condición de control. El análisis puede ser una comparación simple de los resultados medidos después del tratamiento administrado, o una comparación del cambio experimentado por un grupo con el cambio del otro grupo (cuando se ha utilizado un análisis factorial de la varianza para analizar los datos, estos últimos son a menudo aportados como una interacción grupo x tiempo). La comparación puede realizarse mediante un contraste de hipótesis (que proporciona un valor "p", que describe la probabilidad con la que los grupos difieran sólo por el azar) o como una estimación de un tamaño del efecto (por ejemplo, la diferencia en la media o mediana, o una diferencia en las proporciones, o en el número necesario para tratar, o un riesgo relativo o hazard ratio) y su intervalo de confianza.
11	Apunte estimaciones y variabilidad:El estudio proporciona medidas puntuales y de variabilidad para al menos un resultado clave.Nota sobre la administración: Una estimación puntual es una medida del tamaño del efecto del tratamiento. El efecto del tratamiento debe ser descrito como la diferencia en los resultados de los grupos, o como el resultado en (cada uno) de todos los grupos. Las medidas de la variabilidad incluyen desviaciones estándar, errores estándar, intervalos de confianza, rango intercuartílicos (u otros rangos de cuantiles), y rangos. Las estimaciones puntuales y/o las medidas de variabilidad deben ser proporcionadas gráficamente (por ejemplo, se pueden presentar desviaciones estándar como barras de error en una figura) siempre que sea necesario para aclarar lo que se está mostrando (por ejemplo, mientras quede claro si las barras de error representan las desviaciones estándar o el error estándar). Cuando los resultados son categóricos, este criterio se cumple si se presenta el número de sujetos en cada categoría para cada grupo.

La escala PEDro considera dos aspectos de la calidad de los ensayos, a saberla "credibilidad" (o "validez interna") del ensayo y si el ensayo contiene suficiente información estadística para hacerlo interpretable. No mide la "relevancia" (o "generalización" o "validez externa") del ensayo, o el tamaño del efecto del tratamiento. (14)

La mayor parte de los criterios de la lista "se basan en la lista Delphi, desarrollada por Verhagen y sus colegas. La lista Delphi es una lista de características de ensayo que se consideran que están relacionadas con la "calidad" del ensayo por un grupo de expertos de ensayos clínicos. La escala PEDro contiene elementos adicionales sobre la adecuación del seguimiento y comparaciones estadísticas entre grupos. Un elemento presente en la lista Delphi (relativo a los criterios de elegibilidad) está relacionada con la validez externa, por lo que no se corresponde con las dimensiones de la calidad evaluada por la escala de PEDro. Este elemento no se emplea para calcular la puntuación del método que se muestra en los resultados de búsqueda (es por lo que una escala de 11 elementos tan solo ofrece una puntuación sobre 10. Este elemento, sin embargo, se ha conservado por lo que todos los elementos de la lista Delphi están presentes en la escala PEDro.” (15)

CAPÍTULO III: RESULTADOS

3.1. Selección de estudios.

Los estudios identificados fueron 111 registros en las búsquedas Pubmed= 20 Pedro=23 EbscoHost= 36 Scielo 1 Google académico =31

En el tamizaje se encontraron 10 estudios duplicados y en el proceso de elegibilidad fueron excluidos 92 estudios por no cumplir algún criterio de inclusión y exclusión y 01 estudio excluido por encontrar artículo en otro idioma y ser imposible traducir.

Finalmente fueron incluidos 08 estudios.

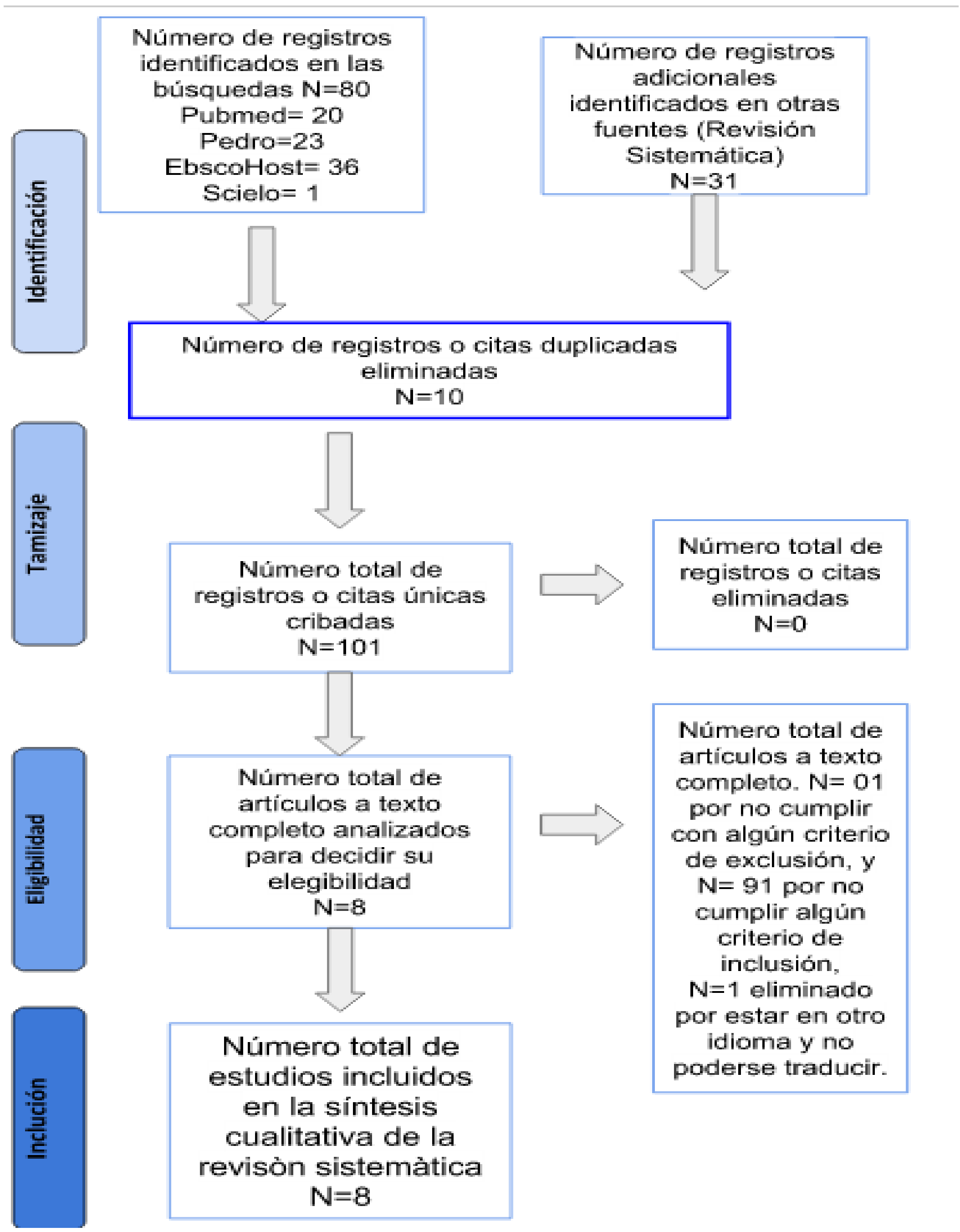

Gráfico 1: SELECCIÓN DE ESTUDIOS

Fuente: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). PreferredReportingItems for SystematicReviews and Meta-Analyses: The PRISMA Statement. PLoSMed 6(7): e1000097. doi:10.1371/journal.pmed1000097

3.2. Características de los estudios

Los estudios seleccionados fueron en su totalidad estudios clínicos controlados y randomizados, a nivel espacio fueron realizados en países, a nivel tiempo fueron publicados entre 2009 y 2016 y la población mayor de 20 y según población, intervención y variable de salida, que puede apreciarse en la tabla 5

Tabla 5 CARACTERÍSTICAS DE LOS ESTUDIOS

Año y Autor	Titulo	Población	Intervención	Variable de salida
Manouras, Nikolaos 2016	"Theefficacy of vertical vs. horizontal plyometric training onspeed, jumping performance and agility in soccer players."	Treinta jugadores de fútbol masculinos (19.1 5.8Años	Se evaluó utilizando la prueba de salto largo permanente, Tras dos ensayos de familiarización, los participantes realizaron tres ensayos máximos con un período de 60 s y el mejor rendimiento (en cm) fue considerado para su análisis. Salto vertical, también se midió mediante la prueba de salto de contra movimiento.	Prueba de salto alto
Meylan C, Malatesta D 2009	Effects of in-season plyometric training within soccer practiceonexplosiveactions of young players.	Catorce niños (13,3 6 0,6 años) fueron seleccionados como Grupo de entrenamiento (TG) y 11 niños (13,1 6 0,6 años) Definido como el grupo de control (CG).	Al inicio y Después del entrenamiento, las acciones explosivas fueron evaluadas Después de 6 pruebas: sprint de 10 metros, prueba de agilidad, salto vertical de 3 (Salto en cuclillas [SJ], salto de contramovimiento [CMJ], contacto Prueba [CT] y prueba de 5 límites múltiples [MB5]).	Sprint de 10 metros, prueba de agilidad, salto vertical de 3 (Salto en cuclillas [SJ], salto de contramovimiento [CMJ], contacto Prueba [CT] y prueba de 5 límites múltiples [MB5]).
Michailidis, Yiannis 2015	"Effect of plyometric training on athletic performance in preadolescent soccer players."	21 jugadores asignados a dos grupos: Grupo de saltos (JG, n = 11) y grupo de control (CG, n = 10 Cuarenta y cinco niños fueron asignados aleatoriamente a Control (CG, N = 21, 10,6 6 0,5 años; Práctica regular de fútbol) o un grupo de entrenamiento pliométrico (PTG, N = 24, 10,6 6 0,6 años.	El JG el rendimiento en el salto de longitud se incrementó significativamente (P = 0,031). También el desempeño deJG aumentó a un sprint de 30 m en un 7,2% (P <0,001). Ninguna de las variables probadas en el CG, demostró la diferencia entre el pre-test y el post-test. Nuestros resultados indican que el entrenamiento pliométrico puede mejorar el rendimiento de carrera a los 30 m sprint y el rendimiento en el salto de longitud enPreadolescentes jugadores de fútbol.	Sprint de 30 metros,salto de longitud.

Año y Autor	Titulo	Población	Intervención	Variable de salida
MICHAILIDIS et al 2013	PLYOMETRICS' TRAINABILITY IN PREADOLESCENT SOCCER ATHLETES	Cuarenta y cinco niños fueron asignados aleatoriamente a Control (CG, N = 21, 10,6 6 0,5 años; Práctica regular de fútbol) o un grupo de entrenamiento pliométrico (PTG, N = 24, 10,6 6 0,6 años;	El PTG indujo un (marcado p <0,05) la mejora en todas las pruebas de velocidad (1.9 a 3.1% en midtraining y 3-5% en el post-entrenamiento) y las pruebas de salto vertical (10 a 18,5% en midtraining y 16-23% en el post-entrenamiento), SH (2,6% en midtraining y el 4,2% en el post-entrenamiento), MB5 (14,6% en midtraining y el 23% en post-entrenamiento), fuerza de las piernas (15% en midtraining y el 28% en post-entrenamiento), la agilidad (5% en midtraining y el 23% en post-entrenamiento), y la distancia patadas (13,6% a 22,5% midtraining y en post-entrenamiento)	Pruebas de salto vertical,fuerzade pierna,agilidad,distancia de patadas.
Ramírez et al 2015	Effect of Vertical, Horizontal, and CombinedPlyometric Training onExplosive, Balance, and Endurance Performance of Young Soccer Players.	Cuarenta jóvenes jugadores de fútbol de edad Entre 10 y 14 años	Se evaluó el salto vertical y horizontal del contramovimiento Con brazos, 5 pruebas de límites múltiples (MB5), salto de 20 cm Índice de resistencia reactiva (RSI20), velocidad de patada máxima(MKV), sprint, cambio de dirección de velocidad (CODS), Yo-Yo intermitentePrueba de recuperación de nivel 1 (Yo-Yo IR1), y elmesurado.	Prueba Salto de 20 cm,Velocidadde patada máxima,Sprint, Yo-yo intermitente,Prueba de recuperación de nivel 1
Ramírez et al 2015	Effect of ProgressiveVolume-BasedOverloadDuring Plyometric Training on Explosive and Endurance Performance in Young Soccer Players	Tres grupos de jugadores de fútbol jóvenes (edad 13,0 ± 2,3 años) se dividieron en: control (CG; n = 8) y pliométrico formación con (PPT; n = 8) y sin (NPPT; n = 8)	Incremento progresivo en el volumen, es decir, 16 saltos por pierna por semana, con un volumen inicial de 80 saltos por pierna en cada sesión.	16 saltos por pierna por semana, con un volumen inicial de 80 saltos por pierna en cada sesión. (fuerza y resistencia)

Ramírez et al 2014	Effects of in-seasonlow-volume high-intensity plyometric training onexplosiveactions and endurance of young soccer players.	Setenta y seis jugadores fueron reclutados y asignados ya sea a un grupo de entrenamiento (TG; n = 38; 13,2 ± 1,8 años) o un grupo de control (GC; n = 38; 13,2 ± 1,8 años), grupo.	Se evaluó un Programa polimétrico de 7 semanas implementado dentro de la práctica futbolística, Mientras que el CG siguió la práctica habitual. Veinte metros Tiempo de sprint (20 m), tiempo de prueba de agilidad en Illinois, contra movimiento Salto (CMJ) de altura, 20- (RSI20) y 40- (RSI40) cm salto de caída Índice de resistencia reactiva, distancia de 5 límites múltiples (MB5),Prueba de patada máxima para la distancia (MKD) y tiempo de 2,4 kmEnsayo se midieron antes y después del período de 7 semanas.	Salto largo permanente
Ramírez et al 2015	Theeffects of interdayrestonadaptation to 6 weeks of plyometric training in young soccer players.	Un total de 166 jugadores, entre 10 y 17 años de edad	Se aplicó el programa de entrenamiento polimétrico durante 6 semanas, 2 sesiones por semana, con una carga de 140 a 260 saltos por sesión, en sustitución de algunos ejercicios específicos de fútbol.	Prueba de carga de 140-260 saltos por sesión.

3.3. Evaluación de la calidad.

La evaluación de la calidad según la escala de Pedro obtuvo en promedio unpuntaje de5,875/10, según se detalla en la siguiente tabla 6

TABLA 6 Evaluación de Calidad

	Evaluación de Calidad - Ensayos Clínicos Controlados								
	ITEMS	Manouras et al. 2016 **	Meylan et al 2009 **	Michailidis et al 2015 **	MICHAILIDIS et al 2013 **	Ramírez et al 2015 **	Ramírez et al 2015 **	Ramírez et al 2014 **	Ramírez et al 2015 **
1	Los criterios de elección	si	si	si	si	si	si	si	si
2	Asignación aleatoria	si	si	si	si	si	si	si	si
3	La asignación fue oculta	no	no	no	no	no	no	no	no
4	Comparabilidad inicial	si	si	si	si	si	si	si	si
5	Todos los sujetos fueron cegados	si	no	no	no	no	no	no	no
6	todos los terapeutas fueron cegados	no	no	no	no	no	no	no	no
7	todos los evaluadores fueron cegados	no	no	no	no	no	no	no	no
8	Seguimiento adecuado	si	si	si	si	si	si	si	si
9	Por intensión de tratar el análisis	si	si	si	si	si	si	si	si
10	Entre el grupo de las comparaciones	si	si	si	si	si	si	si	si
11	Apunte estimaciones y variabilidad	si	si	si	si	si	no	no	si
		7	6	6	6	6	5	5	6

Gráfico 2: Nivel de Calidad Según Pedro

3.4. Síntesis de los resultados.

TABLA 7 Síntesis de Resultados

Autor y año	Propósito y participantes	Intervención y medición	Resultados/Hallazgos
Manouras, Nikolaos 2016	Determinar los beneficios del entrenamiento pliométrico Jóvenes durante el período de la temporada, sugiriendo Que la formación específica durante este período podría ser esencial Para mantener o aumentar la explosividad. Treinta jugadores de fútbol masculinos 19.1 5.8Años	Se intervino mediante ejercicios pliométricos verticales (aceleración, velocidad, agilidad y rendimiento de salto) y se midió antes y después mediante la prueba de salto alto.	Mostró la evidencia de que son herramientas eficaces para mejorar el rendimiento de aceleración, velocidad, agilidad y salto en jóvenes jugadores de futbol durante la temporada.
Meylan C, Malatesta D 2009	Determinar la influencia de un Entrenamiento pliométrico dentro de la práctica regular de fútbol en Acciones de los futbolistas puberales durante la temporada.Catorce niños (13,3 6 0,6 años) fueron seleccionados como Grupo de entrenamiento (TG) y 11 niños (13,1 6 0,6 años)Definido como el grupo de control (CG).	Se intervino mediante un entrenamiento pliométrico de 8 semanas utilizando saltos, hurding, rebotar, footwork, se midió utilizando, sprint de 10 metros, , salto vertical de 3 y salto en cuclillas.	El programa a corto plazo de ejercicio pliométrico tuvo un impacto beneficioso sobre acciones tales como sprints, cambio de dirección y el salto, que son determinantes importantes de las acciones ganadoras en rendimiento de fútbol.

Autor y año	Propósito y participantes	Intervención y medición	Resultados/Hallazgos
Michailidis, Yiannis 2015	El estudio fue investigar la influencia del entrenamiento pliométrico a corto plazo sobre el funcionamiento.Velocidad y capacidad de salto horizontal en una pequeña muestra de niños preadolescentes.21 jugadores asignados a dos grupos: Grupo de saltos (JG, n = 11) y grupo de control (CG, n = 10).	Se intervino mediante un programa de entrenamiento que fue realizado durante 10 semanas utilizando sprint de pie (SLJ), 10 m y sprint de 30 m.	Los resultados indican que el entrenamiento pliométrico Puede mejorar el rendimiento de carrera a los 30 m sprint y el rendimiento en el salto de longitud en Preadolescentes jugadores de fútbol.
MICHAILIDIS et al 2013	Este estudio tuvo como objetivo determinar si los niños preadolescentes presentan capacidad de entrenamiento pliométrico o no. Cuarenta y cinco niños fueron asignados aleatoriamente aControl (CG, N = 21, 10,6 6 0,5 años;Práctica regular de fútbol) o un grupo de entrenamiento pliométrico (PTG,N = 24, 10,6 6 0,6 años.	Se intervino mediante ejercicios pliométricos(salto anterior, lateral arrastrando los pies, ejercicios de escalera, saltos de baja intensidad) realizados 2 veces por semana, se midió utilizando pruebas de velocidad, salto vertical, rendimiento específico de futbol (agilidad), al inicio, durante y después del tratamiento.	El resultado fue que al incluir tratamiento pliométrico en su práctica, se obtienen mayores ganancias de rendimiento.

Autor y año	Propósito y participantes	Intervención y medición	Resultados/Hallazgos
Ramírez et al 2015	El objetivo de este estudio fue comparar los efectos de 6 semanas de verticales, horizontales o combinados verticales y entrenamiento pliometrico horizontal en el músculo explosivo, resistencia, y el rendimiento del equilibrio. Cuarenta jóvenes jugadores de fútbol de edad entre 10 y 14 años.	Se intervino mediante programa de entrenamiento polimétrico a corto plazo (2 sesiones por semana) incorporando ejercicios verticales, horizontales (saltar, sprints, patear, resistencia, y equilibrio de las medidas de rendimiento de los jugadores de futbol. Se midió utilizando salto vertical y horizontal con brazos, salto de 20cm, índice de resistencia reactiva,	Demostró que los ejercicios verticales, horizontales y combinados, inducen mejora significativa en las acciones explosivas, el equilibrio y la capacidad de resistencia, sin embargo, los ejercicios combinados son ventajosos para inducir mejoras en el rendimiento.
Ramírez et al 2015	El objetivo del estudio fue comparar los efectos de la sobrecarga progresiva basada en el volumen constante con sobrecarga basado en el volumen de músculo adaptaciones explosiva y la resistencia de rendimiento durante un corto plazo cada dos semanas (es decir, 6 semanas) intervención de entrenamiento pliométrico en futbolistas jóvenes.Tres grupos de jugadores de fútbol jóvenes (edad 13,0 ± 2,3 años) se dividieron en: control (CG; n = 8) y pliométrico formación con (PPT; n = 8) y sin (NPPT; n = 8)	Se intervino mediante ejercicios pliométricos progresivos en el volumen (16 saltos por pierna por semana), con un volumen inicial de 80 saltos por pierna en cada sesión, se midió utilizando salto horizontal, vertical bilateral y unilateral con los brazos, 10 m lisos.	El resultado muestra que ambos modos con incremento de volumen y sin incremento, muestran una mejora significativa en las medidas explosivas y la resistencia de rendimiento muscular.

Autor y año	Propósito y participantes	Intervención y medición	Resultados/Hallazgos
Ramírez et al 2014	El Objetivo es mejorar las acciones explosivas y la resistencia en el fútbol juvenil es una parte esencial del desarrollo de los jugadores. Setenta y seis jugadores fueron reclutados y asignados ya sea a un grupo de entrenamiento (TG; n = 38; 13,2 ± 1,8 años) o un grupo de control (GC; n = 38; 13,2 ± 1,8 años), grupo.	Se intervino mediante Veinte metros sprint tiempo (20 m), Illinois tiempo de prueba de agilidad, salto con contramovimiento (CMJ) de altura, 20- (RSI20) y 40 (RSI40) cm gota salto índice de fuerza reactiva, y 2,4 kilómetros contrarreloj, se midió utilizando la prueba de salto de contramovimiento utilizando el sistema de Bosco *ergojump.*	Demostró que incluir ejercicios pliométricos verticales en una práctica de fútbol, mejora las acciones explosivas y de resistencia pero los ejercicios horizontales deben incluirse para mejorar el rendimiento de velocidad.
Ramírez et al 2015	El propósito de este estudio fue determinar los efectos del entrenamiento pliométrico corto plazo interpuestas con 24 o 48 horas de descanso entre sesiones de entrenamiento en explosivos y adaptaciones de resistencia en jóvenes jugadores de fútbol. Un total de 166 jugadores, entre 10 y 17 años de edad	Se intervino mediante un programa de entrenamiento pliométrico de 6 semanas, 2 sesiones por semana con una carga de 140 por 260 saltos por sesión, en sustitución de algunos ejercicios específicos del fútbol. Se midió utilizando el salto de potencia, salto contramovimiento de 20 cm, índice de fuerza reactiva, salto de longitud, 20 m tiempo de *sprints* 10 x 5 metros tiempo de agilidad, 20m de ida y vuelta.	El estudio muestra que el entrenamiento pliométrico aplicado 2 veces por semana, muestra resultados similares en jóvenes jugadores de fútbol.

CAPÍTULO IV: DISCUSIÓN Y CONCLUSION

4.1. Discusión.

- Según Manouras et al 2016, en su estudio sobre la Eficacia del entrenamiento pliométrico vertical vs horizontal sobre la velocidad, el rendimiento en salto y agilidad en jugadores de fútbol, identificó que el ejercicio pliométrico (utilizando sprints), se puede utilizar como modalidades efectivas de ejercicio para preservar o mejorar el desempeño de los saltos, la aceleración, la velocidad y la agilidad de los jóvenes jugadores de fútbol. (3)
- En el segundo estudio, realizado por Meylan et al 2009, sobre los efectos del entrenamiento pliométrico en temporada dentro de la práctica futbolística sobre acciones explosivas de jugadores jóvenes, donde el propósito del estudio fue determinar la influencia del entrenamiento pliométrico a corto plazo, donde concluyó que tuvo un impacto beneficioso sobre las acciones explosivas (sprint, cambio de dirección y el salto).(16)
- Según Michailidis et al 2015, en su estudio titulado efecto del entrenamiento polimétrico en el rendimiento atlético en jugadores de fútbol preadolescentes, se concluyó que el entrenamiento polimétrico puede mejorar el rendimiento de carrera a los 30 m sprint y el rendimiento en el salto de longitud de los jugadores de fútbol.(4)
- Según Michailidis et al 2013 en el estudio titulado Capacidad de la polimetría en atletas de futbol preadolescentes, tuvieron como objetivo determinar si los niños preadolescentes exhiben capacitaciones polimétricas o no, se concluyó que complementando una práctica de fútbol con entrenamiento polimétrico conduce a tener mayores ganancias en el rendimiento.(17)

- En el estudio de Ramírez et al 2015, titulado Efecto del Entrenamiento Polimétrico Vertical, Horizontal y Combinado sobre el Desempeño Explosivo, de Equilibrio y fuerza de Jóvenes Jugadores de Fútbol, donde el objetivo fue comparar los efectos de 6 semanas de entrenamiento vertical, horizontal y combinado vertical y horizontal de la polimetría sobre el rendimiento muscular, la resistencia y el equilibrio muscular; el estudio demostró que todos los entrenamientos inducen a mejoras significativas en el rendimiento, sin embargo, el entrenamiento combinado vertical y horizontal resulta más ventajoso en la mejora del rendimiento.(18)
- El autor Ramírez et al 2015, con su estudio titulado Efecto de la sobrecarga progresiva basada en el volumen durante el entrenamiento polimétrico Explosivo rendimiento de resistencia en jóvenes jugadores de fútbol, que tuvo como conclusión que el aumento progresivo en el volumen de entrenamiento polimétrico parece más ventajoso en la mejora del rendimiento deportivo. (19)
- El autor Ramírez et al 2014, en el estudio titulado Efectos del entrenamiento polimétrico de alta intensidad de baja intensidad en temporada en las acciones explosivas y la resistencia de los jugadores jóvenes de fútbol, en este estudio se investigó la eficiencia del programa de entrenamiento polimétrico vertical de corto plazo dentro de la práctica futbolística para mejorar tanto las acciones explosivas como la resistencia en jugadores jóvenes de fútbol. Se concluyó que un programa polimétrico vertical integrado dentro de la práctica regular del fútbol puede substituir los taladros del fútbol para mejorar la mayoría de las acciones y de la resistencia explosivas, pero los ejercicios horizontales también deben ser incluidos para realzar funcionamiento sprinting.(20)

- El autor Ramírez et al 2015, en el estudio titulado Los efectos del descanso interdiario en la adaptación a 6 semanas de entrenamiento pliométrico en jugadores de fútbol jóvenes. donde su propósito de este estudio fue determinar los efectos del entrenamiento polimétrico a corto plazo interpuesto con 24 o 48 horas de descanso entre sesiones de entrenamiento sobre adaptaciones explosivas y de resistencia en jugadores jóvenes de fútbol; como conclusión el estudio muestra que el entrenamiento polimétrico aplicado dos veces a la semana en días consecutivos o no consecutivos da lugar a adaptaciones explosivas y de resistencia similares en jugadores jóvenes de fútbol masculino.(2)
- En los 8 estudios realizados, se llega a discutir que en los hallazgos principales de los anteriormente mencionados, los autores:

  Manouras et al 2016 y Michailidis et al 2013; Coinciden que los ejercicios pliométricos son efectivos frente al rendimiento, tanto de salto como deportivo.

  Meylan et al 2009 y Ramírez et al 2015 (en dos estudios), coinciden que el entrenamiento pliométrico a corto plazo, el combinado (horizontal y vertical) y con aumento progresivo en volumen, es efectivo, ventajoso y beneficioso en la mejora del rendimiento deportivo.

  Anexo: En el estudio de Michailidis et al 2013, se determinó que el entrenamiento pliométrico complementario a las prácticas de fútbol usuales, en niños preadolescentes, conducen a tener ganancias en el rendimiento deportivo.

4.2. Limitaciones

Se encontró un artículo que tuvo que ser eliminado, porque aun teniendo el texto completo, no se pudo traducir, ya que estaba en coreano y en imágenes; es por ello que se tomó la decisión de no incluirlo en el estudio.

4.3. Conclusiones.

- En esta revisión sistemática, pudimos recopilar diferentes bases de datos, las cuales nos brindaron la información necesaria para poder realizarla.
- Gracias a dicha información pudimos responder a nuestra formulación del problema, la cual fue: ¿el ejercicio pliométrico tiene un efecto positivo en el rendimiento deportivo en jóvenes jugadores masculinos de soccer?; donde llegamos a la conclusión que los ejercicios pliométricos tienen un efecto significativamente favorable comparados con el tratamiento/ejercicio habitual, en el rendimiento deportivo en jóvenes jugadores masculinos de soccer.
- Dichos estudios tuvieron los siguientes instrumentos de medición: prueba de salto vertical, salto horizontal y *sprints de 10m y 20m.*
- Con esta Revisión Sistemática pudimos darnos cuenta, de que no existe gran variedad de estudios controlados sobre el tema, realizado por fisioterapeutas, por lo que se sugiere la intervención de los mismos para brindar un aporte en el aspecto de actividad física, no sólo en jugadores de soccer, sino también en otras disciplinas deportivas de élite y amateur.

CAPÍTULO V: FINANCIAMIENTO

Este trabajo fue financiado íntegramente por los autores, quienes participaron conjuntamente con el asesor, Mg. Juan Carlos Benites Azabache en el diseño del estudio, la recolección y análisis de los datos y la preparación del manuscrito.

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Los autores declaran no tener conflicto de interés para la realización de este estudio.

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ANEXOS

RESÚMENES DE ESTUDIOS INVOLUCRADOS

ARTÍCULO 1

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The efficacy of vertical vs. horizontal: Plyometric training on speed, jumping performance and agility in soccer players

Nikolaos Manouras, Zisis Papanikolaou, Konstantina Karatrantou, Polydoros Kouvarakis and Vassilis Gerodimos

Abstract

This study compared the efficacy of a vertical and horizontal plyometric training program on acceleration, speed, jumping performance, and agility in young soccer players during the in-season period. Thirty male soccer players (19.1 ± 5.8 years) were assigned into a horizontal plyometric, a vertical plyometric, or a control group. The horizontal plyometric group and vertical plyometric group participated in an eight-week training program that was performed one day/week (in conjunction with conventional soccer training) and consisted of horizontal (for the horizontal plyometric group) or vertical plyometric exercises (for the vertical plyometric group). Acceleration (10-m sprint), speed (30-m sprint), agility, and jumping performance (horizontal and vertical) were assessed prior and after the completion of plyometric training programs. Agility, 30-m sprint performance, and vertical jumping performance ($p < 0.01$) improved following the completion of training in both horizontal plyometric group and vertical plyometric group, whereas horizontal jumping performance improved only in horizontal plyometric group ($p < 0.01$). There were no significant effects on acceleration for both horizontal plyometric group and vertical plyometric group. Furthermore, no differences were observed between groups in all performance parameters. In control group, acceleration, speed, agility, and jumping performance remained stable throughout the study. To sum up, horizontal or vertical plyometric training programs, consisted of one session/week, may be used by coaches and fitness professionals as effective exercise modalities for *preserving or improving* jumping performance, acceleration, speed, and agility in young soccer players during the in-season period.

Keywords

Strength, power, stretch-shortening cycle, physical fitness, in-season, amateur

Introduction

Soccer is an activity that requires specific skills involving distinct explosive movements and muscle actions at different velocities.[1] Strength, speed, jumping ability, and/or agility are important contributing factors to performance of several fundamental skills in soccer,[2–4] such as abrupt change of direction, accelerating, decelerating, etc. Therefore, the development of speed, jumping performance and agility through specific training interventions should be emphasized in a soccer training program.

Plyometric training is widely used, in sports, as an efficient[5–7] exercise modality for *preserving or improving* different features of physical fitness in athletes during the in-season period, during which the volume and frequency of training should be tightly controlled due to time constraint.[6] Indeed, previous studies[8,9] demonstrated the beneficial effects of plyometric training in young athletes during the in-season period, suggesting that *specific training* during this period might be essential for *maintaining or increasing* explosiveness. There is also evidence that plyometric training incorporated into a conventional soccer training program can cause beneficial effects on speed,[5–7] vertical jumping performance,[10] and agility.[11] With this in mind, recent studies

Reviewer: Lee Brown (California State University, Fullerton, USA)

Department of Physical Education and Sport Science, University of Thessaly, Trikala, Greece

Corresponding author:
Nikolaos Manouras, Department of Physical Education and Sport Sciences, University of Thessaly, Karies, Trikala 42100, Greece.
Email: manouras@pe.uth.gr

ARTÍCULO 2

Effects of In-Season Plyometric Training Within Soccer Practice on Explosive Actions of Young Players

César Meylan[1] and Davide Malatesta[2]

[1]*Institute of Sport and Recreation Research New Zealand, AUT University, Auckland, New Zealand, Australia; and* [2]*Institute of Sport Science, University of Lusanne (ISSUL), Switzerland*

Abstract

Meylan, C and Malatesta D. Effects of in-season plyometric training within soccer practice on explosive actions of young players. *J Strength Cond Res* 23(9): 2605–2613, 2009—In soccer, explosive actions such as jumping, sprinting, and changes of direction are essential to optimal performance not only in adults, but also in children's games. The purpose of the present investigation was to determine the influence of a short-term plyometric training within regular soccer practice on explosive actions of early pubertal soccer players during the in-season. Fourteen children (13.3 ± 0.6 years) were selected as the training group (TG) and 11 children (13.1 ± 0.6 years) were defined as the control group (CG). All children were playing in the same league and trained twice per week for 90 minutes with the same soccer drills. The TG followed an 8-week plyometric program (i.e., jumping, hurdling, bouncing, skipping, and footwork) implemented as a substitute for some soccer drills to obtain the same session duration as CG. At baseline and after training, explosive actions were assessed with the following 6 tests: 10-meter sprint, agility test, 3 vertical jump tests (squat jump [SJ], countermovement jump [CMJ], contact test [CT] and multiple 5 bounds test [MB5]). Plyometric training was associated with significant decreases in 10-m sprint time (−2.1%) and agility test time (−9.6%) and significant increases in jump height for the CMJ (+7.9%) and CT (+10.9%). No significant changes in explosive actions after the 8-week period were recorded for the CG. The current study demonstrated that a plyometric program within regular soccer practice improved explosive actions of young players compared to conventional soccer training only. Therefore, the short-term plyometric program had a beneficial impact on explosive actions, such as sprinting, change of direction, and jumping, which are important determinants of match-winning actions in soccer performance.

Key Words agility, initial acceleration, stretch-shortening cycle, vertical jump

Introduction

Soccer is an intermittent sport that requires different physiological components. In modern football, physiological considerations are increasingly essential to optimal performance not only in adults, but also in children. The capacity of soccer players to produce varied forceful and explosive actions, such as sprinting, jumping, tackling, kicking, turning, and changing pace, highly influences soccer match performance, as suggested by others (30). The capacity to repeat explosive bouts is an important determinant of player performance (35) and is associated with high aerobic power ($\dot{V}O_2max$) (31). However, the ability to produce a powerful single-bout effort (i.e., explosive actions) is as important as aerobic power for success in soccer (30). For instance, high-speed sprinting only contributes up to 3% of the total distance covered in children's games (6), yet most crucial moments of the game such as winning ball possession, scoring, or conceding goals depend on it (30). Initial acceleration, jumping, and agility are various explosive actions that are crucial when the player is involved in fast game play. Initial acceleration can be referred to as short sprint (0–10 m) (23), and agility can be recognized as the ability to change direction, start, and stop quickly (25,34). Game analyses have demonstrated the importance of these qualities in soccer since a mean sprint time of 2.3 seconds (10–12-m sprint) (6) and a mean of 50 turns per game have been recorded (38). Such explosive actions are integral elements for success in soccer and have to be trained independently from aerobic power with an optimal training program (18).

Training for maximal strength has been suggested to play a major role in improving explosive actions as a result of an increased force availability (11). Conversely, explosive high-velocity training has demonstrated greater improvements in

The results of the present study do not constitute endorsement by the NSCA.

Address correspondence to César Meylan, cesar.meylan@aut.ac.nz.

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ARTÍCULO 3

Original Article

Effect of plyometric training on athletic performance in preadolescent soccer players

YIANNIS MICHALIDIS

Department of physical Education and Sport Science, Democritus University of Thrace, Komotini, Greece

ABSTRACT

Michailidis, Y. (2015). Effect of plyometric training on athletic performance in preadolescent soccer players. *J. Hum. Sport Exerc.*, 10(1), pp.15-23. The aim of this study was to investigate the effectiveness of plyometric training on performance of preadolescent soccer players. 21 players assigned to two groups: jumping-group (JG, n = 11) and control-group (CG, n = 10). Training program was performed for 10 weeks. Anaerobic power performances were assessed by using standing long jump (SLJ), 10 m and 30 m sprint. In the JG the performance at the long jump was increased significantly (P = 0.031). Also the performance of JG increased at 30m sprint running by 7.2 % (P < 0.001). None of the variables tested in the CG demonstrated difference between the pre-test and the post-test. Our results indicate that plyometric training can improve running performance at 30 m sprint and the performance at standing long jump in preadolescent soccer players. Key words: PLYOMETRIC, JUMP, SPRINT, PERFORMANCE, PREADOLESCENT.

Corresponding author. Department of Physical Education and Sports Sciences, University Campus, 69100, Komotini, Greece. Tel +30-2229062570, Fax +30-2229062570.
E-mail: michailidis79@hotmail.com
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Artículo 4

Plyometrics' Trainability in Preadolescent Soccer Athletes

Yiannis Michailidis,[1] Ioannis G. Fatouros,[1] Eleni Primpa,[1] Charalampos Michailidis,[2] Alexandra Avloniti,[1] Athanasios Chatzinikolaou,[1] José C. Barbero-Álvarez,[3] Dimitrios Tsoukas,[4] Ioannis I. Douroudos,[1] Dimitrios Draganidis,[1] Diamanda Leontsini,[1] Konstantinos Margonis,[1] Fani Berberidou,[1] and Antonios Kambas[1]

[1]*Department of Physical Education and Sport Sciences, Democritus University of Thrace, Komotini, Greece;* [2]*Department of Physical Education and Sport Sciences, Aristotle University of Thessaloniki, Thessaloniki, Greece;* [3]*Department of Physical Education and Sport, University of Granada, Campus of Melilla, Spain; and* [4]*Medical School, Department of Toxicology, University of Athens, Athens, Greece*

Abstract

Michailidis, Y, Fatouros, IG, Primpa, E, Michailidis, C, Avloniti, A, Chatzinikolaou, A, Barbero-Álvarez, JC, Tsoukas, D, Douroudos, II, Draganidis, D, Leontsini, D, Margonis, K, Berberidou, F, and Kambas, A. Plyometrics' trainability in preadolescent soccer athletes. *J Strength Cond Res* 27(1): 38–49, 2013—Plyometric training (PT) is a widely used method to improve muscle ability to generate explosive power. This study aimed to determine whether preadolescent boys exhibit plyometric trainability or not. Forty-five children were randomly assigned to either a control (CG, $N = 21$, 10.6 ± 0.5 years; participated only in regular soccer practice) or a plyometric training group (PTG, $N = 24$, 10.6 ± 0.6 years; participated in regular soccer practice plus a plyometric exercise protocol). Both groups trained for 12 weeks during the in-season period. The PT exercises (forward hopping, lateral hopping, shuffles, skipping, ladder drills, skipping, box jumps, low-intensity depth jumps) were performed twice a week. Preadolescence was verified by measuring Tanner stages, bone age, and serum testosterone. Speed (0–10, 10–20, 20–30 m), leg muscle power (static jumping, countermovement jumping, depth jumping [DJ], standing long jump [SLJ], multiple 5-bound hopping [MB5]), leg strength (10 repetition maximum), anaerobic power (Wingate testing), and soccer-specific performance (agility, kicking distance) were measured at baseline, midtraining, and posttraining. The CG caused only a modest (1.2–1.8%) increase in speed posttraining. The PTG induced a marked ($p < 0.05$) improvement in all speed tests (1.9–3.1% at midtraining and 3–5% at posttraining) and vertical jump tests (10–18.5% at midtraining and 16–23% at posttraining), SLJ (2.6% at midtraining and 4.2% at posttraining), MB5 (14.6% at midtraining and 23% at posttraining), leg strength (15% at midtraining and 28% at posttraining), agility (5% at midtraining and 23% at posttraining), and kicking distance (13.6% at midtraining and 22.5% at posttraining). Anaerobic power remained unaffected in both groups. These data indicate that (a) prepubertal boys exhibit considerable plyometric trainability, and (b) when soccer practice is supplemented with a PT protocol, it leads to greater performance gains.

Key Words plyometric training, power performance, childhood, football

Introduction

Lower-limb plyometric exercises, that is, jumping, hopping, and bounding, are characterized by the use of the stretch-shortening cycle (SSC) that develops during the transition from a rapid eccentric muscle contraction (deceleration or negative phase) to a rapid concentric muscle contraction (acceleration or positive phase) (37,38). The SSC exercises capitalize on the elastic properties of connective tissue and muscle fibers by allowing the muscle to store elastic energy during the deceleration-negative phase and release it later during the acceleration-positive phase to enhance muscle force and power output (23,38). Systematic lower-limb plyometric training (PT) has been shown to improve consistently various measures and components of muscle power such as vertical jumping ability (19,20,31), speed and acceleration (33,52), maximal and explosive strength (19,26,55), agility (64), and sport-specific performance (57).

Soccer, as a typical intermittent-type sport, incorporates various explosive ballistic motions such as sprinting, kicking, jumping, accelerations and decelerations, tackling, changes of direction, and turning (5). Ball kicking, one of the most fundamental soccer skill, relies on the use of SSC because ball speed depends on the SSC characteristics of the involved

Address correspondence to Ioannis G. Fatouros, ifatouro@phyed.duth.gr.

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ARTÍCULO 5

Effect of Vertical, Horizontal, and Combined Plyometric Training on Explosive, Balance, and Endurance Performance of Young Soccer Players

Rodrigo Ramírez-Campillo,[1] Francisco Gallardo,[1] Carlos Henriquez-Olguín,[2] Cesar M.P. Meylan,[3,4] Cristian Martínez,[5] Cristian Álvarez,[6] Alexis Caniuqueo,[7] Eduardo L. Cadore,[8] and Mikel Izquierdo[9,10]

[1]*Department of Physical Activity Sciences, University of Los Lagos, Osorno, Chile;* [2]*Laboratory of Exercise Sciences, MEDS Clinic, Santiago, Chile;* [3]*Canadian Sport Institute Pacific, Vancouver, British Columbia, Canada;* [4]*Canadian Soccer Association, Ottawa, Ontario, Canada;* [5]*Department of Physical Education, Sport and Recreation, University of La Frontera, Temuco, Chile;* [6]*Family Health Center of Los Lagos, Health Promotion Program, Los Lagos, Chile;* [7]*Laboratory of Physiology and Biomechanics, University Autónoma of Chile, Temuco, Chile;* [8]*Exercise Research Laboratory, Federal University of Rio Grande do Sul, Porto Alegre, Brazil;* [9]*Faculty of Recreation, Sport and Physical Education, University of Santo Tomás, Bogotá D.C, Colombia; and* [10]*Department of Health Sciences, Public University of Navarre, Navarre, Spain*

Abstract

Ramírez-Campillo, R, Gallardo, F, Henriquez-Olguín, C, Meylan, CMP, Martínez, C, Álvarez, C, Caniuqueo, A, Cadore, EL, and Izquierdo, M. Effect of vertical, horizontal, and combined plyometric training on explosive, balance, and endurance performance of young soccer players. *J Strength Cond Res* 29(7): 1784–1795, 2015—The aim of this study was to compare the effects of 6 weeks of vertical, horizontal, or combined vertical and horizontal plyometric training on muscle explosive, endurance, and balance performance. Forty young soccer players aged between 10 and 14 years were randomly divided into control (CG; $n = 10$), vertical plyometric group (VG; $n = 10$), horizontal plyometric group (HG; $n = 10$), and combined vertical and horizontal plyometric group (VHG; $n = 10$). Players performance in the vertical and horizontal countermovement jump with arms, 5 multiple bounds test (MB5), 20-cm drop jump reactive strength index (RSI20), maximal kicking velocity (MKV), sprint, change of direction speed (CODS), Yo-Yo intermittent recovery level 1 test (Yo-Yo IR1), and balance was measured. No significant or meaningful changes in the CG, apart from small change in the Yo-Yo IR1, were observed while all training programs resulted in meaningful changes in explosive, endurance, and balance performance. However, only VHG showed a statistically significant ($p \leq 0.05$) increase in all performance test and most meaningful training effect difference with the CG across tests. Although no significant differences in performance changes were observed between experimental groups, the VHG program was more effective compared with VG (i.e., jumps, MKV, sprint, CODS, and balance performance) and HG (i.e., sprint, CODS, and balance performance) to small effect. The study demonstrated that vertical, horizontal, and combined vertical and horizontal jumps induced meaningful improvement in explosive actions, balance, and intermittent endurance capacity. However, combining vertical and horizontal drills seems more advantageous to induce greater performance improvements.

Key Words explosive actions, stretch-shortening cycle, competitive game, preadolescense, strength and conditioning

Address correspondence to Mikel Izquierdo, mikel.izquierdo@gmail.com.

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Journal of Strength and Conditioning Research

Introduction

Sprinting, jumping, and change of direction speed (CODS) are important determinants for success in adult (42) and young soccer players (4). Although sprinting only contributes up to 3% of the total distance covered in children's games (4), most crucial moments such as winning ball possession, scoring, or conceding goals depend on it (42). It has been proposed that the high degree of plasticity in neuromuscular development during preadolescence, combined with appropriately timed implementation and progression of integrative neuromuscular training (e.g., supplemental training combining general and specific strength and conditioning exercises, such as plyometrics), may allow for strengthened physical development that contributes favorably to athleticism into adulthood (35). Selection of relevant training methods, which contribute to

ARTÍCULO 6

Effect of Progressive Volume-Based Overload During Plyometric Training on Explosive and Endurance Performance in Young Soccer Players

Rodrigo Ramírez-Campillo,[1,2] Carlos Henríquez-Olguín,[2] Carlos Burgos,[2] David C. Andrade,[2] Daniel Zapata,[2] Cristian Martínez,[3] Cristian Álvarez,[4] Eduardo I. Baez,[5] Mauricio Castro-Sepúlveda,[6] Luis Peñailillo,[6] and Mikel Izquierdo[7,8]

[1]*Department of Physical Activity Sciences, University of Los Lagos, Osorno, Chile;* [2]*Laboratory of Exercise Sciences, MEDS Clinic, Santiago, Chile;* [3]*Department of Physical Education, Sport and Recreation, University of La Frontera, Temuco, Chile;* [4]*Family Health Center of Los Lagos, Health Promotion Program, Los Lagos, Chile;* [5]*Department of Sport and Recreation, University of Playa Ancha, Valparaiso, Chile;* [6]*Exercise Science Laboratory, School of Kinesiology, Faculty of Medicine, University of Finis Terrae, Santiago, Chile;* [7]*Faculty of Physical Culture, Sport and Recreation, University of Santo Tomás, Bogotá DC, Colombia; and* [8]*Department of Health Sciences, Public University of Navarre, Navarre, Spain*

Abstract

Ramirez-Campillo, R, Henriquez-Olguin, C, Burgos, C, Andrade, DC, Zapata, D, Martinez, C, Álvarez, C, Baez, EI, Castro-Sepúlveda, M, Peñailillo, L, and Izquierdo, M. Effect of progressive volume-based overload during plyometric training on explosive and endurance performance in young soccer players. *J Strength Cond Res* 29(7): 1884–1893, 2015—The purpose of the study was to compare the effects of progressive volume-based overload with constant volume-based overload on muscle explosive and endurance performance adaptations during a biweekly short-term (i.e., 6 weeks) plyometric training intervention in young soccer players. Three groups of young soccer players (age 13.0 ± 2.3 years) were divided into: control (CG; *n* = 8) and plyometric training with (PPT; *n* = 8) and without (NPPT; *n* = 8) a progressive increase in volume (i.e., 16 jumps per leg per week, with an initial volume of 80 jumps per leg each session). Bilateral and unilateral horizontal and vertical countermovement jump with arms (CMJA), 20-cm drop jump reactive strength index (RSI20), maximal kicking velocity (MKV), 10-m sprint, change of direction speed (CODS), and Yo-Yo intermittent recovery level 1 test (Yo-Yo IR1) were measured. Although both experimental groups significantly increased CMJA, RSI20, CODS, and endurance performance, only PPT showed a significant improvement in MKV and 10-m sprint time. In addition, only PPT showed a significantly higher performance improvement in jumping, MKV, and Yo-Yo IR1 compared with CG. Also, PPT showed higher meaningful improvement compared with NPPT in all (except 1) jump performance measures. Furthermore, although PPT involved a higher total volume compared with NPPT, training efficiency (i.e., percentage change in performance/total jump volume) was similar between groups. Our results show that PPT and NPPT ensured significant improvement in muscle explosive and endurance performance measures. However, a progressive increase in plyometric training volume seems more advantageous to induce soccer-specific performance improvements.

Key Words explosive strength, stretch-shortening cycle, team sports, strength training, football

Address correspondence to Mikel Izquierdo, mikel.izquierdo@gmail.com.

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Journal of Strength and Conditioning Research

Introduction

It has been shown that explosive muscle actions such as sprinting, jumping, and change of direction speed (CODS), along with aerobic power, influence game performance in young soccer players (3). For instance, although sprinting contributes only up to 3% of the total game distance covered by young soccer players (3), most crucial moments (e.g., scoring) depend on it (39). In addition, along with the relevance of neuromuscular pathway training from an explosive-development stand point at young ages (i.e., *trainability window*) (25), soccer-related explosive activities may be important qualities not only at young level (12,45) but also at a later stage of a player's career (18). Therefore, it has been proposed that such explosive actions could affect game performance of soccer players and that they have to be trained independently from aerobic performance from a young age (13).

ARTÍCULO 7

Effects of In-Season Low-Volume High-Intensity Plyometric Training on Explosive Actions and Endurance of Young Soccer Players

RODRIGO RAMÍREZ-CAMPILLO,[1] CÉSAR MEYLAN,[2,3] CRISTIAN ÁLVAREZ,[4] CARLOS HENRÍQUEZ-OLGUÍN,[5] CRISTIAN MARTÍNEZ,[6] RODRIGO CAÑAS-JAMETT,[7,8] DAVID C. ANDRADE,[9] AND MIKEL IZQUIERDO[10]

[1]*Department of Physical Activity Sciences, University of Los Lagos, Osorno, Chile;* [2]*Canadian Sport Institute Pacific, Vancouver, Canada;* [3]*Canadian Soccer Association, Ottawa, Canada;* [4]*Family Health Center of Los Lagos, Health Promotion Program, Los Lagos, Chile;* [5]*Laboratory of Exercise Sciences, MEDS Clinic, Santiago, Chile;* [6]*Physical Education Department, University of La Frontera, Temuco, Chile;* [7]*Laboratory of Physiology, Department of Biological Science, Faculty of Biological Sciences, Andrés Bello University, Viña del Mar, Chile;* [8]*Kinesiology School, Faculty of Rehabilitation Sciences, Andrés Bello University, Viña del Mar, Chile;* [9]*Cellular Physiology Laboratory, Biomedical Department, Faculty of Health Science, University of Antofagasta, Antofagasta, Chile; and* [10]*Department of Health Sciences, Public University of Navarre, Tudela, Spain*

Abstract

Ramírez-Campillo, R, Meylan, C, Álvarez, C, Henríquez-Olguín, C, Martínez, C, Cañas-Jamett, R, Andrade, DC, and Izquierdo, M. Effects of in-season low-volume high-intensity plyometric training on explosive actions and endurance of young soccer players. *J Strength Cond Res* 28(5): 1335–1342, 2014—Integrating specific training methods to improve explosive actions and endurance in youth soccer is an essential part of players' development. This study investigated the efficiency of short-term vertical plyometric training program within soccer practice to improve both explosive actions and endurance in young soccer players. Seventy-six players were recruited and assigned either to a training group (TG; $n = 38$; 13.2 ± 1.8 years) or a control group (CG; $n = 38$; 13.2 ± 1.8 years) group. All players trained twice per week, but the TG followed a 7-week plyometric program implemented within soccer practice, whereas the CG followed regular practice. Twenty-meter sprint time (20-m), Illinois agility test time, countermovement jump (CMJ) height, 20- (RSI20) and 40- (RSI40) cm drop jump reactive strength index, multiple 5 bounds distance (MB5), maximal kicking test for distance (MKD), and 2.4-km time trial were measured before and after the 7-week period. Plyometric training induced significant ($p \le 0.05$) and small to moderate standardized effect (SE) improvement in the CMJ (4.3%; SE = 0.20), RSI20 (22%; SE = 0.57), RSI40 (16%; SE = 0.37), MB5 (4.1%; SE = 0.28), Illinois agility test time (−3.5%, SE = −0.26), MKD (14%; SE = 0.53), 2.4-km time trial (−1.9%; SE = −0.27) performances but had a trivial and nonsignificant effect on 20-m sprint time (−0.4%; SE = −0.03). No significant improvements were found in the CG. An integrated vertical plyometric program within the regular soccer practice can substitute soccer drills to improve most explosive actions and endurance, but horizontal exercises should also be included to enhance sprinting performance.

KEY WORDS agility, explosive strength, stretch-shortening cycle, vertical jump

Introduction

Soccer is an intermittent sport, which requires different physiological components. The capacity to produce varied powerful actions during a 90-minute game is associated with high aerobic capacity (41). However, the ability to produce an explosive single-bout effort is as important as aerobic power for success in soccer (9). This includes movements such as sprinting, jumping, changing direction, throwing, or kicking frequently occurring in soccer (41). Many of these activities not only require maximal power but also a high rate of power development considering the short period spent on the ground to produce power, such as sprinting or changing direction (<100 milliseconds) (1,26). Various studies demonstrated that youth elite and subelite players were found to be

Address correspondence to Mikel Izquierdo, mikel.izquierdo@gmail.com.

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ARTÍCULO 8

The Effects of Interday Rest on Adaptation to 6 Weeks of Plyometric Training in Young Soccer Players

Rodrigo Ramírez-Campillo,[1] César M.P. Meylan,[2,3] Cristian Álvarez-Lepín,[4] Carlos Henriquez-Olguín,[5] Cristian Martinez,[6] David C. Andrade,[7] Mauricio Castro-Sepúlveda,[8] Carlos Burgos,[5] Eduardo I. Baez,[9] and Mikel Izquierdo[10]

[1]Department of Physical Activity Sciences, University of Los Lagos, Osorno, Chile; [2]Canadian Sport Institute Pacific, Vancouver, Canada; [3]Canadian Soccer Association, Ottawa, Canada; [4]Family Health Center of Los Lagos, Health Promotion Program, Los Lagos, Chile; [5]Laboratory of Exercise Sciences, MEDS Clinic, Santiago, Chile; [6]Department of Physical Education, Sport and Recreation, University of La Frontera, Temuco, Chile; [7]Cellular Physiology Laboratory, Biomedical Department, Faculty of Health Science, University of Antofagasta, Antofagasta, Chile; [8]School of Health, Duoc UC, Santiago, Chile; [9]Department of Sport and Recreation, University of Playa Ancha, Valparaiso, Chile; and [10]Department of Health Sciences, Public University of Navarre, Spain

Abstract

Ramirez-Campillo, R, Meylan, CMP, Álvarez-Lepin, C, Henriquez-Olguin, C, Martinez, C, Andrade, DC, Castro-Sepúlveda, M, Burgos, C, Baez, EI, and Izquierdo, M. The effects of interday rest on adaptation to 6 weeks of plyometric training in young soccer players. *J Strength Cond Res* 29(4): 972–979, 2015—The purpose of this study was to determine the effects of short-term plyometric training interposed with 24 or 48 hours of rest between training sessions on explosive and endurance adaptations in young soccer players. A total of 166 players, between 10 and 17 years of age, were randomly divided into 3 groups: a control group (CG; $n = 55$) and 2 plyometric training groups with 24 hours (PT24; $n = 54$) and 48 hours (PT48; $n = 57$) of rest between training sessions. Before and after intervention, players were measured in squat jump, countermovement jump, 20 (RSI20) cm drop jump reactive strength index, broad long jump, 20-m sprint time, 10 × 5-m agility time, 20-m multistage shuttle run test, and sit-and-reach test. The plyometric training program was applied during 6 weeks, 2 sessions per week, with a load from 140 to 260 jumps per session, replacing some soccer-specific drills. After intervention, the CG did not show significant performance changes. PT24 and PT48 groups showed a small-to-moderate significant improvement in all performance tests ($p < 0.001$), with no differences between treatments. Although it has been recommended that plyometric drills should not be conducted on consecutive days, the study shows that plyometric training applied twice weekly on consecutive or nonconsecutive days results in similar explosive and endurance adaptations in young male soccer players.

Key Words maturity, explosive strength, competitive sports, strength training

Introduction

Soccer is an intermittent sport that requires different physiological components. The capacity to produce varied powerful actions during a 90-minute game is associated with high aerobic capacity (33). However, the ability to produce explosive single-bout effort is as important as aerobic power for success in soccer (12), such as sprinting, jumping, or changing direction (33). Plyometric training (PT) is commonly used to increase these types of actions in young soccer players (7,27,28,34), with the advantage of being easy to integrate in soccer practice (space, time, equipment), and replicating the neuromuscular stimulus encountered in explosive soccer activities such as sprinting and jumping (13). Additionally, PT in young soccer players may increase endurance performance (38). Therefore, PT may be advocated as an appropriate approach for enhancing soccer-related performance abilities. However, the characteristics of between-session recovery of a PT that generates optimal gains are not clear (31), especially in young soccer players.

Plyometric training frequency (31) or the rest interval between training sessions (26) may affect its outcome. In young soccer players, PT frequencies of 1 (24,36), 2 (14,19,24,27,28,32,34,40), and 3 (7) sessions per week have been applied effectively. Curiously, most studies in which explosive strength training was applied to this group of

Address correspondence to Mikel Izquierdo, mikel.izquierdo@gmail.com.

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The efficacy of vertical vs. horizontal: Plyometric training on speed, jumping performance and agility in soccer players

Nikolaos Manouras, Zisis Papanikolaou, Konstantina Karatrantou, Polydoros Kouvarakis and Vassilis Gerodimos

Abstract

This study compared the efficacy of a vertical and horizontal plyometric training program on acceleration, speed, jumping performance, and agility in young soccer players during the in-season period. Thirty male soccer players (19.1 ± 5.8 years) were assigned into a horizontal plyometric, a vertical plyometric, or a control group. The horizontal plyometric group and vertical plyometric group participated in an eight-week training program that was performed one day/week (in conjunction with conventional soccer training) and consisted of horizontal (for the horizontal plyometric group) or vertical plyometric exercises (for the vertical plyometric group). Acceleration (10-m sprint), speed (30-m sprint), agility, and jumping performance (horizontal and vertical) were assessed prior and after the completion of plyometric training programs. Agility, 30-m sprint performance, and vertical jumping performance ($p < 0.01$) improved following the completion of training in both horizontal plyometric group and vertical plyometric group, whereas horizontal jumping performance improved only in horizontal plyometric group ($p < 0.01$). There were no significant effects on acceleration for both horizontal plyometric group and vertical plyometric group. Furthermore, no differences were observed between groups in all performance parameters. In control group, acceleration, speed, agility, and jumping performance remained stable throughout the study. To sum up, horizontal or vertical plyometric training programs, consisted of one session/week, may be used by coaches and fitness professionals as effective exercise modalities for *preserving* or *improving* jumping performance, acceleration, speed, and agility in young soccer players during the in-season period.

Keywords

Strength, power, stretch-shortening cycle, physical fitness, in-season, amateur

Introduction

Soccer is an activity that requires specific skills involving distinct explosive movements and muscle actions at different velocities.[1] Strength, speed, jumping ability, and/or agility are important contributing factors to performance of several fundamental skills in soccer,[2–4] such as abrupt change of direction, accelerating, decelerating, etc. Therefore, the development of speed, jumping performance and agility through specific training interventions should be emphasized in a soccer training program.

Plyometric training is widely used, in sports, as an efficient[5–7] exercise modality for *preserving or improving* different features of physical fitness in athletes during the in-season period, during which the volume and frequency of training should be tightly controlled due to time constraint.[6] Indeed, previous studies[8,9] demonstrated the beneficial effects of plyometric training in young athletes during the in-season period, suggesting that *specific training* during this period might be essential for *maintaining or increasing* explosiveness. There is also evidence that plyometric training incorporated into a conventional soccer training program can cause beneficial effects on speed,[5–7] vertical jumping performance,[10] and agility.[11] With this in mind, recent studies

Reviewer: Lee Brown (California State University, Fullerton, USA)

Department of Physical Education and Sport Science, University of Thessaly, Trikala, Greece

Corresponding author:
Nikolaos Manouras, Department of Physical Education and Sport Sciences, University of Thessaly, Karies, Trikala 42100, Greece.
Email: manouras@pe.uth.gr

have focused on the efficacy of different plyometric training interventions (vertical, horizontal, or mixed training combining vertical and horizontal plyometric exercises) to improve the explosive characteristics in soccer players.[5–7,10–15] However, there is no adequate information for the most effective plyometric training regime (*vertical vs. horizontal*).

The majority of previous studies, that investigated the effects of plyometric training on different indices of explosiveness in young soccer players, have used a combined plyometric training program consisted of horizontal and vertical plyometric exercises. The majority of these studies reported significant improvements in speed, jumping performance, and/or agility.[5–7,11,15] However, only few studies[16,17] have compared the efficacy of horizontal or vertical plyometric training in young soccer players. More specifically, Loturco et al.[16] compared the effectiveness of *horizontal* and *vertical* plyometric training in young soccer players *during the pre-season period*. The authors reported that horizontal plyometric training may induce greater adaptations to acceleration (up to 10 m), while vertical plyometric training seems to provoke greater beneficial effects for longer sprint distances (i.e. 10 to 20 m). Ramirez-Campillo et al.[17] also compared the efficiency of horizontal and vertical plyometric training on different explosive indices in young (10–14 years) soccer players, reporting that both training routines may induce similar or in some cases slightly different neuromuscular adaptations during the in-season period.

Based on the above, the purpose of this study was to examine and compare the effects of horizontal and vertical plyometric training programs on acceleration, speed, on horizontal and vertical jumping performance and on agility in young amateur soccer players during the in-season period. This is of importance since (i) horizontal and vertical plyometric training may possibly induce different neuromuscular and kinematic adaptations and (ii) both training routines have been traditionally used in sport settings for improving different features of physical fitness. We hypothesized that both horizontal and vertical plyometric training programs will improve fitness parameters. We, also, hypothesized that the horizontal plyometric training program will induce greater adaptations in acceleration, speed, agility, and horizontal jumping performance, while the vertical plyometric training program will result to greater adaptations regarding the vertical jumping performance.

Method

Participants

Thirty male young soccer players volunteered to participate in the present study. The participants trained at least three times per week, for more than three years. Following a completion of a medical history form, the participants were randomly allocated into a horizontal plyometric training group (HPG; n = 10), a vertical plyometric training group (VPG; n = 10), and a control group (CG; n = 10) (Table 1). All participants were healthy with no injuries of the lower and upper limbs at least six months prior to the commencement of the study. Before the initiation of the study, participants (or adolescent's parents) were informed about the experimental procedures and signed an informed consent form. The study was conducted according to the Declaration of Helsinki and ethical approval was granted by the Ethics Committee of the University of Thessaly.

Table 1. Age and physical characteristics (mean ± SD) of the participants.

	Age (yrs)	Body height (m)	Body mass (kg)
Horizontal plyometric group (n = 10)	19.10 ± 5.75	1.75 ± 0.06	69.80 ± 11.00
Vertical plyometric group (n = 10)	20.75 ± 6.14	1.78 ± 0.07	72.10 ± 11.30
Control group (n = 10)	20.00 ± 3.51	1.82 ± 0.05	77.30 ± 8.30

Procedures

A week prior to the initiation of the study, the participants were informed about the evaluation procedures and were familiarized with the instrumentation and the experimental procedures (testing and training). On the same day, body height and body mass were measured to the nearest 0.1 cm and 0.1 kg, respectively, using a calibrated physician's scale (Seca, Hamburg, Germany). The HPG and VPG participated in an eight-week horizontal (for the HPG) or vertical plyometric training program (for the VPG). The participants (HPG, VPG and CG) were also maintained their specific soccer training regime throughout the study. More specifically, the participants trained three times per week and played one official game. The standard training sessions lasted 60 to 75 min and consisted of skill activities at various intensities, offensive and defensive tactics, and various small-sided games. Agility, acceleration (10-m sprint), speed (30-m sprint), and jumping performance (horizontal and vertical) were measured before and after the completion of plyometric training programs. Participants were instructed to follow their normal diet for two days before the testing, to avoid intense exercise activity for 48 h prior to testing, and to have sufficient rest the night before the testing. Participants were also instructed to abstain from any caffeine, tobacco, and alcohol consumption for at least 24 h before testing.

Measurements

Two days prior to and after the completion of training programs agility, acceleration, speed and jumping performance (horizontal and vertical) were assessed. All tests were conducted in the morning hours (8:30–10:00 a.m.) under controlled environmental conditions (temperature: 18–25°C and humidity: 35–45%) and on the same natural grass pitch during the in-season period (January–March). Prior to the initiation of the testing, the participants performed a standardized 15 min warm-up that included 10 min of running and 5 min of dynamic stretching exercises.

Jumping performance. Both horizontal and vertical jumping ability were assessed. Horizontal jumping performance was evaluated using the standing long jump test, as previously described by the Eurofit Physical Fitness Test Battery.[18] Following two familiarization trials, the participants performed three maximal trials with a resting period of 60 s and the best performance (in cm) was considered for analysis. Vertical jumping performance was also measured by the countermovement jump test using the Bosco ergojump system (Ergojump, Psion© CM, MAGICA, Rome, Italy), as previously described by Gerodimos et al.[19] The system estimates the elevation of the body mass center based on the flight time and calculates the height (cm) of the jump.[20] During CMJ, the participants kept their trunk in an upright position and their hands on hips. The participants were allowed a downward movement by rapidly bending (at 90°) and extending their knees to jump as high as possible. The selection of 90° knee angle (semi squat position) was based on the fact that at this angle, the knee is better stabilized during the phase of contact with the ground.[20] To ensure consistency in jumping technique, the 90° knee angle was measured using an electronic goniometer. Following two familiarization trials, the participants performed three maximal trials with a resting period of 60 s. The best performance (in cm) was considered for analysis.[6]

Acceleration and speed. Acceleration and speed were assessed using the 10 m sprint and the 30 m sprint tests,[21] respectively. All tests were performed in a natural soccer turf, and the participants wore their soccer footwear during the test. Sprint times (for both 10 and 30 sprint tests) were recorded to the nearest 0.01 s using electronic timing lights (Newtest PowerTimer, Newtest Oy, Oulu, Finland). All sprint tests started from the split stance position. More specifically, the participants placed their front foot 50 cm behind the first photocell and started their effort upon hearing an audio signal from the system. The participants performed three maximal trials for each test with a rest period of 3 min between each sprint. The best recorded sprint time (in seconds) was used for the analysis.[22]

Agility. Agility was assessed using the Illinois test according to the recommendations of Miller et al.[23] and Hachana et al.[24] The performance times during the Illinois test were recorded to the nearest 0.01 s using electronic timing lights (Newtest PowerTimer, Newtest Oy, Oulu, Finland). Two timing gates were used during the test; one at the start and one at the finish line. The participants performed three attempts to both left to right and right to left directions.[23] The participants were instructed to complete the test as quickly as possible. Three maximal trials were performed (at each direction) with a rest period of 3 min and the best time (in seconds) was used to evaluate performance.

Training program

The VPG and HPG participated in an eight-week plyometric training program that was performed one day per week (eight training sessions in total) and consisted of horizontal for the HPG or vertical plyometric exercises for the VPG; at the same time, the CG performed technical drills of low intensity. Each training-session lasted 90 to 95 min and consisted of 25 min warm-up (15 min running and 10 min dynamic stretching exercises), 30 min plyometric training (horizontal or vertical), 25–30 min soccer training and 10 min cool-down (5 min running and 5 min stretching exercises). The training load (volume, intensity, number of exercises) was equated between the two groups (HPG and VPG) (Table 2). During the plyometric intervention, the total number of foot contacts progressively increased from 60 to 110 in both HPG and VPG. All exercises were performed with maximal effort and all training sessions were supervised by the principal investigator of this study.

Statistical analysis

All data are presented as means ± SD and were analyzed using Statistica software (Statistica 10.0, StatSoft, Tulsa, Oklahoma, USA). The normality of data was examined using Shapiro–Wilk test. Two-way ANOVAs (group: horizontal, vertical and control; time: pre and post) with repeated measures on "time" factor were used to analyze the data. In case of significant "group × time" interactions, Scheffe post hoc tests were applied to locate the significantly different means. The intra-session reliability for speed, agility, and jumping performance

Table 2. Training load during the vertical and horizontal plyometric training programs.

	Vertical plyometric group			Horizontal plyometric group		
Weeks	Exercises	Sets	Contacts	Exercises	Sets	Contacts
1–2	Vertical ankle jumps	4	6	Horizontal ankle jumps	4	6
	Counter movement jump	4	6	Long jumps	4	6
	Front obstacle jumps	3	4	Diagonal obstacle jumps	3	4
	Total	11	60	Total	11	60
3–4	Vertical ankle jumps	4	10	Horizontal ankle jumps	4	10
	Counter movement jump	4	6	Long jumps	4	6
	Front obstacle jumps	4	4	Diagonal obstacle jumps	4	4
	Total	12	80	Total	12	80
5–6	Counter movement jump	5	8	Long jumps	5	8
	Front obstacle jumps	5	5	Diagonal obstacle jumps	5	5
	Drop jump (40 cm)	5	5	Multiple long jumps	5	5
	Total	15	90	Total	15	90
7–8	Counter movement jump	5	10	Long jumps	5	10
	Front obstacle jumps	5	6	Diagonal obstacle jumps	5	6
	Drop jump (40 cm)	5	6	Multiple long jumps	5	6
	Total	15	110	Total	15	110

Intensity: exercises were performed with maximal effort (intensity: 100 %), Rest: 1-2 min between sets and 2–3 min between exercises.

values was determined using the intra-class correlation coefficient. The reliability for all pre-training tests ranged from 0.81 to 0.99. The level of significance for all statistical analyses was set at $\alpha = 0.05$.

Results

Acceleration (10-m sprint) and speed (30-m sprint)

A significant "group × time" interaction effect was observed on 30-m sprint ($F_{2,27} = 6.24$; $p < 0.01$) (Table 3). Post hoc analysis revealed that 30-m sprint performance improved post-intervention compared to pre-intervention for both HPG ($p < 0.01$) and VPG ($p < 0.01$). In CG, 30-m sprint did not change during the study ($p > 0.05$). Post hoc comparisons between groups revealed that pre-training and post-training sprint values were not different between-groups. Moreover, ANOVA revealed non-significant "group × time" interaction on 10-m sprint performance ($p > 0.05$) (Table 3).

Agility

ANOVAs indicated a significant "group × time" interaction effect on agility (right side: $F_{2,27} = 10.60$, $p < 0.01$; left side: $F_{2,27} = 5.58$, $p < 0.01$) (Table 3). Agility values for both right and left sides significantly improved post-training compared to pre-training for HTG ($p < 0.01$) and VTG ($p < 0.01$), while remained stable throughout the study for the CG. Post hoc comparisons between groups revealed that pre- and post-training agility values were not different between-groups.

Vertical jumping performance

A significant "group × time" interaction effect was observed on vertical jumping performance ($F_{2,27} = 7.38$, $p < 0.01$). Post hoc analysis revealed that vertical jumping performance improved post-training compared to pre-training for both HTG ($p < 0.01$) and VTG ($p < 0.01$), while it remained unchanged for the CG ($p = 0.57$). Post hoc comparisons between groups revealed that pre- and post-training vertical jumping performance values were not different between groups (Table 3).

Horizontal jumping performance

The ANOVA test demonstrated significant "group × time" interaction effect on horizontal jumping ability ($F_{2,27} = 6.14$, $p < 0.01$; Table 3). Post hoc analyses revealed that horizontal jumping performance improved post-intervention compared to pre-intervention in HTG ($p < 0.01$), while it remained unchanged for VTG ($p = 0.125$) and CG ($p = 0.99$). Post hoc comparisons between groups revealed that pre- and post-training horizontal jumping performance values were not different between-groups.

Table 3. Acceleration, speed, agility, and jumping performance values in the horizontal plyometric (HPG), vertical plyometric (VPG) and control (CG) groups pre- and post-training.

Variables	Group	Pre-training	Post-training
Sprint			
10 m (s)	HPG	1.82 ± 0.06	1.76 ± 0.02
	VPG	1.87 ± 0.05	1.82 ± 0.08
	CG	1.88 ± 0.11	1.87 ± 0.11
30 m (s)	HPG	3.70 ± 0.19	3.60 ± 0.16*
	VPG	3.65 ± 0.21	3.54 ± 0.17*
	CG	3.61 ± 0.27	3.60 ± 0.29
Agility			
RS (s)	HPG	16.74 ± 0.41	16.12 ± 0.14*
	VPG	17.14 ± 0.40	16.54 ± 0.38*
	CG	17.12 ± 0.35	17.10 ± 0.35
LS (s)	HPG	16.73 ± 0.46	16.31 ± 0.20*
	VPG	17.23 ± 0.54	16.75 ± 0.40*
	CG	17.12 ± 0.46	17.13 ± 0.47
Jumping ability			
Horizontal (cm)	HPG	236.8 ± 4.30	242.8 ± 6.20#
	VPG	239.0 ± 7.70	242.8 ± 6.20
	CG	236.4 ± 10.20	238.1 ± 9.30
Vertical (cm)	HPG	30.7 ± 3.00	31.7 ± 2.9*
	VPG	29.2 ± 7.10	30.9 ± 6.7*
	CG	32.1 ± 6.80	32.5 ± 6.8

RS: right side; LS: left side.
Note: Values are Means ± SD.
*$p < 0.01$ vs. pre-training in HPG and VPG;
#$p < 0.01$ vs. pre-training in HPG.

Discussion

The novel aspect of this study is that it examined and compared the effectiveness of two different plyometric training interventions (*horizontal and vertical*) on acceleration, speed, jumping performance, and agility in young soccer players during the in-season period. Our results demonstrate that eight weeks of horizontal or vertical plyometric training programs, incorporated into the conventional soccer training, may induce significant improvements on speed, agility, and vertical jumping ability, with no effects on acceleration. Furthermore, we observed that horizontal jumping performance was significantly improved only after the horizontal plyometric training. However, it should be mentioned that there were no significant differences at post-training measurements among groups (plyometric groups vs. conventional soccer group).

Acceleration and speed are important parameters to succeed in soccer.[25] Our findings showed that eight sessions of horizontal or vertical plyometric training (eight weeks, one day/week) improved speed (30-m sprint performance) by approximately 2.70% for HPG and by 3.11% for VPG in young soccer players during the in-season period. Our results are in agreement with previous studies that employed different plyometric training interventions (e.g. horizontal, vertical or mixed training combining horizontal and vertical exercises) in young and/or adult soccer players[5–7,14,15] showing *similar* improvements in sprint performance. The present and the previous studies that did document positive training effects of plyometric training on speed have used training duration of seven to eight weeks with training frequency of one to two days per week and total amount of foot contacts of 40–110. On the other hand, our results partially contradict the findings of Ramirez-Campillo et al.[26] who investigated the neuromuscular adaptations of a *vertical* plyometric training program (seven weeks, two sessions/week) in young soccer players during the in-season period. The authors reported that a vertical plyometric training program consisting of high intensity drop jumps did not have significant effects on 20-m sprint performance. The discrepancy in the findings of our and previous studies with that of Ramirez-Campillo et al.[26] may be related to the independent and/or interactive effects of the sample used (a mixed sample of late adolescents and young adults vs. a mixed sample of children and adolescents in the previous study), the training load of training (60–110 foot contacts vs. 60 foot contacts in the previous study), and/or the type of plyometric exercises.

The short-term vertical or horizontal plyometric training program (eight sessions) that we applied in our study did not improve acceleration (10-m sprint performance) in young soccer players during the in-season period. In the same context, an earlier study also reported a non-significant improvement on 15-m sprint performance[10] following the completion of a vertical plyometric training program consisting of drop jumps. The authors concluded that vertical plyometric training *per se* does not improve the acceleration in soccer players, and recommended the inclusion of horizontal plyometric exercises into the training program for the improvement of acceleration phase during sprinting. In this study, although we applied a horizontal plyometric training program, we still did not observe improvements in acceleration. Thus, the results of this and previous studies suggest that vertical or horizontal plyometric training might not provide an adequate stimulus to improve acceleration. This notion has been strengthened by previous investigators who report that it is more difficult to improve the initial acceleration phase than the maximal running velocity; this is possibly due to a smaller margin for improvement and the different forces involved.[27,28] It is possible, however, that a more demanding (intense) plyometric training protocol with greater duration and training frequency might have resulted to gains in acceleration performance. In contrast to ours and previous findings, Chelly et al.[6] documented an increase in acceleration (5-m sprint) after eight weeks of vertical plyometric training program (training frequency: two sessions/week) during the in-season period in males soccer players.

The basic movement patterns in soccer require high levels of agility.[10] Indeed, many activities in soccer demand rapid changes of direction. Therefore, the development of agility through specific plyometric training interventions, which improve the rate of force development, the power output as well as the efficient use of stretch-shortening cycle (SSC), should be emphasized in a soccer training program.[29–32] Many activities in soccer, such as sprints, rapid changes of direction, or jumps, activate the mechanism of SSC.[14] During the SSC, the muscle is initially stretched (eccentric action) and then shortened (concentric action).[33] Plyometric training has been shown to utilize and improve the SSC mechanism, and therefore, is recommended by many sports scientists as an efficient training modality for improving different explosive actions such as agility, jumping performance, and maximal and explosive strength.[29–34] Indeed, this study showed that a plyometric training using either *vertical or horizontal* exercises results in a 2.5–3.7% gain (reduced time) in agility in young soccer players during the in-season period. It should be noted that the magnitude of training effects did not differ between the two training groups (*horizontal* vs. *vertical*). The findings of the present study are in line with previous investigations reporting similar gains in agility (using the Illinois test) after a vertical or an horizontal plyometric training in young soccer players.[7,10,11,14,19,26] Thus, both plyometric training regimes may be used as effective exercise modalities in soccer players for preserving or improving agility during the in-season period.

We observed that an eight-week (eight sessions) horizontal or vertical plyometric training program improved (by approximately 3.2–5.8%) vertical jumping performance in young soccer players during the in-season period. These results are in accordance with previous studies[5–7,10,14,26] that examined the effects of plyometric training, using a vertical[10,26] or a mixed (horizontal and vertical) training intervention[5–7,14] reporting significant improvements in vertical jumping performance. We also observed that only the horizontal plyometric training program significantly improved (by approximately 2.5 %) the horizontal jumping performance indicating a degree of specificity of training regarding the application of force production. However, we did not observe significant differences at post-training measurements between the two training groups. This finding is in agreement with previous studies[14,33] examining the effect of mixed (horizontal and vertical) plyometric interventions reporting a similar significant gain in horizontal jumping performance. It has been reported that horizontal jumping performance is an important element to succeed in soccer,[15] thus coaches and fitness professionals should make the appropriate decisions regarding the mode of plyometric training (horizontal or vertical plyometric training) that they should implement.

The results of the present study have important practical implication demonstrating that an eight-week plyometric training incorporated into a conventional soccer training program may lead to greater improvements in numerous explosive actions than soccer training alone; even with a minimum training frequency of one session/week. There is evidence that the ability to *maintain or improve* different explosive features of physical fitness during the in-season period is of crucial importance due to the limited time available for individual training. These improvements in various explosive actions, as a result of plyometric training, could be effectively transferred into the game-play performance.[26] According to the results of this study, it also appears that conventional soccer training *per se* is not an efficient training stimulus to *preserve or improve* these variables in this population. This remark highlights the importance of a specific training intervention to preserve or enhance various explosive indices in soccer players during the in-season period, where the emphasis is mostly placed on the technical and tactical development. However, it should be mentioned that we did not observe significant differences at post-training measurements among groups. The lack of differences among groups (plyometric groups and conventional soccer group) that we detected may be partially attributed to the training stimulus (i.e. total training sessions, training frequency, etc.) generated in this study. Thus, a plyometric training stimulus consisted of one session/week is sufficient to *preserve* or *slightly improve* jumping performance, speed, and agility in soccer players during the in-season. For further improvements in jumping performance, speed and agility in young soccer players during the in-season period, coaches and fitness professionals need to perform more specialized training interventions.

Conclusion

Short-term horizontal or vertical plyometric interventions (eight weeks, one session/week, 60–110 foot contacts) are efficient training modalities for improving vertical jumping performance, agility, and speed in young soccer players during the in-season. On the other hand, no effects were documented on the acceleration, suggesting that an alternative training strategy (i.e. higher frequency of training and/or greater duration) is required to improve this parameter in young soccer players, especially in those training periods when the challenge is the enhancement of physical fitness (i.e. pre-season). Further studies are required to determine the efficiency of horizontal and vertical plyometric training programs, using different training characteristics (i.e. greater training frequency, training duration etc.), so as to improve more parameters of physical fitness of soccer players.

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ARTÍCULO 2

Effects of In-Season Plyometric Training Within Soccer Practice on Explosive Actions of Young Players

César Meylan[1] and Davide Malatesta[2]

[1]*Institute of Sport and Recreation Research New Zealand, AUT University, Auckland, New Zealand, Australia; and* [2]*Institute of Sport Science, University of Lusanne (ISSUL), Switzerland*

Abstract

Meylan, C and Malatesta D. Effects of in-season plyometric training within soccer practice on explosive actions of young players. *J Strength Cond Res* 23(9): 2605–2613, 2009—In soccer, explosive actions such as jumping, sprinting, and changes of direction are essential to optimal performance not only in adults, but also in children's games. The purpose of the present investigation was to determine the influence of a short-term plyometric training within regular soccer practice on explosive actions of early pubertal soccer players during the in-season. Fourteen children (13.3 ± 0.6 years) were selected as the training group (TG) and 11 children (13.1 ± 0.6 years) were defined as the control group (CG). All children were playing in the same league and trained twice per week for 90 minutes with the same soccer drills. The TG followed an 8-week plyometric program (i.e., jumping, hurdling, bouncing, skipping, and footwork) implemented as a substitute for some soccer drills to obtain the same session duration as CG. At baseline and after training, explosive actions were assessed with the following 6 tests: 10-meter sprint, agility test, 3 vertical jump tests (squat jump [SJ], countermovement jump [CMJ], contact test [CT] and multiple 5 bounds test [MB5]). Plyometric training was associated with significant decreases in 10-m sprint time (−2.1%) and agility test time (−9.6%) and significant increases in jump height for the CMJ (+7.9%) and CT (+10.9%). No significant changes in explosive actions after the 8-week period were recorded for the CG. The current study demonstrated that a plyometric program within regular soccer practice improved explosive actions of young players compared to conventional soccer training only. Therefore, the short-term plyometric program had a beneficial impact on explosive actions, such as sprinting, change of direction, and jumping, which are important determinants of match-winning actions in soccer performance.

Key Words agility, initial acceleration, stretch-shortening cycle, vertical jump

Introduction

Soccer is an intermittent sport that requires different physiological components. In modern football, physiological considerations are increasingly essential to optimal performance not only in adults, but also in children. The capacity of soccer players to produce varied forceful and explosive actions, such as sprinting, jumping, tackling, kicking, turning, and changing pace, highly influences soccer match performance, as suggested by others (30). The capacity to repeat explosive bouts is an important determinant of player performance (35) and is associated with high aerobic power ($\dot{V}O_2max$) (31). However, the ability to produce a powerful single-bout effort (i.e., explosive actions) is as important as aerobic power for success in soccer (30). For instance, high-speed sprinting only contributes up to 3% of the total distance covered in children's games (6), yet most crucial moments of the game such as winning ball possession, scoring, or conceding goals depend on it (30). Initial acceleration, jumping, and agility are various explosive actions that are crucial when the player is involved in fast game play. Initial acceleration can be referred to as short sprint (0–10 m) (23), and agility can be recognized as the ability to change direction, start, and stop quickly (25,34). Game analyses have demonstrated the importance of these qualities in soccer since a mean sprint time of 2.3 seconds (10–12-m sprint) (6) and a mean of 50 turns per game have been recorded (38). Such explosive actions are integral elements for success in soccer and have to be trained independently from aerobic power with an optimal training program (18).

Training for maximal strength has been suggested to play a major role in improving explosive actions as a result of an increased force availability (11). Conversely, explosive high-velocity training has demonstrated greater improvements in

The results of the present study do not constitute endorsement by the NSCA.

Address correspondence to César Meylan, cesar.meylan@aut.ac.nz.

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Table 1. Anthropometric characteristics of the 2 groups (mean ± *SD*).

	Training group (*n* = 14)		Control group (*n* = 11)	
	Pre-T	Post-T	Pre-T	Post-T
Age (years)	13.3 ± 0.6	13.5 ± 0.51	13.1 ± 0.6	13.3 ± 0.6
Stature (m)	1.59 ± 0.09	1.61 ± 0.09*	1.63 ± 0.1	1.65 ± 0.1*
Body mass (kg)	48.6 ± 9.6	49.5 ± 9.62*	47.4 ± 9.6	48.3 ± 9.8*

Pre-T: pre-training; post-T: post-training.
*Significant difference from pre-test within the group ($p < 0.05$).

rate of force development and explosive actions in comparison with traditional weight training methods for maximal strength (17,36). The literature related to children's strength training reaffirms such controversy. Some studies have found that changes in strength had a significant effect on explosive actions (7,19), whereas others have reported no significant improvements (14,16). The absence of several stimuli during strength training could explain this inconsistency: (a) segmental coordination, in regard to power transport by biarticular muscles, and neural control mechanisms for optimal movement patterns (32); (b) specificity, according to joint angle and angular velocities (13); and (c) eccentric overloading (15).

Plyometric training does provide such training stimuli and has shown evidence to improve explosive actions in pubertal (5,26) and prepubertal (12,22,23) populations. Previous concerns regarding the safety of plyometric training for children have been dispelled by the American College of Sports Medicine (1). To minimize the risk of injury, close supervision, proper technique, and progressive training programs have to be undertaken. Because plyometric training requires similar movements encountered in usual playing activities of children, no specific strength level is required to commence a plyometric program (9). Off-season and pre-season plyometric programs may reduce the instance of injuries and improve sport performance in children by strengthening the supporting structures (i.e., ligaments, tendons, and bone) and enhancing muscular performance (muscular strength, muscular endurance, and muscular power). An inactive off-season period of 8 to 12 weeks is likely to result in a state of detraining in children (22). Plyometric programs, in collaboration with other training regimens, are often implemented only during the pre-season to bring the children to a certain fitness level for the beginning of the season. In such training program design, it is difficult to allocate the improvement in explosive actions to the plyometric training only or the combination of the return to activity after a detraining period and the plyometric training. Previous studies (5,26) demonstrated the benefits of a plyometric training program in pubertal boys during

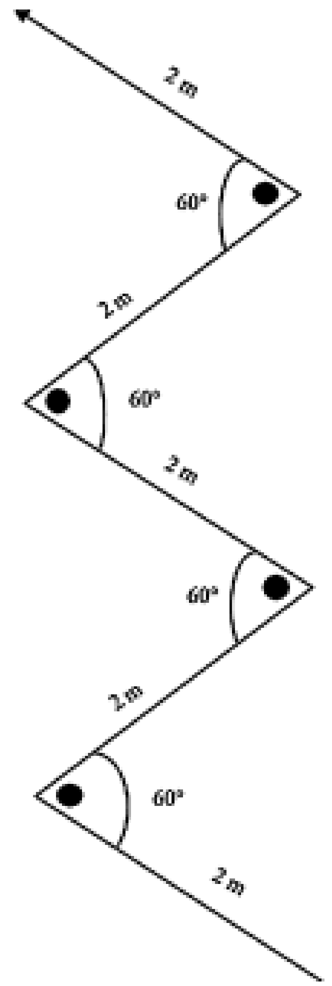

Figure 1. Agility test: 10-m sprint with four 60-degree turns around a pole. ~ Pole

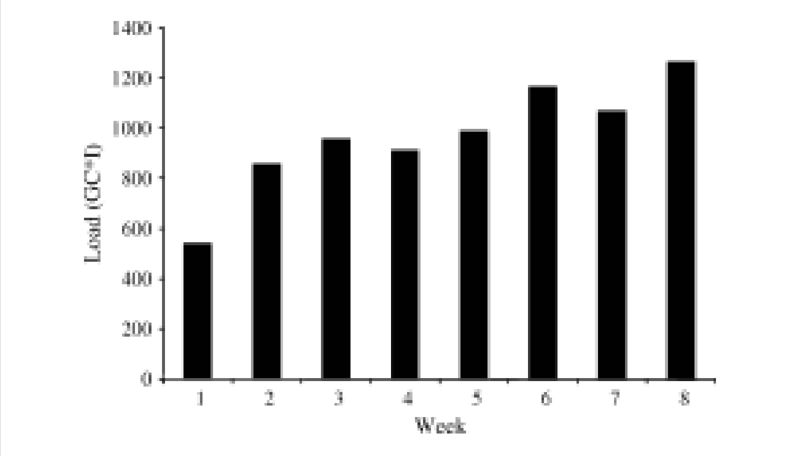

Figure 2. Weekly load of the plyometric program. GC: ground contact; I: intensity.

a basketball season, suggesting that in-season specific training might be necessary to maintain or increase the explosive actions ability. However, in previous studies investigating the effect of plyometric training on explosive actions of prepubertal and pubertal children (5,12,22,23,26), plyometric training was always an additional load to the regular sport activity, raising the question of whether the improvement was a result of the new training regimen or only because of the additional training load. To the author's knowledge, it is unknown if a short-term plyometric program implemented as a substitute for some soccer drills within regular soccer practice in-season would enhance specific explosive actions of early pubertal players compared with soccer training alone. It was hypothesized that the combination of soccer drills and specific power training with no additional training time in-season would enhance explosive actions to a greater extent than soccer drills only.

Methods

Experimental Approach to the Problem

This study examined the ability of a short-term plyometric training program implemented as a substitute for some soccer drills within regular soccer practice to improve explosive actions compared to soccer practice only during the in-season. Two groups were formed from early pubertal male soccer players; 1 followed the modified soccer practice (training group, TG) and the other followed the regular soccer practice (control group, CG). All participants completed a battery of 6 tests before and after an 8-week period. Tests were related to different jump variables, initial acceleration, and agility, which were regarded as essential components to be successful in soccer (31). All participants attended 2 practices per week lasting for 90 minutes.

Subjects

All testing procedures and risks were fully explained, and both parents and participants were asked to provide their written consent prior to the start of the study. The study was approved by the Institutional Review Board for use of human subjects of the university. Fourteen soccer players belonging to the same team were enrolled as the TG and 11 soccer players from a different team were defined as the CG. All players had a 2- to 4-year background of systematic soccer training and competition experience and had just followed a 4-week pre-season training after 2 months of off-season training. Randomized assignment of participants was not possible because of practical limitations. However, both teams played in the same league and age group and trained twice a week for 90 minutes using the same soccer drills. The anthropometric characteristics of the participants are presented in Table 1.

Testing Procedures

Standardized tests of explosive actions were performed before and immediately after training under the same weather and field conditions. Testing sessions were scheduled >48 hours following a competition or hard physical training to minimize the influence of fatigue. Participants followed a familiarization session to reduce any learning effects. Prior to testing, each subject underwent a 15-minute progressive standard warm-up on the field. All tests were performed on the same day and supervised and recorded by the same investigators. Test order was the same on both testing occasions and the better score of 2 trials was recorded for further analysis. Two minutes of rest was accorded between each trial to reduce fatigue effects. While waiting, participants performed low-intensity activity to maintain physiological readiness for the next test.

Vertical Jump Tests. All vertical jump heights were calculated from flight time (3). Both flight time and contact time were measured with a jumping mat (Ergojump, Globus Italia, Codogne, Italy). Three different types of vertical jumps were performed to assess specific parameters of the performance: squat jump (SJ), countermovement jump (CMJ), and contact test (CT). For all jump assessments, participants were asked to keep their hands placed on their hips to eliminate arm swing and to ensure that the back remains upright to reduce angular displacement of the hip. Participants also had to leave the ground with the knees and ankles extended and land in the same position and location to minimize horizontal

Table 2. Results of squat jump (SJ) and countermovement jump (CMJ) (mean ± *SD*).

	Training group (*n* = 14)			Control group (*n* = 11)		
	Pre-T	Post-T	% Δ	Pre-T	Post-T	% Δ
SJ (cm)	30.1 ± 4.1	30.5 ± 3.2	+0.6	27.5 ± 3.7†	26.0 ± 3.6†	−4.5
CMJ (cm)	34.6 ± 4.4	37.2 ± 4.5*	+7.9	30.9 ± 3.1†	29.6 ± 1.9†	−3.8

Pre-T: pre-training; Post-T: post-training; % Δ: difference between Post-T and Pre-T (%).
*Significant difference from pre-test within the group.
†Significant difference between the 2 groups ($p < 0.05$).

displacement and influence on flight time. The SJ consisted of jumping vertically from a static squatting position with a knee angle of 120 degrees, assessing concentric power of the lower limbs. The CMJ test was comparable to SJ except that subjects started the jumps with a rapid downward movement (approximately 120-degree knee angle) to activate the slow stretch-shortening cycle (SSC ≥250 ms). The CT consisted of jumping over a 20-cm hurdle, and, on contact mat landing, immediately jumping as high as possible. The objective was to maximize the ratio between height and ground contact time (GCT), called reactive strength (40). These instructions required the participants to quickly reverse the downward motion of the body to an upward movement induced by a fast SSC (<250 ms) muscle action of the leg extensors. Such technique has previously been found to produce small knee flexion and short GCT (2). Jumping height after rebound and GCT were recorded for CT. Reactive strength was calculated as previously reported in the literature (40): Height (cm)/GCT (s).

Multiple 5 Bounds Test. The multiple 5 bounds test (MB5) was started from a standing position. The participants tried to cover the longest distance by performing a set of 5 forward jumps with alternative left- and right-leg contacts. Because of its specificity, especially for soccer players, the MB5 test is often used instead of the vertical jump as a measure of muscle power and coordination (12). The distance of the MB5 was measured to the nearest 0.5 cm using a tape measure.

10-m Sprint. Infrared photoelectric cells with polarizing filters and a handheld computer were used to measure sprint times to 1/100th of a second (Globus Italia, Codogne, Italy) and were placed at the start and at 10 m. The starting position was standardized for all participants. They started in a standing position (split stance) with the toe of the preferred foot forward 0.3 m behind the starting gate. This was intended to allow some forward lean and cause triggering of the timing system as soon as the subject moved. The photocells were set approximately 0.6 m above the floor, which was typically around hip level to capture the trunk movement rather than a false trigger from a limb. The participants were not permitted to use a "rolling" start, to eliminate momentum, and were instructed to sprint with maximum effort when they were ready. All sprints were performed with running shoes on a hard surface outside.

Agility Test. The agility test was performed on the field, with soccer shoes, and consisted of four 60-degree changes of direction over 10 m (Figure 1). The timing system and start procedure were the same as the 10-m sprint. Poles of approximately 1.5-m high were placed on the floor to indicate the change of direction. The participants were not allowed to touch the poles as they sprinted and changed direction. This test was selected because it required acceleration, deceleration, and balance control, which are facets of agility (34). Its relative simplicity minimized the role of learning effects.

Training Program

For a period of 8 weeks in-season, the TG performed various plyometric drills for 20 to 25 minutes as a substitute for some soccer drills within the usual 90-minute practice twice per week. All plyometric sessions were performed just after the warm-up to ensure that the players were in a rested state and gain optimal benefits from the specific program. Taking into consideration the stress of the plyometric training on the musculotendon unit, exercise intensity was progressively increased from a level classified as low to moderate, an appropriate intensity for children (1,8). Exercise intensity was determined as low to high with a scale of 1 to 5 (8), and exercise volume was determined by the number of ground contacts. The weekly load was calculated with the following formula: intensity × volume. The program was periodized in 2 progressive macrocyles of 3 weeks and 1 final progressive macrocyle of 2 weeks (Figure 2).

Plyometric drills included multiple jumps (ankle hop, vertical and lateral hurdle jump), horizontal and lateral bounding, skipping, and footwork (speed ladder). Each plyometric session was composed of 4 different exercises and 2 to 4 sets of 6 to 12 repetitions. All exercises were executed on the grass to reduce landing impact. Because most children did not have any history of plyometrics, particular attention was paid to demonstration and execution. Four basic techniques were stressed: (a) correct posture (i.e., spine erect, shoulders back) and body alignment (i.e., chest over knees) throughout the jump; (b) jumping straight up for vertical jumps, with no excessive side-to-side or forward-backward movement; (c) soft landings including toe-to-heel rocking and bent knees; and (d) instant recoil preparation for the next jump. Phrases such as "shock absorber" and "recoil like a spring" were used as verbal and visualization cues for each phase of the jump (20). Finally, some principles were respected for optimal benefits of the plyometric sessions. Every week, 1 session focused on vertical power (movement in a vertical direction) and the other on horizontal power (movement in a horizontal direction) with a minimum of 48 hours separating each session and games to ensure the players were always fresh to compete (8). All exercises were adapted to the coordination capacity of the children and performed at full speed. No drill lasted more than 10 seconds to ensure that muscular energy was mainly produced by intramuscular phosphagen degradation (28), and a 90-second rest period was given between each set of exercises to allow for resynthesis of phosphagens (29).

Statistical Analyses

All values are reported as mean ± standard deviation (*SD*). Two-way [time (before vs. after) × group (TG vs. CG)] repeated measures analysis of variance (ANOVA) tests were used to determine differences in jumping and sprint performance variables. Significance was located with Tukey test post-hoc analysis. Relationships between post-training variables of the TG were investigated with Pearson's product moment coefficient. The level of significance was set at $p < 0.05$.

Results

Subject Characteristics

Over the training period significant changes were observed in both groups in stature and body mass ($p < 0.001$).

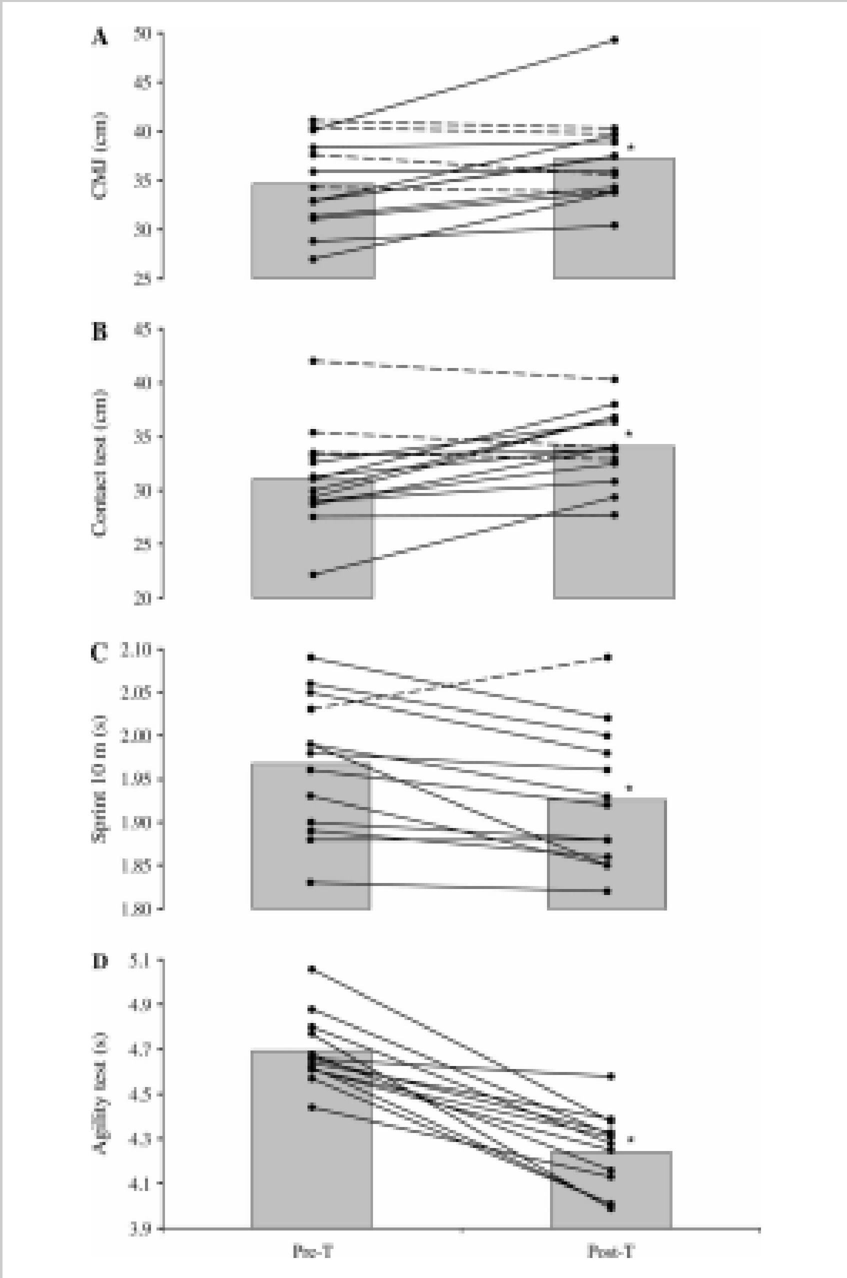

Figure 3. A, Absolute change in the countermovement jump (CMJ). B, Contact test (height after rebound). C, 10-m sprint. D, Agility test performance for the training group. Pre-T: pre-training; Post-T: post-training. *Significant difference from pre-training test within the group; dotted line: nonresponders to training; solid line: responders to training. $n = 14$ for A, B, and C; $n = 13$ for D.

Table 3. Results of contact test (CT) (mean ± *SD*).

	Training group (n = 14)			Control group (n = 11)		
	Pre-T	Post-T	% Δ	Pre-T	Post-T	% Δ
Height (cm)	31.1 ± 4.4	34.1 ± 3.4*	+10.9	29.0 ± 5.9	28.2 ± 3.6†	−0.9
GCT (ms)	243 ± 45	232 ± 40	−2.6	203 ± 39†	192 ± 34†	−3.5
RS (cm/s)	132 ± 28	152 ± 31	+17.6	148 ± 38	151 ± 30	+6.7

Pre-T: pre-training; Post-T: post-training; % Δ: difference between Post-T and Pre-T (%); GCT: ground contact time; RS: reactive strength.
*Significant difference from pre-test within the group.
†Significant difference between the 2 groups ($p < 0.05$).

No significant difference between the 2 groups was recorded before or after training (Table 1).

Jump Performance

Vertical Jump Tests. Changes in SJ and CMJ height are shown in Table 2. At baseline, jump heights in SJ and CMJ were significantly higher in the TG than in CG ($p < 0.05$). After the training period, TG demonstrated a significant increase of 7.9% in CMJ ($p = 0.004$), whereas the change in performance of the CG in this test remained nonsignificant ($p = 0.15$). Figure 3A shows responders and nonresponders to training and mean scores of CMJ performance for the TG (10 responders vs. 4 nonresponders). No significant modification in SJ performance was recorded in any of the groups ($p > 0.05$).

Table 3 illustrates the changes in CT variables. At baseline and post-training, GCT of CT was lower in CG than in TG ($p < 0.05$). The plyometric training followed by the TG had a beneficial impact on fast SSC movement of the lower limbs because jumping height after rebound increased by 10.9% ($p = 0.01$) Figure 3B shows responders and nonresponders to training and mean scores of jump height after rebound for the TG (11 responders vs. 3 nonresponders). However, no significant influence was observed on GCT ($p > 0.05$), resulting in a nonsignificant change in reactive strength ($p > 0.05$). The CG exhibited no significant changes in any of the CT variables ($p > 0.05$).

Multiple 5 Bounds Test. The intervention had no impact on 5 rebound jumps in either group (TG: 9.9 ± 0.9 to 10.3 ± 0.6 m; CG: 9.3 ± 1.0 to 9.6 ± 0.6 m; $p > 0.05$). Still, a significant difference between CG and TG was observed ($p = 0.007$) after training, induced by a 4% increase in this test for the TG ($p = 0.06$). In addition, 5MB performance and reactive strength were positively correlated ($r = 0.66$; $p < 0.01$).

Sprint Performance

10-m Sprint. At baseline, the TG was significantly faster than the CG in the 10-m sprint ($p = 0.02$). Training led to a significant decrease of 2.1% (1.96 ± 0.07 to 1.92 ± 0.07 seconds; $p = 0.004$) in sprint time for the TG, whereas no significant alteration of the CG performance was recorded (2.06 ± 0.12 to 2.01 ± 0.07 seconds; $p = 0.15$). Figure 3C shows responders and nonresponders to training and mean scores of 10-m sprint time for the TG (12 responders vs. 2 nonresponders). After the training period, a significant relationship between CMJ performance and 10-m sprint time was found ($r = -0.67$; $p = 0.007$) (Figure 4).

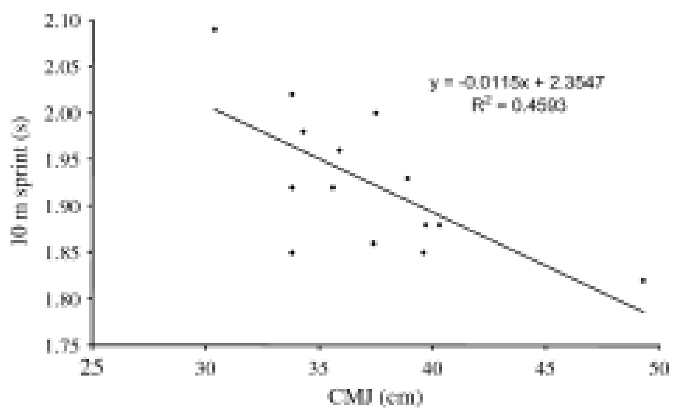

Figure 4. Correlation between 10-m sprint and countermovement jump (CMJ) from post-training values of the training group (n = 14) ($p < 0.01$).

Agility Test. The training program had a beneficial impact on agility of the TG, resulting in a significant decrease of 9.6% (4.69 ± 0.16 to 4.24 ± 0.17 seconds; $p < 0.001$) in the agility test time for the TG. In contrast, agility test time significantly increased by 2.8% in the CG (4.58 ± 0.22 to 4.70 ± 0.25 seconds; $p = 0.03$). Figure 3D shows responders and nonresponders to training and mean scores of agility test time for the TG (13 responders vs. 0 nonresponders).

Discussion

The current study indicated that 8 weeks of plyometric training within soccer practice induced positive effects on explosive actions of early pubertal soccer players. Significant improvements were observed in 10-m sprint, agility test, jump height (CMJ), and jump height after rebound (CT). Figure 3 highlights these results, showing that in most cases not only mean group improvement occurred, but also individual improvement (responders vs. nonresponders). No significant changes in any test variables were observed in the CG, demonstrating the importance of specific power training to enhance explosive actions of soccer players. In addition, because baseline data showed a significant difference between the 2 groups in CMJ and 10-m sprint, the window for improvement in these variables was smaller for the TG. Still, the TG demonstrated a statistically significant performance improvement in these 2 tests, in contrast to the CG. This observation reinforces the value of an independent power training program to enhance explosive actions of soccer players. Such improvement could have a positive influence on game performance because the ability to win challenges and score goals is related to this type of physical demand.

The 10-m sprint (initial acceleration) and agility test had the particularity to assess the specific sprint ability of early pubertal soccer players. To the authors' knowledge, no study has looked at the relevance of a plyometric program incorporated within regular soccer practice, in either an adult or children's population, to improve these qualities. Because an earlier study (25) demonstrated that agility and acceleration are independent qualities in soccer, it was necessary to assess them with specific testing. Both initial acceleration and agility have been found to be powerful discriminators between elite junior players and regional junior players and therefore should be used as descriptive tests for soccer performance (31). The distance of 10 m appeared to be the most relevant to assess the specific quality of acceleration in soccer because of the high frequency of short, high-intensity sprints during a game (6). A significant decrease in 10-m sprint time (−2.1%) in the TG demonstrated the efficiency of a plyometric program to improve specific explosive actions of young soccer players. The percentage of change in performance after a training period in the current study is in accordance with previous findings on initial acceleration in children (7,23). However, none of the aforementioned studies have reported significant improvement.

Initial acceleration has been shown to be more difficult to enhance than maximal velocity, probably because of the smaller margin for improvement and the different forces involved (7,23). Therefore, even if the improvement in the current study was small, it offers insight on the possibility for greater improvements over a longer training period that should increase the capacity to win challenges in game situations. Several studies (10,27,39) were designed to determine the important factors for short-distance sprints. Murphy et al. (27) reported that GCT was the biggest discriminator between fast and slow sprinters at more than 15 m. The current study did not find any significant change in GCT after a vertical preload (CT), but change in GCT during acceleration could have occurred. Further studies should use force-plate or video analysis to determine possible decreases in GCT after plyometric training. Others (10,39) found a relationship between CMJ and the 10-m sprint. These results were confirmed by the present study (Figure 4) and can be explained by the specificity of the acceleration phase where the center of mass is lower and GCT is longer when compared to the maximal velocity phase, resulting in a slow SSC of the muscle in similar motion to CMJ. This relationship verified the validity of an acyclic vertical jump to predict field performance and the role of vertical velocity and forces during initial acceleration.

The agility test was selected for its short duration (4 to 5 seconds) and its ability to test different qualities than the straight sprint (40). Previous studies in early and pubertal soccer players (7,22,31) used different agility tests, lasting from 7 (31) to 19 seconds (7), over a distance of 40 (22,31) to 50 m (7). These large differences in test selection did not allow comparison with the current study. The goal of the present study was to remain specific to the explosive bouts encountered during a soccer game. For this reason, the agility test was short (10 m) with multiple changes of direction. The significant change in agility time performance (−9.6%) demonstrated that a plyometric program can have a positive influence on a field test similar to game play and therefore may have an impact on true soccer performance. The plyometric drills selected contained many powerful lateral movements, which had an impact on the capacity to change direction faster. In addition, the plyometric training program may have improved the eccentric strength of the lower limb, a prevalent component in changes of direction during the deceleration phase (34).

The plyometric program was also effective in significantly increasing jump height of CMJ (+7.9%) and CT (+10.9%) but not SJ (+0.6%). The lack of improvement in the SJ performance can be explained by the study design. The plyometric training exclusively stressed the SSC of the muscles; consequently, pure concentric contraction, assessed by the SJ, was not stimulated during training. Previous studies (12) investigating plyometric training in children have reported the same tendency of stronger improvement in jump tests involving SSC, compared to pure concentric jump tests. In contrast, resistance training, involving minimal SSC of the muscle, has been shown to be more effective in improving SJ performance as compared to CMJ (7,24). Therefore, the training mode must be chosen carefully in regard to the field performance targeted. Because explosive actions in soccer mainly require muscular contractions involving the SSC, the current study did focus on improving such quality. The significant improvement in jump height in CMJ and CT tests confirms the effectiveness of the application of plyometric training in achieving this goal, which may improve game performance. Post-training CMJ performance results by the TG are in accordance with previous results reported in the literature after a plyometric training followed by children (12). In addition, the current results of the CMJ after the plyometric training program also appear to be greater than mixed training methods composed of resistance training and plyometric training followed by children despite a greater training load (22).

Improvement in the fast SSC (<250 ms) capacity of the muscle (32) after the plyometric training was assessed with the CT. Jump height was smaller in the CT compared to CMJ as a result of the requirement to reduce ground contact time (2), but a larger improvement was observed (+10.9%). Such results demonstrated that the plyometric program was more efficient in improving fast SSC capacity of the muscle (<250 ms) with small angular displacement, as compared to slow SSC (>250 ms in CMJ), probably because the movement pattern of the training program was similar to the CT. To the authors' knowledge, the present study is the first to report a significant change in a preloaded jump after a training program of any kind in children. The increased powerful concentric force after the SSC could have been induced by various neuromuscular adaptations involved during the stretch reflex and the storage of elastic energy in the SSC of the muscle: greater muscle stiffness at ground contact resulting in a fast recoil of the muscle (33) and subsequent better use of the elastic energy (4); greater muscle activity as a result of an earlier activation of the stretch reflex (4); and desensitization of the Golgi tendon organs, allowing the elastic component of muscles to undergo greater stretch (21). Because no physiological measurements (e.g. electromyography, motor units activation, muscle stiffness) were taken in the current study, the underlying adaptations induced by the plyometric training remain hypothetical. If such adaptations may enhance jump capacity, they had no significant influence on GCT (−2.3%) of CT. GCT was already below 250 ms (fast SSC) (32); therefore, the margin for improvement was small and an 8-week period was probably insufficient to influence this variable.

The ratio between jump height and GCT of the CT, referred as reactive strength, was calculated because it has been reported to be a predictor of running ability (e.g., sprinting, changes of direction) (40). No significant improvement was observed in this variable (+17.6%) in the TG, which can be explained by the lack of improvement in GCT. However, a significant relationship was found between the reactive strength and MB5 ($r = 0.66$), giving insight to the role of reactive strength in multiple SSC movement, such as maximal running velocity.

Some methodological limitations exist in the current study and need to be addressed. First, the subjects were defined as early pubertal, yet their biological maturation was not assessed. The maturation of the participants can vary considerably when the participants are 12 to 14 years old, which may affect neuromuscular adaptations and athletic performance. Therefore, it would be of interest to report the maturation level of the children and investigate if different neuromuscular adaptations and athletic performance occur after plyometric training depending on their maturation level. Second, the current study did not quantify the neuromuscular changes after plyometric training and no ground reaction force measurements were collected during the jump, sprint, or agility performance. Such methods should be used in further studies to provide a better understanding of the adaptations induced by plyometric training in child populations. Third, no methods were undertaken to determine whether the plyometric training program had a true effect on game play. Only speculation can be made that greater performance in descriptive tests will result in superior match-play performance, as suggested by others (37).

Practical Applications

The practical implication of the current research would be that plyometric training combined with soccer training leads to greater improvements in numerous explosive actions than soccer training alone. Soccer-related athletic abilities such as vertical jumps involving SSC movement (CMJ, CT), acceleration, and agility performance significantly improved in the training group only. Such improvements can be beneficial to winning challenges and could be transferred into game-play performance. The training stimulus was not suitable to improve pure concentric movement (SJ) and predictive measures of field performance (5MB, reactive strength); therefore, strength and conditioning coaches must be aware of the specificity of plyometric training. Besides enhancing explosive actions of young soccer players, plyometric drills demonstrate the following advantages: simulation of explosive sport movements on the field, adaptability to a specific population, integration within practice, and inexpensive equipment requirements compared to a weight room. No training-related injuries were reported; however, coaches should consider progressive increases in the load and ensure exercises are performed on soft landing surfaces, reducing the probability of player injury. To improve the quality of every session, small technical drills activity between sets should be implemented to maintain awareness and discipline among the children who may become impatient when they have to remain inactive. Because there are noticeable athletic differences among children in this age group, it could also be worthwhile to set up 2 different levels of the same exercise to increase the personalization of the training program.

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ARTÍCULO 3

Original Article

Effect of plyometric training on athletic performance in preadolescent soccer players

YIANNIS MICHALIDIS

Department of physical Education and Sport Science, Democritus University of Thrace, Komotini, Greece

ABSTRACT

Michailidis, Y. (2015). Effect of plyometric training on athletic performance in preadolescent soccer players. *J. Hum. Sport Exerc.*, 10(1), pp.15-23. The aim of this study was to investigate the effectiveness of plyometric training on performance of preadolescent soccer players. 21 players assigned to two groups: jumping-group (JG, n = 11) and control-group (CG, n = 10). Training program was performed for 10 weeks. Anaerobic power performances were assessed by using standing long jump (SLJ), 10 m and 30 m sprint. In the JG the performance at the long jump was increased significantly (P = 0.031). Also the performance of JG increased at 30m sprint running by 7.2 % (P < 0.001). None of the variables tested in the CG demonstrated difference between the pre-test and the post-test. Our results indicate that plyometric training can improve running performance at 30 m sprint and the performance at standing long jump in preadolescent soccer players. Key words: PLYOMETRIC, JUMP, SPRINT, PERFORMANCE, PREADOLESCENT.

Corresponding author. Department of Physical Education and Sports Sciences, University Campus, 69100, Komotini, Greece. Tel +30-2229062570, Fax +30-2229062570.
E-mail: michailidis79@hotmail.com
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INTRODUCTION

Today the soccer is becoming more dynamic and the power has become an important aspect of condition for soccer players of all ages. If we take a look at typical movement sequences in soccer (abrupt stops and changes of direction, quick sprints, ball kicking and explosive shots) makes it clear that depend on the stretch-shortening cycle (SSC) characteristics of the involved muscles (Manolopoulos et al., 2004). Such actions generate explosive release and impact in a repetitive manner use the SSC and require rapid force production and high power output.

Plyometrics exercises are suitable for improving various measures and components of muscle power such as vertical jumping ability, speed and acceleration (Fatouros et al., 2000; Gheri et al., 1998). Despite the hundreds of human studies that investigated the effects of this kind of exercises on vertical jumping performance and running velocity, the vast majority of them have performed to adults (Fatouros et al., 2012; Ford et al., 1983). Few studies have accomplished to prepubertal boys (Kotzamanidis, 2006; Lehance et al., 2006). The relevant studies have reported that plyometric exercises improve jumping power and running velocities (Fatouros et al., 2012; Young et al., 1999).

The aim of the present study was to investigate the influence of short-term plyometric training on running velocity and horizontal jumping ability in a small sample of preadolescent boys.

MATERIAL AND METHODS

Participants

Thirty two healthy preadolescent male soccer players volunteered to participate in this study. From those eleven boys were excluded because they exceeded the stages of puberty development according to Tanner scale (first stage). Twenty one soccer players participated. All the subjects were members to the same team, participating in no more than 4 times per week in soccer training (3 trainings and 1 game). The subjects were randomly assigned to a training group (jump group, JG n = 11) or a control group (CG, n = 10). All the subjects were of prepubertal status according to Tanner's (1962) criteria. A written informed consent to participate in the study was provided by all participants and their parents after they were informed of all risks, discomforts and benefits involved in the study. Also the study complies with the ethical recommendations of the declaration of Helsinki.

Procedure

For three weeks before the tests, the team performed a program to protect players from injuries (Faigenbaum et al., 2009; Fry et al., 1991). The program included strength, flexibility and endurance exercises. Also in this period the players familiarized with the tests which accomplished in an indoor sport hall.

Sprint testing

Running performance evaluated with a 30m sprint running. Subjects performed 2 maximal efforts with a 3 minutes interval between trials. For analyses we use the best try. We use 3 pairs of opto-reflective switches (Tag Heuer) that were located at the start and at the end of 30m sprint and also at 10m after the beginning. This system was connected with an electronic chronometer (Omega System) to record the time.

Jump test
The participants performed a standing long jump. They stand behind a line marked on the ground with feet slightly apart. A two foot take-off and landing is used, with swinging of the arms and bending of the knees to provide forward drive. The subjects attempt to jump as far as possible, landing on both feet without falling backwards. The measurement used was the longest of three tries.

Training Program
The duration of the program was 10 weeks and included jumping and running exercises. More specific the subjects performed jumps with two legs and one leg and skipping exercises. Regular soccer practice was performed 3 times per week and induced execution of soccer technical skills, tactics, speed work, and pick-up games. Plyometric training was performed twice a week during the first and third soccer practice each week. The initial number of jumps per session was 60 (without skipping exercises) and gradually increased to 120 jumps at the end of the training period (Table 1).

Table 1. Total sum of jumps and meters of skipping exercises per training session

Week	Exercise	Direction	Sets	Repetitions/meters
1st	jumps between lines with 2 legs	Forward	5	10
	20 cm hurdle hops	Forward	2	5
	skipping	Forward	3	10 m
2nd	jumps between lines with 2 legs	Forward	6	10
	20 cm hurdle hops	Diagonal	2	5
	skipping	Forward	3	10 m
3rd	jumps between lines with 2 legs	Forward	7	5
	skipping	Forward	3	10 m
4th	jumps between lines with 1 leg	Forward	6	10
	20 cm hurdle hops	Lateral	3	5
	skipping	Forward	5	10 m
5th	jumps between lines with 2 legs	Forward	8	10
	skipping	Forward	2	10 m
6th	jumps between lines with 1 leg	Forward	7	10
	30 cm hurdle hops	Diagonal	3	5
	skipping	Forward	3	10 m
7th	jumps between lines with 2 legs	Forward	8	10
	40 cm hurdle hops	Forward	2	5
	skipping	Forward	3	10 m
8th	jumps between lines with 1 leg	Forward	9	10
	skipping	Forward	3	10 m
9th	jumps between lines with 2 legs	Forward	11	10
	40 cm hurdle hops	Forward	2	5
	skipping	Forward	2	10 m
10th	jumps between lines with 2 legs	Forward	11	10
	20 cm hurdle hops	Lateral	3	5
	skipping	Forward	2	10 m

Statistical Analyses
Data analysed by a two-way repeated measures (trial × time) ANOVA. If a significant interaction was obtained, pair wise comparisons were performed through simple contrasts and simple main effects

analysis. The level of significance was set at α = 0.05. The SPSS version 13.0 was used for all analyses (SPSS Inc., Chicago, IL). Data are presented as mean ± SD.

RESULTS

Before training all baseline anthropometric characteristics were similar between JG and CG (Table 2). Training did not affect the participants' anthropometric profile (P = 0.08). In the JG the performance at the long jump was increased by 5.63% (P = 0.031) whereas for CG no significant changes were observed (P = 0.076) (Figure 1). At posttraining sprint time demonstrated a decline in JG only but was not significant (P = 0.063) (Figure 2). In the JG the performance at 30 m was increased by 7.2% (P < 0.001). In contrast the performance of the CG no changed (P = 0.061) (Figure 3). Significant differences observed between the two groups (JG and CG) in long jump (P = 0.026) and at 30m sprint (P = 0.034) (Figures 1 and 3). In the JG the changes in long jump correlated significant with the changes in the 10 and 30m sprints (P = 0.003, r = 0.615, P = 0.016, r = 0.517 respectively).

Table 2. Participants' physical characteristics and training age

	CG (n = 10)		JG (n = 11)	
	Pretraining	Posttraining	Pretraining	Posttraining
Age (y)	11.3 ± 0.6	11.5 ± 0.6	11.4 ± 0.6	11.6 ± 0.6
Height (cm)	147 ± 6	148 ±7	146 ± 7	148 ± 7
Weight (kg)	42.3 ± 7.1	43.5 ± 6.6	43.2 ± 5.2	43.8 ± 5.5
Training age (y)	3.8 ± 0.5		3.7 ± 0.8	

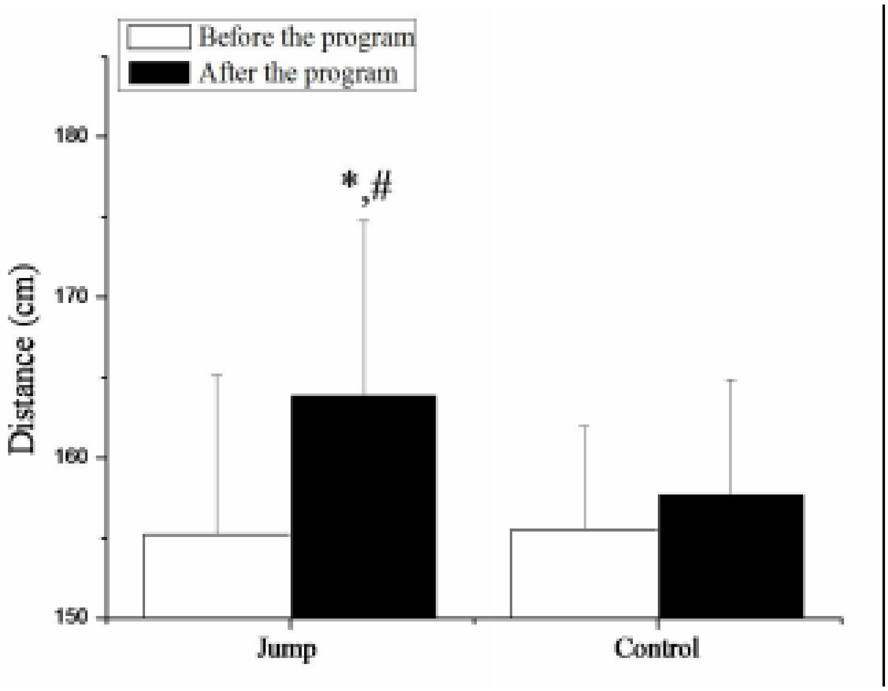

Figure 1. Changes in jump performance. * Denotes significant (P < 0.05) difference with baseline values; # denotes significant (P < 0.05) differences between groups

DISCUSSION

Training with plyometrics has been extensively used for augmenting jumping performance in healthy individuals. This kind of exercise improves different type of jumps like squat jump (SJ), counter movement jump (CMJ), depth jump (DJ), long jump (LJ) (Kubo et al., 2007; Saunders et al., 2006). In some cases observed lack of adaptations that may be related to the nature of the selected exercises for plyometric training (Sale, 1992).

In our study we measure standing long jump. From the literature for horizontal jumping performance it's observable that plyometrics increase performance in both athletes (Paavolainen et al., 1999; Spurrs et al., 2003) and non-athletes (Markovic et al., 2007). Few studies examined this issue to children and the most of them found enhancement of jumping ability (Diallo et al., 2001; Lehance et al., 2006; Michailidis et al., 2013). Our findings are to accordance with those of Diallo et al. (2001), Kotzamanidis (2006) and Lehance et al. (2006). They found that the performance at some kinds of jump (squat jump, standing long jump and at counter movement jump) improved significantly.

A lot of movements in soccer include jumping, hopping and bounding that characterized by the use of the stretch-shortening cycle (SSC) that develops during the transition from a rapid eccentric muscle contraction to a rapid concentric muscle contraction (Markovic et al., 2007; Markovic & Mikulic, 2010). The improvement in speed performance after plyometric training has been attributed to an improvement in ground contact time and muscle tendon stiffness (Mero et al., 1991; Meylan & Malatesta, 2009; Rimmer & Sleivert, 2000). Improvements in sprint performance mentioned in literature (Dodd & Alvar, 2007; Lehance et al., 2005; Markovic et al., 2007; Michailidis et al., 2013; Paavolainen et al., 1999; Rimmer & Sleivert, 2000; Robinson et al., 2004; Tricoli et al., 2005; Wagner & Kocak, 1997; Wilson et al., 1996). On the other hand we have to mention that slight decreases in sprint performance following plyometrics have also been observed (Chimera et al., 2004; Dodd & Alvar, 2007; Herrero et al., 2006; Hortobagyi et al., 1991).

In our study we found that the program improves the running velocity (0-30m) in preadolescents. However Meylan and Malatesta, and Ingle et al. reported a marked reduction of the initial acceleration time and maximal velocity phase of soccer players during early puberty. Kotzamanidis after a training program with plyometrics (10 weeks duration) found that in JG the velocity for the running distances 0-30, 10-20 and 20-30 m increased but not for the distance 0-10 m. In another study, Diallo et al., (2001) investigate the effectiveness of plyometric training on physical performances in prepubescent soccer players. Some of the findings showed that the performances at 20 m running velocity increased at JG. Also our results were in line with the findings of Lehance et al. (2006) and Michailidis et al. (2013). These researchers found that strength and plyometric exercises can improve the ability of sprint in preadolescent soccer players.

A possible explanation for running velocity enhancement at 0-30m and for jumping ability improvement is the increase of force and power of the athletes. Also strength development is associated with a variety of neuromuscular factors (Markovic & Mikulic, 2010) and does not solely depend on muscular mass. At stretch-shortening cycle muscle function, a pre-stretch enhances the maximum force and work output that muscles can produce during the concentric phase. This is the ability that plyometric exercises can improve.

In the present study we observed that a correlation between the performance at long jump and sprint running to preadolescent boys.

This study has some limitations. We use only Tanner scale to estimate the stage of puberty. It is more accurate if you can use extra the bone age and testosterone values. Also for jumping ability we use only the studying long jump test and we did not execute any test for vertical jumping ability.

CONCLUSIONS

In the literature we present studies that examined the influence of training methods (like strength and endurance) to physical performance in young soccer players (Christou et al., 2006). However the plyometric exercises believed that were dangerous and may cause injuries to bones' growth plates that may result in leg-length discrepancy (Faigenbaum & Yap, 2000; Witzke & Snow, 2000) and its association with muscle and tendon damage (Jamurtas et al., 2000; Tofas et al., 2008) which is accompanied by a marked inflammatory response (Chatzinikolaou et al., 2010). So the coaches avoided to perform this kind of exercises. Recent studies prove that if we choose the right exercises we can improve the performance (running velocity and standing long jump) of young soccer players without health risks.

However we have to investigate the influence of different training methods to physical performance of children.

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Artículo 4

Plyometrics' Trainability in Preadolescent Soccer Athletes

Yiannis Michailidis,[1] Ioannis G. Fatouros,[1] Eleni Primpa,[1] Charalampos Michailidis,[2] Alexandra Avloniti,[1] Athanasios Chatzinikolaou,[1] José C. Barbero-Álvarez,[3] Dimitrios Tsoukas,[4] Ioannis I. Douroudos,[1] Dimitrios Draganidis,[1] Diamanda Leontsini,[1] Konstantinos Margonis,[1] Fani Berberidou,[1] and Antonios Kambas[1]

[1]Department of Physical Education and Sport Sciences, Democritus University of Thrace, Komotini, Greece; [2]Department of Physical Education and Sport Sciences, Aristotle University of Thessaloniki, Thessaloniki, Greece; [3]Department of Physical Education and Sport, University of Granada, Campus of Melilla, Spain; and [4]Medical School, Department of Toxicology, University of Athens, Athens, Greece

Abstract

Michailidis, Y, Fatouros, IG, Primpa, E, Michailidis, C, Avloniti, A, Chatzinikolaou, A, Barbero-Álvarez, JC, Tsoukas, D, Douroudos, II, Draganidis, D, Leontsini, D, Margonis, K, Berberidou, F, and Kambas, A. Plyometrics' trainability in preadolescent soccer athletes. *J Strength Cond Res* 27(1): 38–49, 2013—Plyometric training (PT) is a widely used method to improve muscle ability to generate explosive power. This study aimed to determine whether preadolescent boys exhibit plyometric trainability or not. Forty-five children were randomly assigned to either a control (CG, $N = 21$, 10.6 ± 0.5 years; participated only in regular soccer practice) or a plyometric training group (PTG, $N = 24$, 10.6 ± 0.6 years; participated in regular soccer practice plus a plyometric exercise protocol). Both groups trained for 12 weeks during the in-season period. The PT exercises (forward hopping, lateral hopping, shuffles, skipping, ladder drills, skipping, box jumps, low-intensity depth jumps) were performed twice a week. Preadolescence was verified by measuring Tanner stages, bone age, and serum testosterone. Speed (0–10, 10–20, 20–30 m), leg muscle power (static jumping, countermovement jumping, depth jumping [DJ], standing long jump [SLJ], multiple 5-bound hopping [MB5]), leg strength (10 repetition maximum), anaerobic power (Wingate testing), and soccer-specific performance (agility, kicking distance) were measured at baseline, midtraining, and posttraining. The CG caused only a modest (1.2–1.8%) increase in speed posttraining. The PTG induced a marked ($p < 0.05$) improvement in all speed tests (1.9–3.1% at midtraining and 3–5% at posttraining) and vertical jump tests (10–18.5% at midtraining and 16–23% at posttraining), SLJ (2.6% at midtraining and 4.2% at posttraining), MB5 (14.6% at midtraining and 23% at posttraining), leg strength (15% at midtraining and 28% at posttraining), agility (5% at midtraining and 23% at posttraining), and kicking distance (13.6% at midtraining and 22.5% at posttraining). Anaerobic power remained unaffected in both groups. These data indicate that (a) prepubertal boys exhibit considerable plyometric trainability, and (b) when soccer practice is supplemented with a PT protocol, it leads to greater performance gains.

Key Words plyometric training, power performance, childhood, football

Introduction

Lower-limb plyometric exercises, that is, jumping, hopping, and bounding, are characterized by the use of the stretch-shortening cycle (SSC) that develops during the transition from a rapid eccentric muscle contraction (deceleration or negative phase) to a rapid concentric muscle contraction (acceleration or positive phase) (37,38). The SSC exercises capitalize on the elastic properties of connective tissue and muscle fibers by allowing the muscle to store elastic energy during the deceleration-negative phase and release it later during the acceleration-positive phase to enhance muscle force and power output (23,38). Systematic lower-limb plyometric training (PT) has been shown to improve consistently various measures and components of muscle power such as vertical jumping ability (19,20,31), speed and acceleration (33,52), maximal and explosive strength (19,26,55), agility (64), and sport-specific performance (57).

Soccer, as a typical intermittent-type sport, incorporates various explosive ballistic motions such as sprinting, kicking, jumping, accelerations and decelerations, tackling, changes of direction, and turning (5). Ball kicking, one of the most fundamental soccer skill, relies on the use of SSC because ball speed depends on the SSC characteristics of the involved

Address correspondence to Ioannis G. Fatouros, ifatouro@phyed.duth.gr.

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muscles (36). Such actions generate explosive release and impact in a repetitive manner, use the SSC, and require rapid force production and high power output. According to Reilly (51), "although time spent performing these explosive actions represent only a small percentage of a match's total time, yet these actions discriminate between a successful and an unsuccessful performance." Therefore, these qualities need to be trained independently with an optimal training routine (25). It appears that PT not only improves these qualities (19,23,53), but it has also been recommended for players' familiarization with unanticipated changes in direction similar to those used during a soccer match (6).

Despite its well-established effectiveness in adults, plyometrics' efficacy for power training of adolescent athletes, as a part of a general strength and physical conditioning training program, remained questionable until recently. Furthermore, high-impact plyometrics (i.e., depth jumping) may be contraindicated for training of adolescent athletes because of their high inherent risk of injury to bones' growth plates that may result in leg-length discrepancy (18,67) and its association with muscle and tendon damage (30,65), which is accompanied by a marked inflammatory response (11). According to the guideline that athletes who wish to participate in high-impact PT should be able to squat at least 1.5 times their body weight would prevent most adolescent athletes from participation (3). However, recent studies have shown that low- and high-impact plyometrics performed once or twice per week in combination with resistance training may be both safe and effective in various sport activities including soccer (14,17,29,42,50,54,64). Although, a number of studies examined plyometric efficacy in adolescent athletes, there is very limited information for the pediatric population. One study that used PT with preadolescents (10.9 years) reported a marked increase in speed and jumping ability (32). However, that study involved only children that were not involved systematically in training, investigated only a limited number of power variables, and its training regimen included only jump exercises. Therefore, uncertainty exists whether a traditional or a modified PT program would be either safe or effective during preadolescence during which children exhibit a rapid growth and maturation rate.

Plyometric exercises incorporate movements similar to those encountered in children's playing activities that do not require a minimum amount of strength level. Although there are a very large number of children engaged in systematic soccer activity, most of them at a competitive level, there is no information regarding the efficacy of PT on children's physical abilities and soccer-related performance. Evidence from studies with pubertal boys from other sports such as basketball suggests that in-season PT may be beneficial for maintenance or enhancement of athletic performance when they are combined with resistance training and sport-specific training (9,39). To the author's knowledge, it is unknown whether a PT program implemented in combination with regular in-season soccer-specific practice (as compared with soccer training alone) would improve athletic ability and soccer-related performance of preadolescent soccer players. In other words, would preadolescent athletes benefit from a systematic in-season PT protocol as a part of their traditional training plan? And if so, to what extent? Therefore, the aim of this study was to investigate whether the combination of soccer practice and PT would enhance athletic ability and soccer-specific performance at a greater extent than soccer practice alone in prepubertal soccer players.

Methods

Experimental Approach to the Problem

The goal of this study was to determine whether a combination of traditional in-season soccer training and PT is more effective than traditional soccer practice alone (independent variables) in improving power-related performance and soccer-specific performance (dependent variables) of preadolescent soccer players and at what extent (measurement of dependent variables were performed at baseline, midtraining, and posttraining over a 12-week period) by using a randomized, 2-group, repeated measures experimental design. For this reason, prepubertal boys playing for a local soccer club were randomly assigned to either a control group (CG, $N = 21$) that involved only the usual soccer practice or a plyometric training group (PTG, $N = 24$) that involved a PT protocol that was integrated in club's regular in-season soccer practice. Plyometric exercises in PTG were performed as a substitute for some soccer-specific drills to obtain the same duration of each training session as in CG. During their first visit, the participants had their body mass and height, tibia length, arm span, percent body fat, puberty stages (Tanner scale), and maximal oxygen consumption ($\dot{V}O_2max$) measured and underwent a hand wrist x-ray to determine their bone age. During their next 5 visits, the participants in PTG were taught and familiarized with plyometric exercises that were included in the training protocol while all the participants were familiarized with testing procedures. During their sixth visit, the participants had their jumping ability (testing of static long jump, multiple 5-bounds, static jump [SJ], countermovement jump [CMJ], and drop jump [DJ]), leg strength (10 repetition maximum [RM] in squat), speed (30-m sprint), and soccer-related performance (kicking distance and agility testing) measured. Initial testing, medical examination, and familiarization with plyometric exercises were performed within a 2-week period before the commencement of participants' in-season period. Testing was repeated after 6 (midtraining; MID) and 12 (posttraining; POST) weeks of training. Measurement of performance variables was performed 48 hours after the last training session of the 6th and 12th weeks and was completed in 2 days time (jump and speed testing on the first day, strength and soccer-related testing on the second day). Testing was preceded by a 15-minute warm-up session, and it was followed by a 10-minute cool-down period. During training, all the participants competed in 6 matches and received the same soccer training stimuli. All training sessions and measurements were conducted at the same day and time and under exactly the same conditions. The participants were instructed to follow the same diet pattern before testing. The participants consumed water ad libitum to ensure proper hydration during training and testing.

Subjects

Forty-five healthy preadolescent male soccer players volunteered to participate in this study. All the participants were involved in organized youth soccer training for at least 3 years (3–4 practices weekly) before the study. None of the participants had any prior experience of PT. Parents or guardians of 78 boys were approached. From those, 68 consented to the participation of their children in the study. Nine boys were excluded because of limited compliance to the experimental protocol, whereas 14 others were excluded because they exceeded the required cut-off value for bone age, prepubertal testosterone values, and stages of puberty development according to Tanner scale (first stage). All training and testing procedures and any possible risks and discomforts were fully explained in detail to both parents and guardians and participants before the start of the study. A written informed consent for participation in the study was provided by all parents and guardians of the participants. The local Institutional Review Board approved the study. Participants' characteristics are shown in Table 1.

Procedures

Plyometric Training Protocol. The participants in both groups trained for 12 consecutive weeks. A standardized warm-up protocol consisting of running, calisthenics, and stretching, was performed before each training session. Both groups participated in regular soccer practice throughout the study, but only the PTG performed the PT protocol. Regular soccer practice was performed 3 times per week and included execution of soccer technical skills (dribbling, passing, tackling and defense, ball handling, heading), tactics, speed work, and pick-up games (practice contents were identical for the 2 groups each time). Plyometric training (20–25 minutes per session) was performed twice a week, 72 hours apart, during the first and third soccer practice each week totaling 70–90 minutes of practice time. Plyometric training preceded soccer practice (immediately after warm-up) to ensure full neuromuscular activation and included numerous types of jumps, hops, skips, and footwork. The first PT phase or macrocycle (6 weeks) consisted of single- and double-leg forward hops over hurdles, lateral hops over hurdles, and lateral shuffles over a box, skipping, and footwork (ladder drills). The second PT macrocycle (6 weeks) consisted of footwork, skipping, single- and double-leg box jumps and relatively low-intensity depth jumps. Each PT practice consisted of 4 exercises performed in 2–4 sets (separated by 90- to 180-second rest intervals) of 5–10 repetitions per set. To limit stress on the musculotendon unit during the execution of plyometric drills, intensity was progressively increased from a low to moderate level, as previously suggested for children (1). The intensity of plyometric drills was determined by the classification model of plyometric exercise intensities as previously described (12,49). The height of depth jumps (performed with both legs) was initially set at 10 and 20 cm and progressively increased to 30 cm (32). Plyometric training included a total number of 60 jumps per session during the first macrocycle and gradually increased to 120 jumps per session toward the end of training. Plyometric drills were performed on the grass of the soccer field to reduce landing stress. Plyometric exercises were adjusted according to participants' coordination level and were executed at maximal intensity. Use of proper technique was emphasized during every practice through the use of verbal cues, demonstrations by the researchers, and graphic illustrations of exercises.

Table 1. Participants' physical characteristics and training age.*†

	CG (n = 21)		PTG (n = 24)	
	Pretraining	Posttraining	Pretraining	Posttraining
Age (y)	10.6 ± 0.5	10.8 ± 0.6	10.7 ± 0.7	10.9 ± 0.7
Height (cm)	145 ± 7.3	148 ± 6.8	147 ± 8.6	150 ± 7.0
Weight (kg)	41.7 ± 6.4	43.4 ± 6.9	42.5 ± 7.2	44.2 ± 7.5
Arm span (m)	1.54 ± 0.2	1.55 ± 0.2	1.53 ± 0.1	1.53 ± 0.2
Body fat (%)	13.8 ± 2.1	13.6 ± 2.3	14.2 ± 2.1	14.0 ± 1.7
Bone age (y)	10.9 ± 1.4	10.7 ± 1.7	11.0 ± 1.3	10.9 ± 1.5
Tanner score	1.4 ± 0.3	1.4 ± 0.4	1.3 ± 0.2	1.4 ± 0.3
Testosterone ($ng \cdot dl^{-1}$)	15.3 ± 1.3	16.1 ± 2.2	14.7 ± 1.8	15.7 ± 1.6
$\dot{V}O_2max$ ($L \cdot s^{-1}$)	1.88 ± 0.6	1.91 ± 0.5	1.86 ± 0.5	1.90 ± 0.6
Training age (y)	3.6 ± 0.6		3.4 ± 0.4	

*CG = control group; PTG = plyometric training group; $\dot{V}O_2max$ = maximal oxygen consumption.
†Data are presented as mean ± SD.

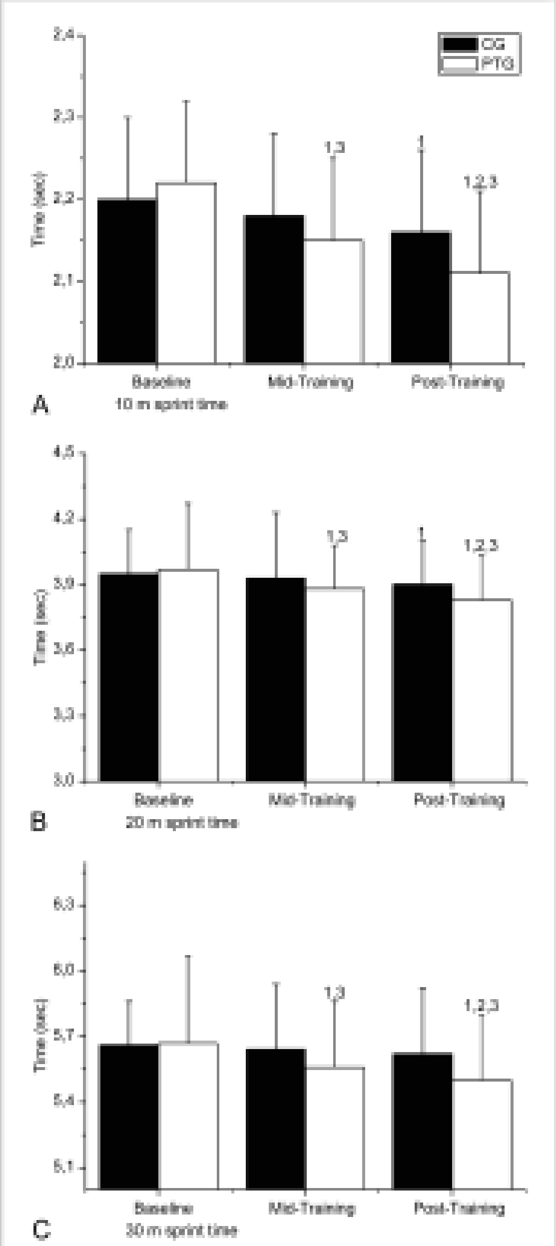

Figure 1. Changes in sprint times across time.[1] Denotes significant ($p < 0.05$) difference with baseline values; [2]denotes significant ($p < 0.05$) between midtraining and posttraining; differences between groups; [3]denotes significant ($p < 0.05$) differences between groups; CG = control group; PTG = plyometric training group.

Anthropometrics and Assessment of Maturity Status. Body mass was measured to the nearest 0.1 kg (Beam Balance 710, Seca, United Kingdom) with the participants wearing their underclothes and barefooted. Standing height was measured to the nearest 0.1 cm (Stadiometer 208, Seca). Body fat percentage was estimated based on the sum of triceps and calf skinfold thicknesses measured with a Harpenden caliper on the right side of the body as described (60). Arm span (i.e., the distance from the left to the right dactylion of the hands with palms facing forward on the wall and with the extended arms abducted horizontally at the same level with the shoulders) was measured to the nearest centimeter with a measuring tape. Stages of pubertal development were determined according to Tanner's criteria (63). Drawings of Tanner's 5 stages of genital development were provided to the participants and their guardians for joint assessment of participants' status of sexual maturity. Skeletal maturation (bone age) was determined with an x-ray of the left hand and wrist under full body protection against radioactivity according to the Greulich-Pyle methodology (21).

Maximal Oxygen Consumption ($\dot{V}O_2max$) Assesment. The $\dot{V}O_2max$ was measured during a graded exercise test on a treadmill as described (22). To ascertain that $\dot{V}O_2max$ had been attained, a $\dot{V}O_2$ plateau and a $\dot{V}O_2$ elevation <1 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ despite further increases in the workload had to be seen while RER should >1.0. Heart rate, brachial artery cuff pressure, and ratings of perceived exertion (6–20 Borg scale) were monitored continuously during the test. The $\dot{V}O_2$ was measured continuously by open-circuit spirometry and averaged every 30 seconds with the use of an automated online pulmonary gas exchange system via breath-by-breath analysis (Oxycon Champion IEC 601-1, Jaeger, Würzburg, Germany).

Performance Testing. Testing was performed under standardized environmental conditions (19–22° C, relative humidity of 42–45%) 48 hours after a practice session or competition to minimize the effects of fatigue. Testing was preceded by a 15-minute warm-up session (low-intensity cycling, calisthenics, and stretching) and followed by a 10-minute cool-down period. The same test order was applied on all testing sessions. The best performance of 2 testing trials (separated by a 5-minute resting interval of very low physical activity to ensure recovery and physiological readiness for the second trial) was recorded for later analysis (except for Wingate and strength testing).

Speed Testing. A 30-m sprint test with 10-m splits (0–10 and 10–20 m were measured as well) was used to measure speed performance. Sprint testing was performed with the participants wearing running shoes on a hard surface outdoors. After a 5-second countdown, the participants ran in front of 4 infrared photoelectric gates (NewTest Ltd., Kiviharjuntie, Finland) that recorded horizontal velocity at each gate. The participants sprinted from a standing starting position with the toe of the front foot approximately 0.3 m behind the first gate. Photocells were placed 0.6 m above the ground (approximately at hip level) to capture the movement of the trunk rather than a false signal because of a limb motion (42). The coefficient of variation for test-retest trials was 3.3%.

Standing Long Jump Testing. The participants adapted a starting standing position with their feet at shoulder width

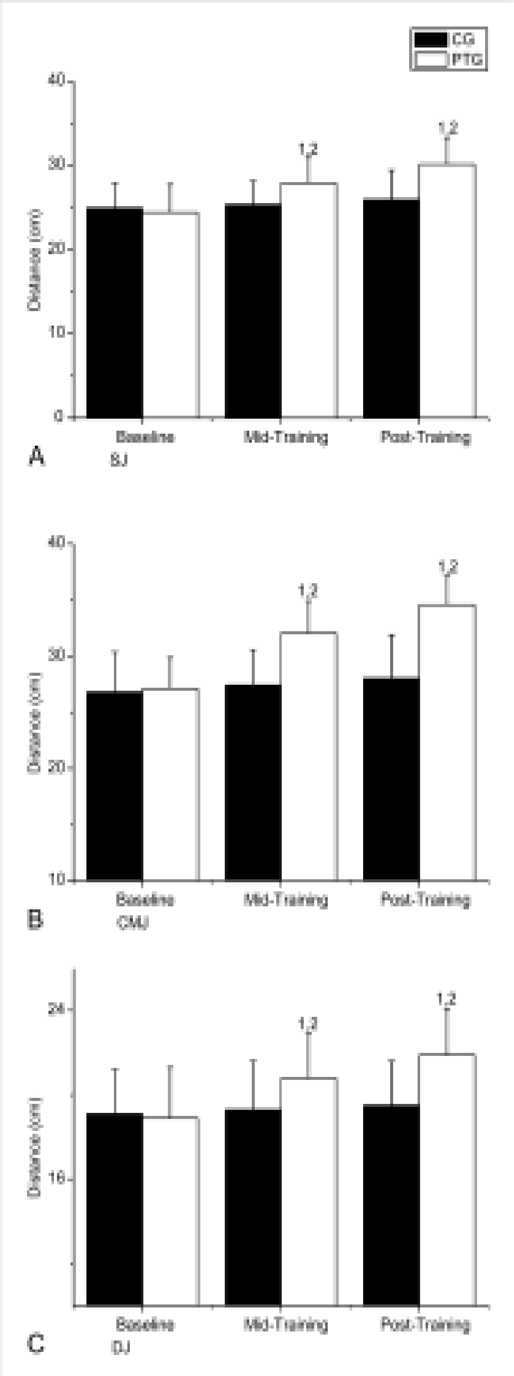

Figure 2. Changes in jump performance. [1] Denotes significant ($p < 0.05$) difference with baseline values; [2]denotes significant ($p < 0.05$) differences between groups; CG = control group; PTG = plyometric training group; SJ = standing jump; CMJ = countermovement jump; DJ = depth jump.

(behind a line marked on the ground) and their hands on the hips. The participants executed a countermovement with the legs and then jumped horizontally as far as possible, as described (29). The horizontal distance between the starting line and the heel of the rear foot was recorded with a fiber-glass tape measure. The coefficient of variation for test-retest trials was 2.6%.

Multiple 5 Bounds Test. The participants, from a standing position, attempted to cover the longest possible distance with 5 forward jumps and by alternating left- and right-leg contacts (42). This test is considered a soccer-specific test, and it has been recommended for the measurement of lower limp muscle power and coordination instead of the vertical jump (VJ) test (14). The greater distance covered was recorded to the nearest 0.5 cm with a tape. The coefficient of variation for test-retest trials was 2.7%.

Vertical Jump Testing. The participants performed 3 jump tests: (a) SJ: participants, from a stationary semisquatted position (90° angle at the knees), performed a maximal VJ; (b) CMJ: participants, from an upright standing position, performed a fast preliminary motion downwards by flexing their knees and hips followed by an explosive upward motion by extending their knees and hips; (c) DJ: after jumping of a bench (height 30 cm) and landing on the ground, the participants executed a maximal VJ. All 3 tests were performed with the arms akimbo. The VJ height was measured with an Ergojump contact platform (Newtest, Oulu, Finland). Flight times were measured by a digital timer connected to the contact platform and were used to calculate jump height (30). The coefficients of variation for test-retest trials were 2.9, 3.5, and 2.4% SJ, CMJ, and DJ, respectively.

Assessment of Leg Strength. Dynamic lower-limb strength was measured by the 10RM barbell squat test. This procedure of muscle strength measurement has been recommended as a safe testing and training modality for children as long as proper supervision and instruction is warranted (27). The test was performed after a warm-up session (at 25% of estimated 10RM. The participants should lift a weight for 14–16 repetitions with proper technique. Thereafter, the total weight increased by 10% while the repetition range decreased accordingly until a "repetition maximum" was obtained (usually within 4–5 attempts) (29). Range of motion at the knee was standardized with a manual goniometer. The participants begun the squat motion at 30° of knee flexion and descended to 90° (to parallel position) at the bottom position. Testers informed the participants when starting and finishing positions were obtained. The participants were allowed to rest for 10 minutes between testing trials. The successful maximal load was recorded as the maximum weight lifted. Spotters were present during the entire lift. The intraclass correlation coefficient estimated for test-retest trials within the same week was 0.90.

Wingate Testing. A 30-second Wingate testing was performed as described (29) on a cycle ergometer (model 834E, Monark AB, Varberg, Sweden) after a 5-minute warm-up. The test was followed by a 5-minute cool-down. External resistance to pedaling was set to 0.075 kg of resistance per kilogram of

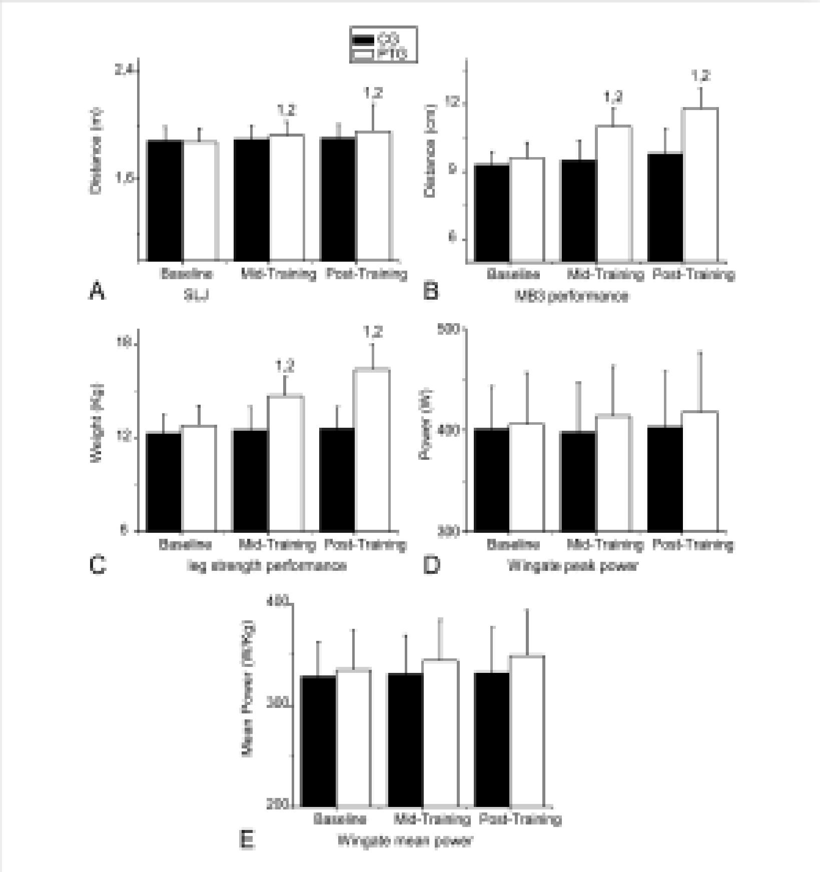

Figure 3. Changes in standing long jump performance, multiple 5-bound test performance, leg strength, and anaerobic power. [1] Denotes significant ($p < 0.05$) difference with baseline values; [2] denotes significant ($p < 0.05$) differences between groups; CG = control group; PTG = plyometric training group; SLJ = standing long jump; MB5 = multiple 5-bound test; PP = peak power; MP = mean power.

body mass, which is acceptable for prepubertal children (2). The criterion variables derived from the test were mean (MP) and peak (PP) anaerobic power. The coefficient of variation for test-retest trials was 3.9%.

Soccer-Specific Performance. Kicking performance was measured as previously described (54). Briefly, participants had to shoot (10 attempts, 30-second rest between attempts) the soccer ball (size 5) from a starting point (midpoint of the end zone line) to a regular soccer goal (70 yd away at the center of the field) after a warm-up. Kicking distance (in meters) from the starting point to the point of first contact of the ball with the ground was recorded. The longest 5 attempts were recorded, averaged and used for analysis. The coefficient of variation for test-retest trials was 3.5%. Agility testing was performed on the soccer field (with soccer footwear) as described (42). Time-to-complete the test was recorded with the use of 2 infrared photoelectric gates (NewTest Ltd., Kiviharjuntie, Finland) that recorded horizontal velocity. Change of direction was indicated with poles that were placed on the ground. The specific test is relatively simple for children and examines players' ability for acceleration, deceleration, and balance control, all essential components of agility (58). The coefficient of variation of agility testing for test-retest trials was 4.1%.

Blood Collection and Testosterone Measurement. Blood samples (4 ml) were drawn via venipuncture from an antecubital arm vein using a safety butterfly set equipment for children with the participants always in a semirecumbent position. Blood was collected into Vacutainer tubes containing SST-Gel and Clot Activator. Blood was allowed to clot at room temperature and subsequently centrifuged (1,500*g*, 4° C, 15 minutes) for serum separation. The resulting serum was used for the measurement of testosterone concentration. Samples were stored and frozen at −75° C until analyzed. Blood samples thawed only once before analysis. Testosterone was analyzed with a commercially available enzyme-linked immunosorbent assay kit (DRG Diagnostics, Germany). The intraassay and interassay CV for testosterone was 4.0 and 5.1%, respectively.

Statistical Analyses

Data are presented as means ± *SD*. Data normality was verified with the 1-sample Kolmogorov-Smirnoff test; therefore, a nonparametric test was not necessary. Data were analyzed by a 2-way repeated measures (trial × time) analysis of variance with planned contrasts on different time points based on the 2-group, repeated measures experimental design that was used in the study. Assumptions of linear statistics were met as verified by the Levine test for homogeneity of variance and Kolmogorov-Smirnoff test for normality. When a significant effect was found, post hoc analysis was performed through a Bonferonni test. The level of significance was set at $\alpha = 0.05$. The SPSS version 10.0 was used for all analyses (SPSS Inc., Chicago, IL, USA).

Results

The 2 groups were comparable according to chronological age, height, body composition, bone age, stages of puberty

Table 6. Differences between CG ($n = 10$), VG ($n = 10$), HG ($n = 10$), and VHG ($n = 10$) in the training effects (with 90% confidence limits) on performance variables.*†

	VG-CG	HG-CG	VHG-CG
Vertical countermovement jump with arms	6.9 (−0.5 to 14.9) Small	2.5 (−3.1 to 8.5) Trivial	6.5 (0.4 to 14.0) Small
Horizontal countermovement jump with arms	5.4 (−0.5 to 11.6) Small	15.7 (6.1 to 26.1) Moderate	18.1 (10.6 to 26.1) Moderate
20-cm drop jump reactive strength index	11.5 (4.9 to 18.4) Small	7.9 (−1.2 to 17.9) Small	14.1 (7.7 to 20.9) Small
Multiple 5 bounds test	4.1 (−2.8 to 11.4) Small	9.9 (3.3 to 17.0) Small	11.1 (1.8 to 21.2) Small
Maximal kicking velocity	2.5 (−8.1 to 14.4) Trivial	6.8 (−1.5 to 15.8) Small	8.4 (−1.2 to 19.0) Small
15-m sprint time	−4.7 (−10.1 to 0.9) Moderate	−6.8 (−11.5 to −1.9) Moderate	−8.0 (−11.9 to −3.9) Moderate
30-m sprint time	−0.8 (−8.3 to 7.4) Trivial	−2.5 (−6.5 to 1.6) Small	−5.3 (−9.5 to −0.9) Small
Change of direction speed test time	−2.8 (−10.2 to 5.3) Small	−2.7 (−8.5 to 3.5) Small	−5.1 (−9.9 to −0.1) Small
Yo-Yo intermittent recovery level 1 test	6.3 (0.6 to 12.4) Small	5.3 (−11.4 to 25.1) Trivial	7.9 (−1.9 to 18.7) Small
Anterior-posterior normal stance eyes open	−6.5 (−13.4 to 1.0) Small	−6.2 (13.3 to 1.4) Trivial	−8.8 (−16.5 to −0.4) Small
Medial-lateral normal stance eyes open	−11.8 (−19.2 to −3.8) Small	−4.8 (−10.5 to 1.3) Trivial	−12.2 (−16.2 to −7.9) Small
Anterior-posterior normal stance eyes closed	−4.7 (−17.7 to 10.2) Trivial	−8.9 (−20.6 to 4.4) Small	−14.4 (−25.8 to −1.3) Small
Medial-lateral normal stance eyes closed	−6.7 (−10.8 to −2.3) Trivial	−5.3 (−16.3 to 7.1) Trivial	−13.6 (−19.5 to −7.2) Small
	HG-VG	**VHG-VG**	**VHG-HG**
Vertical countermovement jump with arms	−3.8 (−9.0 to 1.8) Small	0.0 (−6.5 to 7.0) Trivial	3.6 (−2.0 to 9.4) Trivial
Horizontal countermovement jump with arms	7.6 (−0.7 to 16.5) Small	9.8 (4.0 to 16.0) Small	−2.9 (−13.7 to 9.2) Trivial
20-cm drop jump reactive strength index	−3.6 (−11.0 to 4.5) Trivial	2.0 (−2.1 to 6.2) Trivial	5.3 (−2.0 to 13.0) Trivial
Multiple 5 bounds test	5.0 (0.5 to 9.7) Small	6.1 (−1.8 to 14.6) Small	−0.2 (−7.4 to 7.6) Trivial
Maximal kicking velocity	3.9 (−5.7 to 14.4) Trivial	5.4 (−5.2 to 17.3) Small	1.6 (−6.7 to 10.6) Trivial
15-m sprint time	−1.7 (−7.2 to 4.0) Small	−3.0 (−7.8 to 2.0) Small	−1.4 (−5.6 to 3.0) Trivial
30-m sprint time	−0.7 (−7.1 to 6.1) Trivial	−3.5 (−9.9 to 3.3) Small	−2.3 (−4.8 to 0.3) Small
Change of direction speed test time	0.9 (−4.6 to 6.7) Trivial	−1.6 (−5.8 to 2.8) Small	−2.2 (−7.4 to 3.2) Small
Yo-Yo intermittent recovery level 1 test	1.1 (−14.9 to 20.1) Trivial	3.6 (−5.7 to 13.9) Trivial	−0.1 (−15.8 to 18.6) Trivial
Anterior-posterior normal stance eyes open	−0.4 (−2.7 to 1.9) Trivial	−3.2 (−8.3 to 2.2) Trivial	−1.8 (−7.1 to 3.8) Trivial
Medial-lateral normal stance eyes open	3.7 (−7.1 to 15.8) Trivial	−4.3 (−13.8 to 6.2) Trivial	−7.6 (−11.9 to −3.1) Small
Anterior-posterior normal stance eyes closed	−4.2 (−9.9 to 1.8) Trivial	−10.0 (−16.5 to −2.9) Small	−6.1 (−11.0 to −0.8) Small
Medial-lateral normal stance eyes closed	2.0 (−9.6 to 15.1) Trivial	−6.9 (−12.7 to −0.7) Small	−8.9 (−18.9 to 2.4) Small

*VG = vertical plyometric training group; HG = horizontal plyometric training group; VHG = combined vertical + horizontal plyometric training group.

†Effects are shown in percentage units and probabilistic inferences about the true standardized magnitude.

Statistical Analyses

All values are reported as mean ± *SD*. Relative changes (%) in performance and standardized effects (SE) are expressed with 90% confidence limits. Normality and homoscedasticity assumptions were checked, respectively, with Shapiro-Wilk and Levene tests. To determine the effect of the intervention on performance adaptations, a 2-way analysis of variance with repeated measurements (4 groups × 2 times) was applied. When a significant F value was achieved across time or between groups, Tukey post hoc procedures were performed to locate the pairwise differences between the mean values. The α level was set at $p \leq 0.05$ for statistical significance. All statistical calculations were performed using STATISTICA statistical package (version 8.0; StatSoft, Inc., Tulsa, OK, USA). In addition to this null hypothesis testing, data were also assessed using magnitude of based inference statistics (16). Threshold values for assessing magnitudes of SE (changes as a fraction or multiple of baseline *SD*) were 0.20, 0.60, 1.2, and 2.0 for small, moderate, large, and very large, respectively (16). Magnitudes of differences in training effects between groups were evaluated nonclinically (16): if the confidence interval overlapped thresholds for substantial positive and negative values, the effect was deemed unclear. The effect was otherwise clear and reported as the magnitude of the observed value with a qualitative probability, as above. We obtained a relatively high intraclass correlation coefficient and low coefficient of variation for the vertical countermovement jump with arms test (0.91 and 3.5%, respectively), horizontal countermovement jump with arms test (0.95 and 3.7%, respectively), 20-cm drop jump RSI (0.94 and 3.7%, respectively), multiple 5 bounds test (0.95 and 4.8%, respectively), MKV test (≥0.91 and <4.4%, respectively), 15-m sprint time test (0.93 and 2.5%, respectively), 30-m sprint time test (0.95 and 1.9%, respectively), CODS test (0.91 and 3.5%, respectively), anterior-posterior normal stance eyes open test (0.94 and 4.1%, respectively), medial-lateral normal stance eyes open test (0.94 and 4.1%, respectively), anterior-posterior normal stance eyes closed test (0.81 and 6.9%, respectively), and medial-lateral normal stance eyes closed test (0.94 and 4.3%, respectively).

Results

Before training, no significant differences were observed between groups in vertical CMJ, horizontal CMJ, RSI, multiple bound test (Table 3), kicking velocity, 15-m and 30-m sprint time, CODS, Yo-Yo IR1 (Table 4), or balance (Table 5) test performance.

No statistically significant changes in the CG were observed, although a small meaningful change (0.23 SE) in Yo-Yo IR1 was noted (Table 4). In comparison with the CG, horizontal training groups (i.e., HG and VHG) showed a significantly ($p \leq 0.05$) higher performance change and SE in horizontal CMJ and multiple bound test, whereas vertical training groups (i.e., VG and VHG) showed a significantly ($p \leq 0.05$) higher performance change and SE in the RSI (Table 3). Also, in comparison with the CG, the VHG showed a significantly ($p \leq 0.05$) higher performance change and SE in kicking velocity, 15-m sprint time, 30-m sprint time, CODS, Yo-Yo IR1 (Table 4), and balance (both, medial-lateral and anterior-posterior) test (Table 5).

Except for the HG and VG groups in the vertical CMJ and multiple bound test (respectively), all plyometric training groups showed a significant ($p \leq 0.05$) increase and small to moderate meaningful SE in vertical CMJ, horizontal CMJ, RSI, and multiple bound test (Table 3). No statistically significant differences in performance changes were observed between training groups (Table 3), although vertical training was more effective to a small effect at improving vertical CMJ performance in comparison with horizontal training. In addition, horizontal training (i.e., HG and VHG) was more effective to a small effect than vertical training (i.e., VG) at improving horizontal CMJ and multiple bound test performance (Table 6).

Although the 3 plyometric training groups had a small to moderate meaningful SE in kicking velocity, 15-m and 30-m sprint, CODS, Yo-Yo IR1 (Table 4), and balance test (Table 5), only the combined vertical and horizontal program had a statistically significant ($p \leq 0.05$) effect in all performance test. In addition, the combined vertical and horizontal training group improved more (small effect) than the VG and HG in 30-m sprint, CODS, and balance performance test and also improved more (small effect) than the VG in kicking velocity and 15-m sprint performance test (Table 6). The HG improved more (small effect) than the VG in 15-m sprint performance test to a small effect (Table 6).

Discussion

The results of this study indicated a specificity of training effect, where the use of vertical exercises induced a significantly greater increase in performance tests in the vertical plane, whereas the use of horizontal exercises induced a significantly greater increase in performance tests in the horizontal plane. Also, the results indicate that, compared with CG, only a combination of vertical and horizontal training stimulus achieved a significantly greater increase in almost all (i.e., 9 of 13) performance measures. Finally, our results demonstrated that the combination of soccer drills and specific explosive training with no additional training time in-season optimizes general and soccer-specific explosiveness, balance, and endurance performance in young soccer players.

The results from the VCMJ, HCMJ, RSI20, and MB5 test all demonstrated the training principle of specificity in plyometric training (25,41), which can be explained by factors such as eccentric overloading, segmental coordination, and muscular activation (45). Groups trained in the specific direction of the jump test consistently improved to a greater extend (Table 6) and increased the gap with the CG (Table 3). The magnitude change in VCMJ was similar or even higher than previously reported for similar slow SSC muscle actions (SE = 0.51–0.75) (10,31,50) after explosive training with young soccer players using an intervention of similar duration or number of sessions. The magnitude change in RSI20 was similar than previously reported

(SE = 0.41–0.90) (39) after plyometric training with young soccer players. Considering the necessity to produce a high rate of force development in explosive actions (29), the improvement in RSI may have enhanced physical parameters of game performance. The improvement observed could have been induced by various neuromuscular adaptations (23); however, because no physiological measurements were made, only speculations are possibly. Finally, the magnitude change in MB5 in this study was similar than previously reported (SE = 0.62–0.63) (10,31) after explosive training with young soccer players. An increase in MB5 may be achieved by motor coordination adaptations, which can be related to the specificity of movements used during training (10). The fact that the HG and VHG performed horizontal plyometric drills, achieving a significantly higher performance change in MB5 than the CG, would support such contention considering the horizontal nature of the MB5.

Although previously it has been shown that a combination of vertical and horizontal (46) or unilateral and bilateral (12) plyometric exercises can increase MKV, this is the first study to compare the effects of vertical, horizontal, and combined vertical and horizontal jumps, including unilateral and bilateral drills, in MKV of young soccer players. All training programs induced a meaningful increase in MKV performance, but the VHG improved more to a small effect and significantly in MKV compared with VG and CG (Tables 4 and 6), suggesting that a combination of vertical and horizontal exercises may induce higher MKV performance changes in young soccer players than plyometric drills applied in only 1 plane of direction. Although differences in type of training program applied make comparisons between different studies difficult, others have found significant increases in kicking performance after plyometric training in young soccer players (12,24,32), in both dominant and nondominant kicking legs (12). It has been suggested that the increased MKV performance may be attributed to increased strength and power of legs' extensor muscles (32), agonists-antagonists muscle coordination, and greater recruitment of motor units (12). It may be that these neuromuscular and strength-power adaptations had an effect on the biomechanical factors related to kicking performance, such as maximum linear velocity of the toe, ankle, knee, and hip at ball contact (20), which may have cumulatively or individually contributed to a higher ball kicking velocity.

All training groups showed a meaningful decrease (i.e., SE between 0.30 and 0.99) in 15 and 30-m sprint times, but only the VHG demonstrated a significant ($p \leq 0.05$) change compared with CG (Table 4). The results also demonstrated a small beneficial effect of horizontal stimulus for 15-m sprint time and implementing some vertical stimulus to decrease 30-m sprint time (Table 6). Although others have found similar effects (SE = 0.29–1.1) in sprint performance after plyometric training in young soccer players (31–32), this was the first study to compare the effects of vertical, horizontal, and combined vertical and horizontal plyometric training in 15 and 30-m sprint times in young soccer players. As the training intervention in the HG and VHG incorporates horizontal stimulus, this may had increased the chances to gain adaptations considering the importance of horizontal force production and application in sprint performance (18,34). This agrees with previous studies, where vertical plyometric training fails to improve sprint performance in young soccer players (39). The higher increase in sprint performance in VHG coincides with previous results (48). The CG did not exhibit a meaningful or statistically significant improvement in sprint performance in this study, and conducting soccer training only in-season may even induce decay in sprint performance (39). These observations reinforce the value of an independent explosive training program to enhance acceleration and maximal sprint ability of young soccer players during their in-season. The increase in both acceleration and maximal running velocity can be related to leg power (7), which can be increased with plyometric training in young soccer players (6,38). Although acceleration improvement may be more related with the slower SSC and rate of power production nature of the acyclic jumps (i.e., countermovement jumps) (8) performed during training, leg stiffness developed through stiffer plyometric exercises (i.e., cyclic jumps) may transfer to maximal running velocity improvement (7). Therefore, in addition to the more favorable sprint performance changes observed after the combination of vertical and horizontal plyometric exercises in this study, these results reinforce the need to add variation in plyometric cycle (i.e., cyclic and acyclic movement) to improve the different neuromuscular variables related with sprint performance.

This study demonstrated that all plyometric training stimulus induced a meaningful increase in CODS performance, with a small to moderate SE (Table 4). However, only VHG showed a statistically significant increase and significant change in comparison with the CG (Table 4). Also, the VHG program was more effective at improving CODS performance compared with VG and HG to a small effect (Table 6). All training programs contained exercises designed to induce short contact times and subsequently increase RSI, which may predict the ability to change directions while running (51). Also, an improved CODS performance may be related to changes in power development or increased eccentric strength level, which can impact COD performance during the deceleration phase (47). This study demonstrated that combined horizontal and vertical plyometric training was more efficient at driving multiple explosive-related adaptations, which seemed to have transferred to CODS performance in young soccer players. The important differences between CODS tests used among studies make results comparison difficult; however, using the same CODS test as in our study, others have found an even greater change in performance after plyometric training in young soccer players (9.7%; SE = 2.8) (31). Because greater change occurred in the multi-plane training stimulus group in this study, it can be argued that greater magnitude of change in the study of Meylan and Malatesta (31) may be because of more variety in stimulus but also the intervention duration in comparison with this study.

Our results demonstrated a significant and small meaningful increase in Yo-Yo IR1 performance in all training groups (Table 4). In young soccer players, plyometric training may not induce a significant increase in underlying aerobic qualities such as $\dot{V}O_2$max (32) or lactate threshold (14) but may still have a meaningful effect on a intermittent recovery endurance performance test with repeated changes of direction (50). This discrepancy is likely related to the fact that the change in explosive performance after a plyometric training can contribute to the change of direction during an intermittent test (e.g., Yo-Yo IR1 or 30–15 intermittent fitness test) with change of direction (3) or running economy (26), independently from the influence on $\dot{V}O_2$max (32) or lactate threshold (14). As previously stated, all training groups demonstrated a meaningful change in reactive strength (i.e., RSI20), which may transfer into improved running economy and enhance aerobic performance independently of others aerobic indicators (e.g., $\dot{V}O_2$max or lactate threshold) (37).

A novel aspect of this study was to analyze the effect of plyometric training on youth soccer players balance and the different effect of various plyometric training interventions on balance capability. Our results showed that although all training groups achieve a meaningful change in all measures of anterior-posterior and medial-lateral balance (Table 5), only VHG achieved a significantly higher performance change in anterior-posterior balance in comparison with CG (Table 5) and also a higher SE to a small effect in both medial-lateral and anterior-posterior balance compared with VG, HG, and CG (Table 6). Improvements in balance after plyometric training have already been shown after 6 weeks (36,52) and in young athletes (5,36). Because balance improvements may not only result in an increased athletic performance but also in reduced lower-extremity injury risk in soccer players (52), our results reinforce the value of plyometric training as an effective strategy to reduce injury risk in young athletes. There was no significant difference in medial-lateral balance postintervention in all the groups (Table 5). As the training was anterior-posterior in nature for all groups, which resulted in better balance in that plane, there is an argument to also include medial-lateral plyometric-based exercises to improve the associated balance capability. The improvement in balance performance may be related to improved cocontraction of lower-extremity muscles (33) or changes in proprioception and neuromuscular control (15), which appeared to be direction specific based on this study. Furthermore, to enhance functional balance, initial emphasis on landing mechanics (i.e., acyclic jumps) during plyometric training may prove more beneficial for complex high speed unilateral repetitive dynamic tasks taxing postural control (i.e., sprinting, change of direction) as compared with fast SSC plyometrics (i.e., cyclic) (5).

Practical Applications

The replacement of some soccer drills with high-intensity plyometric exercises may positively affect jump, sprint, kicking, CODS, endurance, and balance performance in young soccer players during the in-season period. These adaptations can be achieved in the short-term and may potentially increase competitive performance and may reduce injury risk. When programming, the practitioner must be cognizant of the training response being specific to the direction of force production in the plyometric drills. The combination of vertical and horizontal jump stimulus was more advantageous to youth soccer players to gain meaningful improvements in explosive performance, balance, and intermittent aerobic capacity than vertical or horizontal plyometric stimulus alone. Such approach appeared relevant to the multidirectional nature of soccer but may not have the same positive effect where a direction of force production is dominant (e.g., volleyball). As most sports are unilateral in nature, it is recommended to find the right balance and progression between bilateral and unilateral training stimulus, although whether a training stimulus is more advantageous than the other is still to debate. A combination of acyclic to cyclic jump may also prove relevant to the specificity of the sport and the level of athlete movement competency and dynamic balance. Finally, although plyometric training can induce an increase in explosive, endurance, and balance performance in young soccer players, to optimize training adaptations, this training strategy should be adequately applied in a more complex training plan that incorporates other explosive (e.g., sprints), endurance, technical, and tactical-oriented training methods.

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ARTÍCULO 5

Effect of Vertical, Horizontal, and Combined Plyometric Training on Explosive, Balance, and Endurance Performance of Young Soccer Players

Rodrigo Ramírez-Campillo,[1] Francisco Gallardo,[1] Carlos Henriquez-Olguín,[2] Cesar M.P. Meylan,[3,4] Cristian Martínez,[5] Cristian Álvarez,[6] Alexis Caniuqueo,[7] Eduardo L. Cadore,[8] and Mikel Izquierdo[9,10]

[1]*Department of Physical Activity Sciences, University of Los Lagos, Osorno, Chile;* [2]*Laboratory of Exercise Sciences, MEDS Clinic, Santiago, Chile;* [3]*Canadian Sport Institute Pacific, Vancouver, British Columbia, Canada;* [4]*Canadian Soccer Association, Ottawa, Ontario, Canada;* [5]*Department of Physical Education, Sport and Recreation, University of La Frontera, Temuco, Chile;* [6]*Family Health Center of Los Lagos, Health Promotion Program, Los Lagos, Chile;* [7]*Laboratory of Physiology and Biomechanics, University Autónoma of Chile, Temuco, Chile;* [8]*Exercise Research Laboratory, Federal University of Rio Grande do Sul, Porto Alegre, Brazil;* [9]*Faculty of Recreation, Sport and Physical Education, University of Santo Tomás, Bogotá D.C, Colombia; and* [10]*Department of Health Sciences, Public University of Navarre, Navarre, Spain*

Abstract

Ramírez-Campillo, R, Gallardo, F, Henriquez-Olguín, C, Meylan, CMP, Martínez, C, Álvarez, C, Caniuqueo, A, Cadore, EL, and Izquierdo, M. Effect of vertical, horizontal, and combined plyometric training on explosive, balance, and endurance performance of young soccer players. *J Strength Cond Res* 29(7): 1784–1795, 2015—The aim of this study was to compare the effects of 6 weeks of vertical, horizontal, or combined vertical and horizontal plyometric training on muscle explosive, endurance, and balance performance. Forty young soccer players aged between 10 and 14 years were randomly divided into control (CG; $n = 10$), vertical plyometric group (VG; $n = 10$), horizontal plyometric group (HG; $n = 10$), and combined vertical and horizontal plyometric group (VHG; $n = 10$). Players performance in the vertical and horizontal countermovement jump with arms, 5 multiple bounds test (MB5), 20-cm drop jump reactive strength index (RSI20), maximal kicking velocity (MKV), sprint, change of direction speed (CODS), Yo-Yo intermittent recovery level 1 test (Yo-Yo IR1), and balance was measured. No significant or meaningful changes in the CG, apart from small change in the Yo-Yo IR1, were observed while all training programs resulted in meaningful changes in explosive, endurance, and balance performance. However, only VHG showed a statistically significant ($p \leq 0.05$) increase in all performance test and most meaningful training effect difference with the CG across tests. Although no significant differences in performance changes were observed between experimental groups, the VHG program was more effective compared with VG (i.e., jumps, MKV, sprint, CODS, and balance performance) and HG (i.e., sprint, CODS, and balance performance) to small effect. The study demonstrated that vertical, horizontal, and combined vertical and horizontal jumps induced meaningful improvement in explosive actions, balance, and intermittent endurance capacity. However, combining vertical and horizontal drills seems more advantageous to induce greater performance improvements.

Key Words explosive actions, stretch-shortening cycle, competitive game, preadolescense, strength and conditioning

Introduction

Sprinting, jumping, and change of direction speed (CODS) are important determinants for success in adult (42) and young soccer players (4). Although sprinting only contributes up to 3% of the total distance covered in children's games (4), most crucial moments such as winning ball possession, scoring, or conceding goals depend on it (42). It has been proposed that the high degree of plasticity in neuromuscular development during preadolescence, combined with appropriately timed implementation and progression of integrative neuromuscular training (e.g., supplemental training combining general and specific strength and conditioning exercises, such as plyometrics), may allow for strengthened physical development that contributes favorably to athleticism into adulthood (35). Selection of relevant training methods, which contribute to

Address correspondence to Mikel Izquierdo, mikel.izquierdo@gmail.com.

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the development of soccer-related explosive activities from a young age, must therefore be on the forefront of the practitioner's mind to increase the chance of the player's success (21). As demonstrated by others (27), power increases with age and is related to the improvement of 1 or both of its components, velocity or force. Velocity at peak power appeared to be the changing factor in peak power output before peak height velocity (PHV—a somatic biological maturity indicator that reflects the maximum velocity in statural growth during adolescence), whereas force at peak power was a more important determinant during and post-PHV (27). Based on these findings, training for velocity in the initial phase of a player development has been recommended (30).

Unloaded or body mass plyometric training provides such a high velocity training stimuli in young soccer players (10,31–32), affecting maximal muscle power of different movements (30). The effectiveness of plyometric training depend on several factors such as eccentric overloading, segmental coordination, specificity of joint angle, and angular velocities (13,45). However, few studies offer optimum plyometric training design in relation to exercise selection and their associated direction of force production (9). Vertical and horizontal explosive exercises (e.g., jumping) may depend on different neuromuscular capabilities. For example, the stretch-shortening cycle (SSC) contributes less to horizontal than vertical jump performance, because a vertical load on the musculotendinous unit generates a bigger stretching load, allowing greater accumulation and use of elastic energy during the concentric phase (18,28). As specificity is an important requirement for training induced adaptations, performance changes in explosive neuromuscular actions may require specific training strategies. Although it is common to find muscle power evaluations incorporating bilateral, vertical and acyclic muscle actions (e.g., squat jump, countermovement jump) in the literature, unilateral, horizontal and cyclic muscle actions may best reflect competitive athletic performance changes (28). Most movements implicate a combination of vertical, horizontal, and lateral force production, especially where speed and CODS are important in a multidirectional sport such as soccer (18,31). Recent reviews on the topic (41,43) suggest that plyometric training should include horizontal and vertical movements to enhance vertical and horizontal power. Most previous studies have prescribed vertical plyometric exercises in young soccer players (14,49–50) or have been vertical dominant (10,32). Only 1 plyometric intervention provided an equal vertical and horizontal stimulus (31). However, no studies have established the different effect of vertical, horizontal, or the combination of both types of plyometric exercises on explosive performance of young soccer players.

Apart from sprinting, jumping, and CODS, explosive training may also enhance kicking and endurance and balance performance. Although explosive training has consistently showed a positive effect on kicking performance (12,24), its effect on endurance remains controversial. Studies in youth soccer players did not demonstrate improvement in $\dot{V}O_2max$ (32) or lactate thresholds (14), whereas others (50) demonstrated an increase in performance during a Yo-Yo intermittent recovery level 1 test (Yo-Yo IR1). Also, balance may be a fundamental quality for both execution of technical movements and prevention of injuries (43); however, the plyometric training effect on young soccer players balance is currently unknown (5,36).

Given the limitations previously cited, our objective was to assess the effect of plyometric exercises in the vertical plane, horizontal plane, and their combination on several explosive, balance, and endurance performance measures in young soccer players.

Methods

Experimental Approach to the Problem

This study was designed to address the question of how a short-term plyometric training program of moderate frequency (2 sessions per week), incorporating vertical,

Table 1. Descriptive data of the CG, VG, HG, and VHG.*

	CG (*n* = 10)	VG (*n* = 10)	HG (*n* = 10)	VHG (*n* = 10)
Age (y)	11.4 ± 2.4	11.6 ± 1.4	11.4 ± 1.9	11.2 ± 2.3
Height (cm)	146 ± 16.2	144 ± 9.6	150 ± 12.3	141 ± 14.4
Body mass (kg)	42.2 ± 13.2	40.0 ± 5.9	44.6 ± 11.0	40.1 ± 12.8
Body mass index (kg·m^{-2})	19.4 ± 2.2	19.3 ± 2.0	19.6 ± 2.0	19.3 ± 2.8
Predicted years from age of peak height velocity (y)	−2.0 ± 2.0	−2.3 ± 1.9	−2.0 ± 1.6	−2.2 ± 1.8
Session rating of perceived exertion	450 ± 173	492 ± 296	432 ± 189	420 ± 248
Soccer experience (y)	3.9 ± 2.3	3.6 ± 2.3	4.1 ± 2.6	3.5 ± 2.3

*CG = control group; VG = vertical plyometric training group; HG = horizontal plyometric training group; VHG = combined vertical + horizontal plyometric training group.

horizontal, or vertical and horizontal exercises would affect differently jumping, sprinting, kicking, endurance, CODS, and balance performance measures in young soccer players. After the initial measurements, participants were randomly assigned to a control group (CG, $n = 10$), or 1 of the 3 training group: vertical plyometric training group (VG, $n = 10$), horizontal plyometric training group (HG, $n = 10$), and combined vertical and horizontal plyometric training group (VHG, $n = 10$). Measurements were repeated postintervention.

Subjects

Forty young male soccer players (aged between 10 and 14 years) with no background in regular strength or plyometric training volunteered to participate in this study. Exclusion criteria included participants with (a) potential medical problems or a history of ankle, knee, or back pathology that compromised their participation or performance in the study and (b) any lower extremity reconstructive surgery in the past 2 years or unresolved musculoskeletal disorders. Despite not pair-matching individuals based on an independent variable, there were no significant differences between groups' characteristics at baseline (Table 1).

Participants (and their parents or guardians) were informed about the experimental procedures and about possible risks and benefits associated with participation in the study and signed an informed consent before any of the tests were performed. The study was conducted in accordance with the Declaration of Helsinki and was approved by the institutional review board for use of human subjects from the university.

Testing Procedures

Participants were familiarized with the test procedures 2 weeks before the initial assessment to reduce learning effects. Measurements were undertaken 1 week before and after the intervention. To reduce the potential effect of cumulative fatigue on dependent variable outcomes, before and after intervention, athletes had 7 days of rest between the last training session and first measurement session. In addition, in

TABLE 2. Six-week plyometric training program.*†

Group	Exercises‡§	Set × repetitions (mode of execution)					
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
VG ($n = 10$)	Vertical right leg	3 × 5 (C)	3 × 6 (C)	3 × 7 (C)	3 × 8 (C)	3 × 9 (C)	3 × 10 (C)
		3 × 5 (A)	3 × 6 (A)	3 × 7 (A)	3 × 8 (A)	3 × 9 (A)	3 × 10 (A)
	Vertical left leg	3 × 5 (C)	3 × 6 (C)	3 × 7 (C)	3 × 8 (C)	3 × 9 (C)	3 × 10 (C)
		3 × 5 (A)	3 × 6 (A)	3 × 7 (A)	3 × 8 (A)	3 × 9 (A)	3 × 10 (A)
	Vertical bilateral	6 × 5 (C)	6 × 6 (C)	6 × 7 (C)	6 × 8 (C)	6 × 9 (C)	6 × 10 (C)
		6 × 5 (A)	6 × 6 (A)	6 × 7 (A)	6 × 8 (A)	6 × 9 (A)	6 × 10 (A)
	Total per leg	90	104	125	144	162	180
HG ($n = 10$)	Horizontal right leg	3 × 5 (C)	3 × 6 (C)	3 × 7 (C)	3 × 8 (C)	3 × 9 (C)	3 × 10 (C)
		3 × 5 (A)	3 × 6 (A)	3 × 7 (A)	3 × 8 (A)	3 × 9 (A)	3 × 10 (A)
	Horizontal left leg	3 × 5 (C)	3 × 6 (C)	3 × 7 (C)	3 × 8 (C)	3 × 9 (C)	3 × 10 (C)
		3 × 5 (A)	3 × 6 (A)	3 × 7 (A)	3 × 8 (A)	3 × 9 (A)	3 × 10 (A)
	Horizontal bilateral	6 × 5 (C)	6 × 6 (C)	6 × 7 (C)	6 × 8 (C)	6 × 9 (C)	6 × 10 (C)
		6 × 5 (A)	6 × 6 (A)	6 × 7 (A)	6 × 8 (A)	6 × 9 (A)	6 × 10 (A)
	Total per leg	90	104	125	144	162	180
VHG ($n = 10$)	Horizontal left leg	2 × 5 (C)	2 × 6 (C)	2 × 7 (C)	2 × 8 (C)	2 × 9 (C)	2 × 10 (C)
		2 × 5 (A)	2 × 6 (A)	2 × 7 (A)	2 × 8 (A)	2 × 9 (A)	2 × 10 (A)
	Horizontal right leg	2 × 5 (C)	2 × 6 (C)	2 × 7 (C)	2 × 8 (C)	2 × 9 (C)	2 × 10 (C)
		2 × 5 (A)	2 × 6 (A)	2 × 7 (A)	2 × 8 (A)	2 × 9 (A)	2 × 10 (A)
	Vertical left leg	2 × 5 (C)	2 × 6 (C)	2 × 7 (C)	2 × 8 (C)	2 × 9 (C)	2 × 10 (C)
		2 × 5 (A)	2 × 6 (A)	2 × 7 (A)	2 × 8 (A)	2 × 9 (A)	2 × 10 (A)
	Vertical right leg	2 × 5 (C)	2 × 6 (C)	2 × 7 (C)	2 × 8 (C)	2 × 9 (C)	2 × 10 (C)
		2 × 5 (A)	2 × 6 (A)	2 × 7 (A)	2 × 8 (A)	2 × 9 (A)	2 × 10 (A)
	Bilateral vertical	2 × 5 (C)	2 × 6 (C)	2 × 7 (C)	2 × 8 (C)	2 × 9 (C)	2 × 10 (C)
		2 × 5 (A)	2 × 6 (A)	2 × 7 (A)	2 × 8 (A)	2 × 9 (A)	2 × 10 (A)
	Bilateral horizontal	2 × 5 (C)	2 × 6 (C)	2 × 7 (C)	2 × 8 (C)	2 × 9 (C)	2 × 10 (C)
		2 × 5 (A)	2 × 6 (A)	2 × 7 (A)	2 × 8 (A)	2 × 9 (A)	2 × 10 (A)
	Total per leg	80	96	112	128	144	160

*VG = vertical plyometric training group; HG = horizontal plyometric training group; VHG = combined vertical + horizontal plyometric training group; C = cyclic; A = acyclic.

†The volume of contacts described is per session and remains the same for the 2 plyometric training sessions completed each

the week preceding performance measurements, no competitive game was performed, and athletes were asked to reduce the intensity of their regular physical education classes. Tests were completed in 3 days and always administered in the same order, at the same time of the day, by the same investigators, with >48 hours of rest from physical activity. Participants were instructed to use the same athletic shoes and clothes during all testing sessions. Tests were conducted indoors on a wooden surface. Throughout testing, an investigator subject ratio of 1:1 was maintained. Ten minutes of standard warm-up (i.e., submaximal running with CODS, 20 vertical and 10 horizontal submaximal jumps) were executed before testing.

On day 1, the standing height, sitting height, body mass, body composition, vertical (VCMJ) and horizontal (HCMJ) countermovement jump with arms for maximal vertical and horizontal distance, 20-cm drop jump reactive strength index (RSI20), and the multiple 5 bounds test (MB5) for maximal horizontal distance were completed. Anthropometric measurements were taken using a stadiometer (Bodymeter 206; SECA, Hamburg, Germany) and an electrical scale (BF100_Body Complete; Beurer, Ulm, Germany), and the athletes maturity status was determined using predicted years from age of PHV (i.e., PHV offset) (33). Jump height during the VCMJ (i.e., centimeter) and jump height divided by contact time during the RSI20 (i.e., $mm \cdot ms^{-1}$) were measured with an electronic contact mat system (Ergojump; Globus Italy, Codogne, Italy). Players could use their arms during the VCMJ, while keeping their arms akimbo during the RSI20. Takeoff and landing was standardized to full knee and ankle extension on the same spot. The participants were instructed to maximize jump height and minimize ground contact time during the RSI20 after dropping down from a 20-cm drop box. HCMJ and 5 multiple bounds test (MB5) were completed with arm swings and measured with a tape measure to the nearest centimeter. All jump protocols have been previously described (40).

On day 2, the 15-m sprint time for acceleration and 30-m sprint time for maximal speed, the maximal kicking velocity test (MKV), and a soccer-specific CODS test (31) were performed. The 15 and 30-m sprint time was measured using single beam infrared photoelectric cells (Globus Italy) placed

TABLE 3. Training effects (with 90% confidence limits) for the jump performance variables for the CG ($n = 10$), VG ($n = 10$), HG ($n = 10$), and VHG ($n = 10$).*

	Baseline mean ± *SD*	Performance change (%)	Magnitude of training effect
Vertical countermovement jump with arms (cm)			
CG	29.6 ± 6.4	3.0 (−2.1 to 8.4)	0.13 (−0.09 to 0.36)
VG	30.2 ± 3.5	9.7 (4.4 to 15.4)†	0.75 (0.34 to 1.16)‖
HG	31.6 ± 6.8	5.9 (3.1 to 8.9)	0.24 (0.13 to 0.35)‡
VHG	30.2 ± 7.4	12.3 (5.6 to 19.5)§	0.51 (0.24 to 0.79)‡
Horizontal countermovement jump with arms (cm)			
CG	162 ± 29	2.1 (−3.4 to 7.9)	0.11 (−0.18 to 0.39)
VG	160 ± 15	9.8 (5.5 to 14.3)†	0.94 (0.54 to 1.35)‖
HG	156 ± 33	24.2 (11.0 to 39.1)§¶	0.96 (0.46 to 1.45)‖
VHG	151 ± 36	19.0 (14.0 to 24.3)§#	0.68 (0.51 to 0.85)‖
20-cm drop jump reactive strength index ($mm \cdot ms^{-1}$)			
CG	1.42 ± 0.41	3.4 (−1.9 to 9.0)	0.12 (−0.07 to 0.30)
VG	1.26 ± 0.20	15.7 (12.1 to 19.5)§#	0.90 (0.71 to 1.10)‖
HG	1.32 ± 0.36	12.1 (4.8 to 19.9)†	0.41 (0.17 to 0.65)‡
VHG	1.17 ± 0.41	17.1 (13.8 to 20.6)§#	0.62 (0.34 to 0.50)‖
Multiple 5 bounds test (cm)			
CG	833 ± 166	2.2 (−3.6 to 8.4)	0.11 (−0.18 to 0.39)
VG	840 ± 86.4	7.0 (3.0 to 11.1)	0.53 (0.24 to 0.83)‡
HG	862 ± 167	13.7 (10.2 to 17.4)§#	0.62 (0.47 to 0.77)‖
VHG	810 ± 163	13.0 (6.1 to 20.3)§#	0.63 (0.30 to 0.95)‖

*VG = vertical plyometric training group; HG = horizontal plyometric training group; VHG = combined vertical + horizontal plyometric training group.
†Significant difference pre- to posttraining ($p \leq 0.05$).
‡Small standardized effect.
§Significant difference pre- to posttraining ($p < 0.01$).
‖Moderate standardized effect.
¶Significant difference with the CG posttraining ($p < 0.01$).
#Significant difference with the CG posttraining ($p \leq 0.05$).

at 0, 15, and 30 m and leveled ~0.7 m above the floor (i.e., hip level) to capture the trunk movement rather than a false trigger from a limb. The starting position was standardized to a still split standing position with the toe of the preferred foot forward and behind the starting line. Sprint start was given by a random sound, which triggers timing. The CODS test has been described elsewhere (31), and the timing system and procedures were the same as the 30-m sprint. For the MKV, participants kicked a size 5 soccer ball (Nike Seitiro, FIFA certified) for maximal velocity measured by a radar gun (Sports Radar Speed Gun SR3600; Sports Radar, Homosassa, FL), according to a previously described protocol (2). Basically, participants performed a maximal instep kick with their dominant leg after a run up of 2 strides, directed toward a goal net with a cue to aim (i.e., a vertical square target placed in its center) to increase the reliability of the test. The distance between the ball and the target was 4 m. Participants were given 2 practice and 3 valid maximal trials, with ≥1 minute of rest between trials.

On day 3, bilateral balance and the Yo-Yo IR1 were completed. As previously reported for balance testing (1), participants completed 2 stability tests performed on a balance platform at a sample rate of 1,000 Hz (Bertec BP5050 balance plate platform; Bertec, Corp., Columbus, OH, USA): (a) normal stance, eyes open and (b) normal stance, eyes closed. The average of 2 trials for each test was used for subsequent analysis. Both anterior-posterior and medial-lateral data were collected during each trial. The Yo-Yo IR1 test was executed as previously described (19). Before testing, participants perform a warm-up consisting of the first 4 running bouts in the test. Participants achieved a mean of 206 $b \cdot min^{-1}$ (i.e., 98% of theoretical maximal heart rate [220-age]) at the end of the test, suggesting maximal effort.

Training Design

The current experiment was completed during competition period. Participants performed plyometric drills as a substitute for some soccer drills within the usual 90-minute

Table 4. Training effects (with 90% confidence limits) for the soccer-specific explosive and endurance performance variables for the CG ($n = 10$), VG ($n = 10$), HG ($n = 10$), and VHG ($n = 10$).*

	Baseline mean ± *SD*	Performance change (%)	Magnitude of training effect
Maximal kicking velocity ($km \cdot h^{-1}$)			
CG	63.0 ± 15.5	4.1 (−2.4 to 11.0)	0.18 (−0.11 to 0.46)
VG	60.6 ± 6.0	7.1 (−1.6 to 16.5)	0.47 (−0.11 to 1.06)†
HG	59.8 ± 16.1	11.1 (5.8 to 16.7)	0.36 (0.19 to 0.53)†
VHG	58.3 ± 15.9	15.5 (6.8 to 24.1)‡§	0.67 (0.31 to 1.02)‖
15-m sprint time (s)			
CG	3.37 ± 0.26	1.7 (−1.8 to 5.4)	0.18 (−0.19 to 0.56)
VG	3.46 ± 0.15	−3.5 (−7.7 to 0.8)	−0.49 (−1.09 to 0.11)†
HG	3.42 ± 0.33	−5.1 (−8.5 to −1.6)‡	−0.55 (−0.94 to −0.17)†
VHG	3.51 ± 0.20	−6.0 (−8.4 to −3.4)§¶	−0.99 (−1.41 to −0.56)‖
30-m sprint time (s)			
CG	5.93 ± 0.63	−1.0 (−5.0 to 3.2)	−0.07 (−0.39 to 0.24)
VG	6.04 ± 0.41	−2.8 (−9.0 to 3.9)	−0.30 (−0.99 to 0.40)†
HG	5.98 ± 0.63	−4.0 (−5.2 to −2.8)‡	−0.37 (−0.48 to −0.26)†
VHG	6.13 ± 0.52	−5.8 (−7.9 to −3.7)§	−0.63 (−0.87 to −0.40)‖
Change of direction speed test time (s)			
CG	5.30 ± 0.48	1.1 (−3.0 to 5.3)	0.09 (−0.27 to 0.46)
VG	5.31 ± 0.27	−2.5 (−5.4 to 0.4)	−0.43 (−0.93 to 0.07)†
HG	5.36 ± 0.45	−1.9 (−6.2 to 2.6)	−0.21 (−0.71 to 0.29)†
VHG	5.36 ± 0.52	−5.1 (−8.5 to −1.6)‡§	−0.70 (−1.02 to −0.18)‖
Yo-Yo intermittent recovery level 1 test (m)			
CG	742 ± 228	6.6 (1.5 to 12.0)	0.23 (0.05 to 0.41)†
VG	686 ± 176	11.0 (5.9 to 16.4)‡	0.41 (0.22 to 0.59)†
HG	786 ± 329	15.1 (−1.4 to 34.4)‡	0.35 (−0.04 to 0.74)†
VHG	684 ± 331	15.5 (7.0 to 24.8)‡	0.31 (14.0 to 0.47)†

*VG = vertical plyometric training group; HG = horizontal plyometric training group; VHG = combined vertical + horizontal plyometric training group.
†Small standardized effect.
‡Significant difference pre- to posttraining ($p \le 0.05$).
§Significant difference with the CG posttraining ($p \le 0.05$).
‖Moderate standardized effect.
¶Significant difference pre- to posttraining ($p < 0.01$).

practice twice per week for 6 weeks. Before beginning the training period, participants were instructed to properly execute all the exercises to be performed during this period. In addition, all training sessions were supervised using a trainer to player ratio of 1:4, and particular attention was paid to demonstration and execution. The plyometric drills were performed just after the warm-up and separated with a minimum of 48 hours (including games). All groups completed the same amount of total jumps, using the same surface and time of the day for training, with the same rest intervals between jumps (i.e., 15 seconds for acyclic jumps) and series (i.e., 60 seconds). Aside from the formal training intervention, all participants attended to their regular physical education classes.

Vertical plyometric training group and HG executed horizontal and vertical exercises, respectively, whereas VHG combined them. All groups use arm swing during jumps, combining cyclic and acyclic, in addition to unilateral and bilateral jumps. Participants were asked to achieve maximal vertical height and horizontal distance for acyclic jumps and with minimum ground contact time for cyclic jumps. Maximal intensity during training was verified in a randomly assigned subsample of participants (2 from each plyometric group; $n = 6$) during 2 randomly assigned training sessions, by measuring contact times, height, and distance of jumps drills, using the same procedures as during testing. A detailed description of the training program is depicted in Table 2.

To control that all soccer players receive the training load during intervention, the session rating of perceived exertion (RPE) was determined as previously described (17) and is reported in Table 1. Briefly, each athlete's session RPE was collected about 30 minutes after each soccer training session and game to ensure that the perceived effort was referred to the whole session rather than the most recent exercise intensity. In this study, the Chilean translation of the 10-point category ratio scale (CR10-scale) modified by Foster et al. (11) was used. This scale was modified to better reflect the Chilean idiomatic English.

Table 5. Training effects (with 90% confidence limits) for the balance performance variables for the CG ($n = 10$), VG ($n = 10$), HG ($n = 10$), and VHG ($n = 10$).*

Balance condition	Baseline mean ± *SD*	Performance change (%)	Magnitude of training effect
Anterior-posterior normal stance eyes open (cm)			
CG	0.497 ± 0.130	−4.3 (−11.3 to 3.2)	−0.15 (−0.42 to 0.11)
VG	0.424 ± 0.110	−9.9 (−11.4 to −8.5)	−0.35 (−0.41 to −0.30)†
HG	0.521 ± 0.199	−11.2 (−13.3 to −9.0)‡	−0.32 (−0.38 to −0.25)†
VHG	0.467 ± 0.165	−16.2 (−23.2 to −8.6)§‖	−0.49 (−0.74 to −0.25)†
Medial-lateral normal stance eyes open (cm)			
CG	0.342 ± 0.106	−2.8 (−6.9 to 1.5)	−0.08 (−0.19 to 0.04)
VG	0.324 ± 0.106	−10.7 (−19.4 to −1.1)§	−0.29 (−0.55 to −0.03)†
HG	0.325 ± 0.071	−7.6 (−11.6 to −3.5)	−0.35 (−0.54 to −0.16)†
VHG	0.332 ± 0.093	−14.8 (−16.5 to −13.0)§	−0.43 (−0.48 to −0.37)†
Anterior-posterior normal stance eyes closed (cm)			
CG	0.748 ± 0.221	−4.2 (−16.3 to 9.7)	−0.13 (−0.55 to 0.29)
VG	0.601 ± 0.237	−8.9 (−14.2 to −3.3)	−0.23 (−0.38 to −0.08)†
HG	0.637 ± 0.182	−12.7 (−14.1 to −11.3)	−0.46 (−0.51 to −0.4)†
VHG	0.703 ± 0.208	−18.7 (−22.7 to −14.6)§‖	−0.62 (−0.77 to −0.47)¶
Medial-lateral normal stance eyes closed (cm)			
CG	0.317 ± 0.099	−4.4 (−8.5 to 0.2)	−0.13 (−0.24 to −0.01)
VG	0.384 ± 0.113	−11.3 (−13.0 to −9.5)‡	−0.30 (−0.35 to −0.25)†
HG	0.307 ± 0.147	−9.4 (−18.4 to 0.7)‡	−0.23 (−0.48 to 0.02)†
VHG	0.344 ± 0.075	−17.3 (−21.7 to −12.7)§	−0.86 (−1.11 to −0.61)¶

*VG = vertical plyometric training group; HG = horizontal plyometric training group; VHG = combined vertical + horizontal plyometric training group.
†Small standardized effect.
‡Significant difference pre- to posttraining ($p \le 0.05$).
§Significant difference pre- to posttraining ($p < 0.01$).
‖Significant difference with the CG posttraining ($p \le 0.05$).
¶Moderate standardized effect.

Table 6. Differences between CG ($n = 10$), VG ($n = 10$), HG ($n = 10$), and VHG ($n = 10$) in the training effects (with 90% confidence limits) on performance variables.*†

	VG-CG	HG-CG	VHG-CG
Vertical countermovement jump with arms	6.9 (−0.5 to 14.9) Small	2.5 (−3.1 to 8.5) Trivial	6.5 (0.4 to 14.0) Small
Horizontal countermovement jump with arms	5.4 (−0.5 to 11.6) Small	15.7 (6.1 to 26.1) Moderate	18.1 (10.6 to 26.1) Moderate
20-cm drop jump reactive strength index	11.5 (4.9 to 18.4) Small	7.9 (−1.2 to 17.9) Small	14.1 (7.7 to 20.9) Small
Multiple 5 bounds test	4.1 (−2.8 to 11.4) Small	9.9 (3.3 to 17.0) Small	11.1 (1.8 to 21.2) Small
Maximal kicking velocity	2.5 (−8.1 to 14.4) Trivial	6.8 (−1.5 to 15.8) Small	8.4 (−1.2 to 19.0) Small
15-m sprint time	−4.7 (−10.1 to 0.9) Moderate	−6.8 (−11.5 to −1.9) Moderate	−8.0 (−11.9 to −3.9) Moderate
30-m sprint time	−0.8 (−8.3 to 7.4) Trivial	−2.5 (−6.5 to 1.6) Small	−5.3 (−9.5 to −0.9) Small
Change of direction speed test time	−2.8 (−10.2 to 5.3) Small	−2.7 (−8.5 to 3.5) Small	−5.1 (−9.9 to −0.1) Small
Yo-Yo intermittent recovery level 1 test	6.3 (0.6 to 12.4) Small	5.3 (−11.4 to 25.1) Trivial	7.9 (−1.9 to 18.7) Small
Anterior-posterior normal stance eyes open	−6.5 (−13.4 to 1.0) Small	−6.2 (13.3 to 1.4) Trivial	−8.8 (−16.5 to −0.4) Small
Medial-lateral normal stance eyes open	−11.8 (−19.2 to −3.8) Small	−4.8 (−10.5 to 1.3) Trivial	−12.2 (−16.2 to −7.9) Small
Anterior-posterior normal stance eyes closed	−4.7 (−17.7 to 10.2) Trivial	−8.9 (−20.6 to 4.4) Small	−14.4 (−25.8 to −1.3) Small
Medial-lateral normal stance eyes closed	−6.7 (−10.8 to −2.3) Trivial	−5.3 (−16.3 to 7.1) Trivial	−13.6 (−19.5 to −7.2) Small
	HG-VG	**VHG-VG**	**VHG-HG**
Vertical countermovement jump with arms	−3.8 (−9.0 to 1.8) Small	0.0 (−6.5 to 7.0) Trivial	3.6 (−2.0 to 9.4) Trivial
Horizontal countermovement jump with arms	7.6 (−0.7 to 16.5) Small	9.8 (4.0 to 16.0) Small	−2.9 (−13.7 to 9.2) Trivial
20-cm drop jump reactive strength index	−3.6 (−11.0 to 4.5) Trivial	2.0 (−2.1 to 6.2) Trivial	5.3 (−2.0 to 13.0) Trivial
Multiple 5 bounds test	5.0 (0.5 to 9.7) Small	6.1 (−1.8 to 14.6) Small	−0.2 (−7.4 to 7.6) Trivial
Maximal kicking velocity	3.9 (−5.7 to 14.4) Trivial	5.4 (−5.2 to 17.3) Small	1.6 (−6.7 to 10.6) Trivial
15-m sprint time	−1.7 (−7.2 to 4.0) Small	−3.0 (−7.8 to 2.0) Small	−1.4 (−5.6 to 3.0) Trivial
30-m sprint time	−0.7 (−7.1 to 6.1) Trivial	−3.5 (−9.9 to 3.3) Small	−2.3 (−4.8 to 0.3) Small
Change of direction speed test time	0.9 (−4.6 to 6.7) Trivial	−1.6 (−5.8 to 2.8) Small	−2.2 (−7.4 to 3.2) Small
Yo-Yo intermittent recovery level 1 test	1.1 (−14.9 to 20.1) Trivial	3.6 (−5.7 to 13.9) Trivial	−0.1 (−15.8 to 18.6) Trivial
Anterior-posterior normal stance eyes open	−0.4 (−2.7 to 1.9) Trivial	−3.2 (−8.3 to 2.2) Trivial	−1.8 (−7.1 to 3.8) Trivial
Medial-lateral normal stance eyes open	3.7 (−7.1 to 15.8) Trivial	−4.3 (−13.8 to 6.2) Trivial	−7.6 (−11.9 to −3.1) Small
Anterior-posterior normal stance eyes closed	−4.2 (−9.9 to 1.8) Trivial	−10.0 (−16.5 to −2.9) Small	−6.1 (−11.0 to −0.8) Small
Medial-lateral normal stance eyes closed	2.0 (−9.6 to 15.1) Trivial	−6.9 (−12.7 to −0.7) Small	−8.9 (−18.9 to 2.4) Small

*VG = vertical plyometric training group; HG = horizontal plyometric training group; VHG = combined vertical + horizontal plyometric training group.
†Effects are shown in percentage units and probabilistic inferences about the true standardized magnitude.

Statistical Analyses

All values are reported as mean ± *SD*. Relative changes (%) in performance and standardized effects (SE) are expressed with 90% confidence limits. Normality and homoscedasticity assumptions were checked, respectively, with Shapiro-Wilk and Levene tests. To determine the effect of the intervention on performance adaptations, a 2-way analysis of variance with repeated measurements (4 groups × 2 times) was applied. When a significant F value was achieved across time or between groups, Tukey post hoc procedures were performed to locate the pairwise differences between the mean values. The α level was set at $p \le 0.05$ for statistical significance. All statistical calculations were performed using STATISTICA statistical package (version 8.0; StatSoft, Inc., Tulsa, OK, USA). In addition to this null hypothesis testing, data were also assessed using magnitude of based inference statistics (16). Threshold values for assessing magnitudes of SE (changes as a fraction or multiple of baseline *SD*) were 0.20, 0.60, 1.2, and 2.0 for small, moderate, large, and very large, respectively (16). Magnitudes of differences in training effects between groups were evaluated nonclinically (16): if the confidence interval overlapped thresholds for substantial positive and negative values, the effect was deemed unclear. The effect was otherwise clear and reported as the magnitude of the observed value with a qualitative probability, as above. We obtained a relatively high intraclass correlation coefficient and low coefficient of variation for the vertical countermovement jump with arms test (0.91 and 3.5%, respectively), horizontal countermovement jump with arms test (0.95 and 3.7%, respectively), 20-cm drop jump RSI (0.94 and 3.7%, respectively), multiple 5 bounds test (0.95 and 4.8%, respectively), MKV test (≥0.91 and <4.4%, respectively), 15-m sprint time test (0.93 and 2.5%, respectively), 30-m sprint time test (0.95 and 1.9%, respectively), CODS test (0.91 and 3.5%, respectively), anterior-posterior normal stance eyes open test (0.94 and 4.1%, respectively), medial-lateral normal stance eyes open test (0.94 and 4.1%, respectively), anterior-posterior normal stance eyes closed test (0.81 and 6.9%, respectively), and medial-lateral normal stance eyes closed test (0.94 and 4.3%, respectively).

Results

Before training, no significant differences were observed between groups in vertical CMJ, horizontal CMJ, RSI, multiple bound test (Table 3), kicking velocity, 15-m and 30-m sprint time, CODS, Yo-Yo IR1 (Table 4), or balance (Table 5) test performance.

No statistically significant changes in the CG were observed, although a small meaningful change (0.23 SE) in Yo-Yo IR1 was noted (Table 4). In comparison with the CG, horizontal training groups (i.e., HG and VHG) showed a significantly ($p \le 0.05$) higher performance change and SE in horizontal CMJ and multiple bound test, whereas vertical training groups (i.e., VG and VHG) showed a significantly ($p \le 0.05$) higher performance change and SE in the RSI (Table 3). Also, in comparison with the CG, the VHG showed a significantly ($p \le 0.05$) higher performance change and SE in kicking velocity, 15-m sprint time, 30-m sprint time, CODS, Yo-Yo IR1 (Table 4), and balance (both, medial-lateral and anterior-posterior) test (Table 5).

Except for the HG and VG groups in the vertical CMJ and multiple bound test (respectively), all plyometric training groups showed a significant ($p \le 0.05$) increase and small-to-moderate meaningful SE in vertical CMJ, horizontal CMJ, RSI, and multiple bound test (Table 3). No statistically significant differences in performance changes were observed between training groups (Table 3), although vertical training was more effective to a small effect at improving vertical CMJ performance in comparison with horizontal training. In addition, horizontal training (i.e., HG and VHG) was more effective to a small effect than vertical training (i.e., VG) at improving horizontal CMJ and multiple bound test performance (Table 6).

Although the 3 plyometric training groups had a small to moderate meaningful SE in kicking velocity, 15-m and 30-m sprint, CODS, Yo-Yo IR1 (Table 4), and balance test (Table 5), only the combined vertical and horizontal program had a statistically significant ($p \le 0.05$) effect in all performance test. In addition, the combined vertical and horizontal training group improved more (small effect) than the VG and HG in 30-m sprint, CODS, and balance performance test and also improved more (small effect) than the VG in kicking velocity and 15-m sprint performance test (Table 6). The HG improved more (small effect) than the VG in 15-m sprint performance test to a small effect (Table 6).

Discussion

The results of this study indicated a specificity of training effect, where the use of vertical exercises induced a significantly greater increase in performance tests in the vertical plane, whereas the use of horizontal exercises induced a significantly greater increase in performance tests in the horizontal plane. Also, the results indicate that, compared with CG, only a combination of vertical and horizontal training stimulus achieved a significantly greater increase in almost all (i.e., 9 of 13) performance measures. Finally, our results demonstrated that the combination of soccer drills and specific explosive training with no additional training time in-season optimizes general and soccer-specific explosiveness, balance, and endurance performance in young soccer players.

The results from the VCMJ, HCMJ, RSI20, and MB5 test all demonstrated the training principle of specificity in plyometric training (25,41), which can be explained by factors such as eccentric overloading, segmental coordination, and muscular activation (45). Groups trained in the specific direction of the jump test consistently improved to a greater extend (Table 6) and increased the gap with the CG (Table 3). The magnitude change in VCMJ was similar or even higher than previously reported for similar slow SSC muscle actions (SE = 0.51–0.75) (10,31,50) after explosive training with young soccer players using an intervention of similar duration or number of sessions. The magnitude change in RSI20 was similar than previously reported

(SE = 0.41–0.90) (39) after plyometric training with young soccer players. Considering the necessity to produce a high rate of force development in explosive actions (29), the improvement in RSI may have enhanced physical parameters of game performance. The improvement observed could have been induced by various neuromuscular adaptations (23); however, because no physiological measurements were made, only speculations are possibly. Finally, the magnitude change in MB5 in this study was similar than previously reported (SE = 0.62–0.63) (10,31) after explosive training with young soccer players. An increase in MB5 may be achieved by motor coordination adaptations, which can be related to the specificity of movements used during training (10). The fact that the HG and VHG performed horizontal plyometric drills, achieving a significantly higher performance change in MB5 than the CG, would support such contention considering the horizontal nature of the MB5.

Although previously it has been shown that a combination of vertical and horizontal (46) or unilateral and bilateral (12) plyometric exercises can increase MKV, this is the first study to compare the effects of vertical, horizontal, and combined vertical and horizontal jumps, including unilateral and bilateral drills, in MKV of young soccer players. All training programs induced a meaningful increase in MKV performance, but the VHG improved more to a small effect and significantly in MKV compared with VG and CG (Tables 4 and 6), suggesting that a combination of vertical and horizontal exercises may induce higher MKV performance changes in young soccer players than plyometric drills applied in only 1 plane of direction. Although differences in type of training program applied make comparisons between different studies difficult, others have found significant increases in kicking performance after plyometric training in young soccer players (12,24,32), in both dominant and nondominant kicking legs (12). It has been suggested that the increased MKV performance may be attributed to increased strength and power of legs' extensor muscles (32), agonists-antagonists muscle coordination, and greater recruitment of motor units (12). It may be that these neuromuscular and strength-power adaptations had an effect on the biomechanical factors related to kicking performance, such as maximum linear velocity of the toe, ankle, knee, and hip at ball contact (20), which may have cumulatively or individually contributed to a higher ball kicking velocity.

All training groups showed a meaningful decrease (i.e., SE between 0.30 and 0.99) in 15 and 30-m sprint times, but only the VHG demonstrated a significant ($p \leq 0.05$) change compared with CG (Table 4). The results also demonstrated a small beneficial effect of horizontal stimulus for 15-m sprint time and implementing some vertical stimulus to decrease 30-m sprint time (Table 6). Although others have found similar effects (SE = 0.29–1.1) in sprint performance after plyometric training in young soccer players (31–32), this was the first study to compare the effects of vertical, horizontal, and combined vertical and horizontal plyometric training in 15 and 30-m sprint times in young soccer players. As the training intervention in the HG and VHG incorporates horizontal stimulus, this may had increased the chances to gain adaptations considering the importance of horizontal force production and application in sprint performance (18,34). This agrees with previous studies, where vertical plyometric training fails to improve sprint performance in young soccer players (39). The higher increase in sprint performance in VHG coincides with previous results (48). The CG did not exhibit a meaningful or statistically significant improvement in sprint performance in this study, and conducting soccer training only in-season may even induce decay in sprint performance (39). These observations reinforce the value of an independent explosive training program to enhance acceleration and maximal sprint ability of young soccer players during their in-season. The increase in both acceleration and maximal running velocity can be related to leg power (7), which can be increased with plyometric training in young soccer players (6,38). Although acceleration improvement may be more related with the slower SSC and rate of power production nature of the acyclic jumps (i.e., countermovement jumps) (8) performed during training, leg stiffness developed through stiffer plyometric exercises (i.e., cyclic jumps) may transfer to maximal running velocity improvement (7). Therefore, in addition to the more favorable sprint performance changes observed after the combination of vertical and horizontal plyometric exercises in this study, these results reinforce the need to add variation in plyometric cycle (i.e., cyclic and acyclic movement) to improve the different neuromuscular variables related with sprint performance.

This study demonstrated that all plyometric training stimulus induced a meaningful increase in CODS performance, with a small to moderate SE (Table 4). However, only VHG showed a statistically significant increase and significant change in comparison with the CG (Table 4). Also, the VHG program was more effective at improving CODS performance compared with VG and HG to a small effect (Table 6). All training programs contained exercises designed to induce short contact times and subsequently increase RSI, which may predict the ability to change directions while running (51). Also, an improved CODS performance may be related to changes in power development or increased eccentric strength level, which can impact COD performance during the deceleration phase (47). This study demonstrated that combined horizontal and vertical plyometric training was more efficient at driving multiple explosive-related adaptations, which seemed to have transferred to CODS performance in young soccer players. The important differences between CODS tests used among studies make results comparison difficult; however, using the same CODS test as in our study, others have found an even greater change in performance after plyometric training in young soccer players (9.7%; SE = 2.8) (31). Because greater change occurred in the multiplane training stimulus group in this study, it can be argued that greater magnitude of change in the study of Meylan and Malatesta (31) may be because of more variety in stimulus but also the intervention duration in comparison with this study.

Our results demonstrated a significant and small meaningful increase in Yo-Yo IR1 performance in all training groups (Table 4). In young soccer players, plyometric training may not induce a significant increase in underlying aerobic qualities such as $\dot{V}O_2$max (32) or lactate threshold (14) but may still have a meaningful effect on a intermittent recovery endurance performance test with repeated changes of direction (50). This discrepancy is likely related to the fact that the change in explosive performance after a plyometric training can contribute to the change of direction during an intermittent test (e.g., Yo-Yo IR1 or 30–15 intermittent fitness test) with change of direction (3) or running economy (26), independently from the influence on $\dot{V}O_2$max (32) or lactate threshold (14). As previously stated, all training groups demonstrated a meaningful change in reactive strength (i.e., RSI20), which may transfer into improved running economy and enhance aerobic performance independently of others aerobic indicators (e.g., $\dot{V}O_2$max or lactate threshold) (37).

A novel aspect of this study was to analyze the effect of plyometric training on youth soccer players balance and the different effect of various plyometric training interventions on balance capability. Our results showed that although all training groups achieve a meaningful change in all measures of anterior-posterior and medial-lateral balance (Table 5), only VHG achieved a significantly higher performance change in anterior-posterior balance in comparison with CG (Table 5) and also a higher SE to a small effect in both medial-lateral and anterior-posterior balance compared with VG, HG, and CG (Table 6). Improvements in balance after plyometric training have already been shown after 6 weeks (36,52) and in young athletes (5,36). Because balance improvements may not only result in an increased athletic performance but also in reduced lower-extremity injury risk in soccer players (52), our results reinforce the value of plyometric training as an effective strategy to reduce injury risk in young athletes. There was no significant difference in medial-lateral balance postintervention in all the groups (Table 5). As the training was anterior-posterior in nature for all groups, which resulted in better balance in that plane, there is an argument to also include medial-lateral plyometric-based exercises to improve the associated balance capability. The improvement in balance performance may be related to improved cocontraction of lower-extremity muscles (33) or changes in proprioception and neuromuscular control (15), which appeared to be direction specific based on this study. Furthermore, to enhance functional balance, initial emphasis on landing mechanics (i.e., acyclic jumps) during plyometric training may prove more beneficial for complex high speed unilateral repetitive dynamic tasks taxing postural control (i.e., sprinting, change of direction) as compared with fast SSC plyometrics (i.e., cyclic) (5).

Practical Applications

The replacement of some soccer drills with high-intensity plyometric exercises may positively affect jump, sprint, kicking, CODS, endurance, and balance performance in young soccer players during the in-season period. These adaptations can be achieved in the short-term and may potentially increase competitive performance and may reduce injury risk. When programming, the practitioner must be cognizant of the training response being specific to the direction of force production in the plyometric drills. The combination of vertical and horizontal jump stimulus was more advantageous to youth soccer players to gain meaningful improvements in explosive performance, balance, and intermittent aerobic capacity than vertical or horizontal plyometric stimulus alone. Such approach appeared relevant to the multidirectional nature of soccer but may not have the same positive effect where a direction of force production is dominant (e.g., volleyball). As most sports are unilateral in nature, it is recommended to find the right balance and progression between bilateral and unilateral training stimulus, although whether a training stimulus is more advantageous than the other is still to debate. A combination of acyclic to cyclic jump may also prove relevant to the specificity of the sport and the level of athlete movement competency and dynamic balance. Finally, although plyometric training can induce an increase in explosive, endurance, and balance performance in young soccer players, to optimize training adaptations, this training strategy should be adequately applied in a more complex training plan that incorporates other explosive (e.g., sprints), endurance, technical, and tactical-oriented training methods.

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ARTÍCULO 6

Effect of Progressive Volume-Based Overload During Plyometric Training on Explosive and Endurance Performance in Young Soccer Players

Rodrigo Ramírez-Campillo,[1,2] Carlos Henríquez-Olguín,[2] Carlos Burgos,[2] David C. Andrade,[2] Daniel Zapata,[2] Cristian Martínez,[3] Cristian Álvarez,[4] Eduardo I. Baez,[5] Mauricio Castro-Sepúlveda,[6] Luis Peñailillo,[6] and Mikel Izquierdo[7,8]

[1]*Department of Physical Activity Sciences, University of Los Lagos, Osorno, Chile;* [2]*Laboratory of Exercise Sciences, MEDS Clinic, Santiago, Chile;* [3]*Department of Physical Education, Sport and Recreation, University of La Frontera, Temuco, Chile;* [4]*Family Health Center of Los Lagos, Health Promotion Program, Los Lagos, Chile;* [5]*Department of Sport and Recreation, University of Playa Ancha, Valparaiso, Chile;* [6]*Exercise Science Laboratory, School of Kinesiology, Faculty of Medicine, University of Finis Terrae, Santiago, Chile;* [7]*Faculty of Physical Culture, Sport and Recreation, University of Santo Tomás, Bogotá DC, Colombia; and* [8]*Department of Health Sciences, Public University of Navarre, Navarre, Spain*

Abstract

Ramirez-Campillo, R, Henriquez-Olguin, C, Burgos, C, Andrade, DC, Zapata, D, Martinez, C, Álvarez, C, Baez, EI, Castro-Sepúlveda, M, Peñailillo, L, and Izquierdo, M. Effect of progressive volume-based overload during plyometric training on explosive and endurance performance in young soccer players. *J Strength Cond Res* 29(7): 1884–1893, 2015—The purpose of the study was to compare the effects of progressive volume-based overload with constant volume-based overload on muscle explosive and endurance performance adaptations during a biweekly short-term (i.e., 6 weeks) plyometric training intervention in young soccer players. Three groups of young soccer players (age 13.0 ± 2.3 years) were divided into: control (CG; $n = 8$) and plyometric training with (PPT; $n = 8$) and without (NPPT; $n = 8$) a progressive increase in volume (i.e., 16 jumps per leg per week, with an initial volume of 80 jumps per leg each session). Bilateral and unilateral horizontal and vertical countermovement jump with arms (CMJA), 20-cm drop jump reactive strength index (RSI20), maximal kicking velocity (MKV), 10-m sprint, change of direction speed (CODS), and Yo-Yo intermittent recovery level 1 test (Yo-Yo IR1) were measured. Although both experimental groups significantly increased CMJA, RSI20, CODS, and endurance performance, only PPT showed a significant improvement in MKV and 10-m sprint time. In addition, only PPT showed a significantly higher performance improvement in jumping, MKV, and Yo-Yo IR1 compared with CG. Also, PPT showed higher meaningful improvement compared with NPPT in all (except 1) jump performance measures. Furthermore, although PPT involved a higher total volume compared with NPPT, training efficiency (i.e., percentage change in performance/total jump volume) was similar between groups. Our results show that PPT and NPPT ensured significant improvement in muscle explosive and endurance performance measures. However, a progressive increase in plyometric training volume seems more advantageous to induce soccer-specific performance improvements.

Key Words explosive strength, stretch-shortening cycle, team sports, strength training, football

Address correspondence to Mikel Izquierdo, mikel.izquierdo@gmail.com.

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Introduction

It has been shown that explosive muscle actions such as sprinting, jumping, and change of direction speed (CODS), along with aerobic power, influence game performance in young soccer players (3). For instance, although sprinting contributes only up to 3% of the total game distance covered by young soccer players (3), most crucial moments (e.g., scoring) depend on it (39). In addition, along with the relevance of neuromuscular pathway training from an explosive-development stand point at young ages (i.e., *trainability window*) (25), soccer-related explosive activities may be important qualities not only at young level (12,45) but also at a later stage of a player's career (18). Therefore, it has been proposed that such explosive actions could affect game performance of soccer players and that they have to be trained independently from aerobic performance from a young age (13).

Plyometric training (i.e., an explosive-type strength training method) has been established as a sport-specific, effective, time-saving, economical, and easy-to-implement training strategy in soccer facilities with young soccer players, which has shown to induce improvements in several explosive (e.g., jump, sprint, CODS) (8,26,29) and soccer-specific endurance performance measures (46). Thus, plyometric training has been advocated as an appropriate approach to achieve soccer-related performance improvements, which can be attributed mainly to neuromuscular adaptations (23). However, although coaches and researchers have attempted to identify the primary governing factors underlying plyometric training effects, the optimal handling of program variables to maximize performance adaptations is not yet clear (41), particularly in young soccer players.

The progressive overload training principle aims to stimulate continuing adaptations and consists of progressively increasing the training loads in time, by modifying mainly the training volume and intensity (36,42). This training principle may have a positive effect on young soccer player's jump, sprint, and CODS performance during resistance training (5). More so, plyometric training with a progressive overload has been used in young soccer players (8,9,22,26,29,46), although these studies did not compare the effect of progressive overload with constant overload (i.e., they did not use a control group). Only 1 study (42) conducted in young rugby players have analyzed the independent effect of progressive intensity-based overload during plyometric training. However, to the best of our knowledge, no study has shown the effect of a progressive volume-based compared with constant volume-based overload during plyometric training in young soccer players. Therefore, the purpose of this study was to compare the effect of progressive volume-based overload with constant volume-based overload during a short-term (i.e., 6 weeks) plyometric training intervention in young soccer players during their in-season period, by replacing some of their soccer-specific technical and tactical drills. We hypothesized that a progressive increase in volume during a short-term plyometric training program would induce higher performance improvements compared with a constant volume of plyometric drills.

Methods

Experimental Approach to the Problem

This study was designed to compare the effects of a 6-week plyometric training program, with and without an increase in volume across time on several explosive and endurance performance measures in young soccer players. Sample size was computed based on the changes observed in the reactive strength index ($\Delta = 0.33$ mm·ms^{-1}; SD = 0.3) after a short-term plyometric training study performed in young soccer players (37). Thus, a total of 6 participants per group would yield a power of 80% and an alpha level of 0.05. After baseline measurements, participants were randomly assigned to a control group (CG, $n = 8$), which received only soccer training and to 2 groups that completed a plyometric training program with (PPT, $n = 8$) and without (NPPT, $n = 8$) progressive increase in training volume in 6 weeks. The randomization sequence was generated electronically and concealed until interventions were assigned. Although initially a fourth research group was considered with a total jump volume equal to that achieved by the PPT but without a progressive increase in volume (i.e., to control for the effect of volume compared with the effect of progressive volume-based overload), unfortunately this group was not incorporated because this training approach would have involved a high volume of plyometric training over hard training surface from the beginning of intervention, which may have increased the injury risk in participants. Therefore, ethical issues preclude us from including a fourth group.

Subjects

Twenty-four young (Age range 11–15 years of age) male soccer players from the same soccer club and without previous or current regular strength or plyometric training volunteered for this study. All groups participated in the same soccer club and training program (i.e., 20 minutes of technical drills; 40 minutes of tactical drills; 20 minutes of small-sided games; 40 minutes of simulated competitive games), receiving a similar soccer-related load (i.e., session rating of perceived exertion, Table 1), in addition to a similar competitive training load (i.e., 4-5 competitive games during the experimental period). Subjects were reminded to maintain their usual physical activity habits during the experiment. Weekly nonsoccer sport practice was similar between CG (1.5 ± 1.2 h·wk^{-1}), NPPT (1.6 ± 1.4 h·wk^{-1}), and PPT (1.6 ± 1.9 h·wk^{-1}). In addition, all groups received a similar volume of weekly physical education-related activity (CG = 113 ± 31 min·wk^{-1}), NPPT (113 ± 31 min·wk^{-1}), and PPT (105 ± 32 min·wk^{-1}).

Exclusion criteria were (a) potential medical problems or a history of ankle, knee, or back injury that could compromise participation or performance in the study, (b) any lower extremity reconstructive surgery in the past 2 years or unresolved musculoskeletal disorders. Individuals taking medically prescribed vitamins or minerals supplements were not excluded. Despite not pair-matching individuals based on an independent variable, there were no significant differences between group characteristics at baseline (Table 1). Participants (and their parents or guardians) were informed about the experimental procedures and about possible risks and benefits associated with participation in the study, and they signed an informed consent before the start of the study. The study was conducted in accordance with the Declaration of Helsinki and was approved by the ethics committee of the responsible department.

Testing Procedures

The participants were carefully familiarized with the measurements during several submaximal and maximal actions in 2 nonconsecutive learning sessions in 2 weeks before basal measurements. Each participant also completed several

TABLE 1. Descriptive data of the control group (CG; $n = 8$), plyometric training group with (PPT; $n = 8$) and without (NPPT; $n = 8$) a progressive increase in volume across time.

	CG	PPT	NPPT
Age (y)	13.0 ± 1.9	12.8 ± 2.8	13.0 ± 2.1
Height (cm)	159 ± 8.5	160 ± 13.4	161 ± 10.1
Body mass (kg)	53.2 ± 11.1	53.9 ± 14.1	53.8 ± 7.6
Body mass index ($kg \cdot m^{-2}$)	20.8 ± 2.3	20.6 ± 1.0	20.7 ± 2.4
Body fat (%)	14.2 ± 4.8	14.6 ± 5.8	13.7 ± 3.2
Upper-body fat (%)	15.5 ± 3.8	15.5 ± 6.5	14.8 ± 3.2
Lower-body fat (%)	13.3 ± 5.6	13.8 ± 5.3	12.6 ± 3.3
Muscle mass (%)	46.2 ± 6.8	45.1 ± 4.9	45.5 ± 2.6
Predicted years from age of peak height velocity (y)	0.4 ± 1.6	0.3 ± 2.0	0.4 ± 1.5
Session rating of perceived exertion	371 ± 243	428 ± 180	428 ± 249
Soccer experience (y)	4.1 ± 1.5	4.0 ± 1.4	4.1 ± 1.5

explosive-type actions to become familiar with the exercises used during training. Measurements were taken 1 week before and 1 week after the intervention. All tests were always administered in the same order, same time of day, and by the same investigator, who was blinded to the training group of the participants. Testing sessions were scheduled >48 hours after a match or hard physical training to minimize the influence of fatigue. All participants (and their parents or guardians) were instructed to (a) have a good night sleep (≥8 hours) before each testing day and (b) have a meal rich in carbohydrates and to be well hydrated before measurements. Participants were motivated to give their maximum effort during the performance measurements. All tests were completed in 2 days. On day 1, standing and sitting height, body mass, vertical countermovement jump with arms (CMJA), horizontal bilateral and unilateral CMJA, and 20-cm drop jump reactive strength index (RSI20) were measured (in this order). On day 2, measurements taken included a 10-m sprint test (i.e., acceleration), maximal kicking velocity test (MKV), CODS test (i.e., *t*-test), and the Yo-Yo intermittent recovery level 1 test (Yo-Yo IR1) (in this order). Ten minutes of standard warm-up (6 minutes of submaximal running with several displacements and 2 submaximal jump exercises of 20 vertical jumps and 10 longitudinal

TABLE 2. Six-week plyometric training program.*

Exercises	Set × repetitions (mode of execution)					
	Week 1†	Week 2	Week 3	Week 4	Week 5	Week 6
Horizontal left leg	2 × 5 (C)	2 × 6 (C)	2 × 7 (C)	2 × 8 (C)	2 × 9 (C)	2 × 10 (C)
	2 × 5 (A)	2 × 6 (A)	2 × 7 (A)	2 × 8 (A)	2 × 9 (A)	2 × 10 (A)
Horizontal right leg	2 × 5 (C)	2 × 6 (C)	2 × 7 (C)	2 × 8 (C)	2 × 9 (C)	2 × 10 (C)
	2 × 5 (A)	2 × 6 (A)	2 × 7 (A)	2 × 8 (A)	2 × 9 (A)	2 × 10 (A)
Vertical left leg	2 × 5 (C)	2 × 6 (C)	2 × 7 (C)	2 × 8 (C)	2 × 9 (C)	2 × 10 (C)
	2 × 5 (A)	2 × 6 (A)	2 × 7 (A)	2 × 8 (A)	2 × 9 (A)	2 × 10 (A)
Vertical right leg	2 × 5 (C)	2 × 6 (C)	2 × 7 (C)	2 × 8 (C)	2 × 9 (C)	2 × 10 (C)
	2 × 5 (A)	2 × 6 (A)	2 × 7 (A)	2 × 8 (A)	2 × 9 (A)	2 × 10 (A)
Bilateral vertical	2 × 5 (C)	2 × 6 (C)	2 × 7 (C)	2 × 8 (C)	2 × 9 (C)	2 × 10 (C)
	2 × 5 (A)	2 × 6 (A)	2 × 7 (A)	2 × 8 (A)	2 × 9 (A)	2 × 10 (A)
Bilateral horizontal	2 × 5 (C)	2 × 6 (C)	2 × 7 (C)	2 × 8 (C)	2 × 9 (C)	2 × 10 (C)
	2 × 5 (A)	2 × 6 (A)	2 × 7 (A)	2 × 8 (A)	2 × 9 (A)	2 × 10 (A)

*The group that did not progressively increase training volume across time used the volume depicted in week 1 during the 6 weeks of training.

†The volume of contacts described is per session and that remains the same for the 2 plyometric training session completed each week.

C = cyclic; A = acyclic.

Table 3. Training effects (with 90% confidence limits) for the jump performance variables for the control group (CG; $n = 8$) and plyometric training group with (PPT; $n = 8$) and without (NPPT; $n = 8$) a progressive increase in volume across time.

	Baseline mean ± SD	Performance change (%)	Magnitude of training effect
Vertical countermovement jump with arms (cm)			
CG	29.2 ± 9.4	2.6 (−4.0 to 9.6)	0.07 (−0.11 to 0.24)
NPPT	28.5 ± 10.4	10.9 (−2.0 to 25.4)[a]	0.23 (−0.04 to 0.50)*
PPT	27.9 ± 8.7	16.6 (1.6 to 36.8)[a]	0.54 (0.06 to 1.02)*
Horizontal countermovement jump with arms (cm)			
CG	154 ± 35.3	−1.8 (−5.7 to 2.3)	−0.07 (−0.22 to 0.08)
NPPT	163 ± 42.6	4.6 (−2.9 to 12.7)	0.13 (−0.09 to 0.35)
PPT	160 ± 27.9	7.9 (0.3 to 16.0)[a,d]	0.40 (0.02 to 0.79)*
Right leg horizontal countermovement jump with arms (cm)			
CG	135 ± 33.4	4.0 (−2.9 to 11.4)	0.14 (−0.10 to 0.39)
NPPT	138 ± 35.3	2.8 (−3.7 to 9.6)	0.08 (−0.11 to 0.28)
PPT	138 ± 27.7	13.5 (3.4 to 24.7)[b,d]	0.59 (0.15 to 1.02)*
Left leg horizontal countermovement jump with arms (cm)			
CG	135 ± 30.1	1.0 (−4.4 to 6.7)	0.04 (−0.17 to 0.25)
NPPT	136 ± 42.9	14.1 (6.5 to 22.3)[b]	0.36 (0.17 to 0.55)*
PPT	134 ± 27.0	21.2 (10.8 to 32.7)[c,e]	0.95 (0.50 to 1.40)†
20-cm drop jump reactive strength index ($mm \cdot ms^{-1}$)			
CG	0.080 ± 0.029	−1.9 (−20.4 to 21.1)	−0.04 (−0.44 to 0.37)
NPPT	0.062 ± 0.022	14.0 (−15.2 to 53.3)[a]	0.23 (−0.29 to 0.75)*
PPT	0.072 ± 0.034	36.1 (1.7 to 82.3)[a,d]	0.73 (0.0.4 to 1.43)†

*Small standardized effect.
†Moderate standardized effect; a, b, and c denote significant difference pretraining to posttraining ($p \le 0.05$, $p < 0.01$, and $p < 0.001$, respectively). d and e: denote significant difference with the CG after training ($p \le 0.05$ and $p < 0.01$, respectively).

jumps) were executed before each testing day. Participants were instructed to use the same athletic shoes and clothes during the preintervention and postintervention testing. All tests were conducted indoor on a wooden surface. At least 2 minutes of rest was allowed between each trial to reduce the effects of fatigue. While waiting, participants performed low-intensity activity to maintain physiological readiness for the next test. The best score of 3 trials was recorded for all performance tests, apart from the single Yo-Yo IR1.

Anthropometric Measurements. Height and sitting height were measured using a stadiometer (Bodymeter 206; SECA, Hamburg, Germany), and body mass was measured with an electrical bioimpedance scale (BF 100_Body Complete; Beurer, Ulm, Germany). Furthermore, the athletes' maturity status was determined using predicted years from age of peak height velocity (PHV) (i.e., PHV offset) (31). To predict PHV offset, the following variables were considered: gender, date of birth, date of measurement, height, sitting height, and body mass. A growth utility program (http://taurus.usask.ca/growthutility/phv_ui.cfm?type=1) based on the study by Mirwald et al. (31) was used to analyze values for these variables and calculate PHV offset. Based on PHV offset, participants ranged from −2.2 to +1.6 years, −2.4 to +1.9 years, and −2.4 to +1.9 years in the CG, NPPT, and PPT group, respectively. Therefore, in the 3 groups of soccer players, an equal distribution of subjects (i.e., 4:4) before and after pubertal spurt of body height (i.e., maturity status) was achieved. More so, based on PHV offset, the participants from the CG (PHV offset = 0.4 ± 1.6), NPPT (PHV offset = 0.4 ± 1.5), and PPT (PHV offset = 0.3 ± 2.0) did not show significant differences at baseline.

Countermovement Jump With Arms Measurements. Vertical jumps were measured using an electronic contact mat system (Ergojump; Globus, Codogne, Italy), and maximal horizontal jump distance was measured using a 5-m long fiber glass metric tape endorsed to a wooden floor. Participants were instructed to use their arms to aid in the jump, positioning their foot shoulders wide apart for the bilateral jumps and with 1 foot stand (right and leg) for the unilateral jumps. In addition, subjects were instructed to perform a fast

TABLE 4. Training effects (with 90% confidence limits) for the soccer-specific explosive and endurance performance variables for the control group (CG; $n = 8$) and plyometric training group with (PPT; $n = 8$) and without (NPPT; $n = 8$) a progressive increase in volume across time.

	Baseline mean ± SD	Performance change (%)	Magnitude of training effect
Maximal kicking velocity (km·h⁻¹)			
CG	64.4 ± 13.9	−0.9 (−4.9 to 3.2)	−0.04 (−0.22 to 0.14)
NPPT	68.3 ± 15.4	5.7 (4.4 to 7.0)	0.17 (0.14 to 0.21)
PPT	67.1 ± 16.3	10.1 (8.4 to 11.8)[b,d]	0.34 (0.28 to 0.39)*
10-m sprint time (s)			
CG	2.60 ± 0.21	−1.1 (−4.1 to 2.0)	−0.13 (−0.48 to 0.23)
NPPT	2.64 ± 0.36	−0.9 (−4.1 to 2.3)	−0.06 (−0.26 to 0.14)
PPT	2.71 ± 0.29	−1.6 (−4.2 to −1.1)[a]	−0.14 (−0.37 to −0.09)
Change of direction speed test time (s)			
CG	13.0 ± 1.4	−6.0 (−10.9 to 0.9)[a]	−0.58 (−1.08 to −0.09)*
NPPT	13.0 ± 2.1	−7.6 (−10.8 to −4.3)[b]	−0.43 (−0.62 to −0.24)*
PPT	13.1 ± 1.5	−9.0 (−13.0 to −4.8)[b]	−0.82 (−1.21 to −0.43)†
Yo-Yo intermittent recovery level 1 test (m)			
CG	987 ± 394	2.7 (−2.7 to 8.3)	0.07 (−0.08 to 0.22)
NPPT	990 ± 440	11.6 (8.5 to 14.7)[b]	0.27 (0.20 to 0.34)*
PPT	993 ± 457	15.3 (10.3 to 20.4)[c,d]	0.31 (0.21 to 0.40)*

*Small standardized effect.
†Moderate standardized effect; a, b, and c denote significant difference pretraining to posttraining ($p \leq 0.05$, $p < 0.01$, and $p < 0.001$, respectively). d denotes significant difference with the CG after training ($p \leq 0.05$).

downward movement (approximately to 120° of knee angle) followed by a maximal jump effort, landing in an upright position during vertical jumps.

20-cm Drop Jump Reactive Strength Index. The RSI20 was determined on a contact mat (Ergojump; Globus, Codogne, Italy) with arms akimbo. Take-off and landing was standardized to full knee and ankle extension on the same spot. The participants were instructed to maximize jump height and minimize ground contact time after dropping down from a 20-cm drop box.

Sprint and Change of Direction Speed Performance. The 10-m sprint time were measured to the nearest 0.01 seconds using single beam infrared photoelectric cells (Ergotester; Globus). The starting position was standardized to a still split standing position with the toe of the preferred foot forward and behind the starting line. Sprint start was given by a random sound, which triggers timing. The photoelectric signal was positioned at 10-m and set ~0.7 m above the floor (i.e., hip level) to capture trunk movement rather than a false trigger from a limb. The CODS test has been described previously (35). The timing system and procedures were same as the 10-m sprint.

Maximal Kicking Velocity. Participants kicked a size 5 soccer ball (Nike Seitiro, Fédération Internationale de Football Association-certified) for maximal velocity measured by a radar gun (Sports Radar Speed Gun SR3600, Homosassa, FL, USA), according to a previously described protocol (1). Basically, participants performed a maximal instep kick with their dominant leg after a run-up of 2 strides, directed toward a goal net with a cue to aim (i.e., a vertical square target placed in its center) to increase the reliability of the test. The distance between the ball and the target was 4 m.

Yo-Yo IR1. The test was executed as previously described (17). Basically, 2 markers were positioned at a distance of 20 m, and the players performed repeated 20-m shuttle runs interspersed with 10 seconds of active recovery. The time allowed for a shuttle was progressively decreased. Before testing, participants performed a warm-up consisting of the first 4 running bouts in the test. Throughout testing, an investigator to participant ratio of 1:1 was maintained. Participants achieved ≥96% of theoretical maximal heart rate (measured with hearth rate monitor Forerunner 910XT, Garmin, Taipei, Taiwan) at the end of the test, suggesting maximal effort.

Internal Training Load Determination. To assure that all soccer players receive the same total soccer training load during intervention, the session rating of perceived exertion (RPE) was determined as previously described (15). In this study, the Spanish version of the 10-point category ratio scale (CR10-scale) modified by Foster et al. (10) was used.

Table 5. Differences between control group (CG; $n = 8$), plyometric training group with (PPT; $n = 8$) and without (NPPT; $n = 8$) a progressive increase in volume across time in the training effects* (with 90% confidence limits) on performance variables.

	NPPT − CG	PPT − CG	PPT − NPPT
Vertical countermovement jump with arms	8.9 (−6.6 to 26.9) Small	15.2 (−2.5 to 36.0) Small	6.5 (−11.8 to 28.6) Trivial
Horizontal countermovement jump with arms	6.5 (−3.0 to 16.9) Small	11.8 (2.9 to 21.4) Small	4.9 (−5.0 to 15.9) Small
Right leg horizontal countermovement jump with arms	−2.6 (−11.0 to 6.6) Trivial	9.8 (−2.8 to 24.0) Small	11.2 (−1.5 to 25.5) Small
Left leg horizontal countermovement jump with arms	14.4 (4.8 to 24.9) Small	20.7 (7.8 to 35.2) Moderate	6.9 (−5.1 to 20.4) Small
20-cm drop jump reactive strength index	15.3 (−21.5 to 69.2) Small	51.8 (9.4 to 110.5) Moderate	30.7 (−10.6 to 91.0) Small
Maximal kicking velocity	6.5 (2.1 to 11.1) Small	11.2 (6.5 to 16.1) Small	4.2 (2.1 to 6.4) Trivial
10-m sprint time	1.1 (−3.1 to 5.4) Trivial	−1.1 (−4.9 to 2.8) Trivial	−1.3 (−5.2 to 2.8) Trivial
Change of direction speed test time	−1.6 (−7.6 to 4.7) Trivial	−3.8 (−10.2 to 3.0) Small	−2.2 (−7.6 to 3.6) Trivial
Yo-Yo intermittent recovery level 1 test	8.0 (1.9 to 14.5) Small	12.3 (4.8 to 20.3) Small	3.4 (−2.2 to 9.3) Trivial

*Effects are shown in percentage units and probabilistic inferences about the true standardized magnitude.

Training Efficiency. Training efficiency was calculated as the relative (i.e., percentage) change of a performance variable divided by the total volume of jumps per leg completed during the 6 weeks of plyometric training, as suggested previously (7).

Training

PPT and NPPT performed a plyometric intervention with and without a progressive increase in training volume, respectively. The plyometric interventions were created based on previous research experience from our research team (38). Both groups used arm-swing during jumps, combining cyclic and acyclic, in addition to unilateral and bilateral, jumps. For acyclic drills, participants were motivated during each jump to achieve maximal intensity vertical height and horizontal distance; while during cyclic jumps, participants were motivated to maximize the ratio between vertical height or horizontal distance and ground contact time. Maximal intensity was verified in a randomly assigned subsample of participants (2 from each group) during 2 randomly assigned training sessions, by measuring contact times, height, and distance of jumps drills, using same procedures as in CMJA and RSI20 measurement procedures (described above). A detailed description of the training program is depicted in Table 2. The order of exercises execution was randomized in each training session to add variation during training.

Plyometric training was completed during the in-season period. Participants performed plyometric drills as a substitute for some low-intensity technical-tactical soccer drills at the beginning of their usual 120-minute practice twice per week for 6 weeks. The PPT group replaces the technical drills and the first portion (i.e., first 20 minutes) of the tactical drills by plyometric drills. Before the intervention, participants were instructed to properly execute the exercises to be done during the training period. Plyometric sessions were performed after the warm-up, which was the same for the plyometric training groups and for the control group. Both groups used the same surface and time of day for training, with the same rest intervals between sessions (i.e., 48 hours), sets (i.e., 60 seconds), and jumps (i.e., 15 seconds for acyclic jumps).

Statistical Analyses

All values are reported as mean ± SD. Relative changes (%) in performance and standardized effects (SE = changes as a fraction or multiple of baseline SD) are expressed with 90% confidence limits. Normality and homoscedasticity assumptions for all data before and after intervention were checked with Shapiro-Wilk and Levene tests, respectively. To determine the effect of the intervention on dependent variables, a 2-way analysis of variance with repeated measurements (3 groups × 2 times) was used. When a significant F value was achieved across time or between groups, Sheffe post hoc procedures were performed to locate the pairwise differences between the means. In addition, a 1-way analysis of variance was used to compare relative changes between groups. The α level was set at $p \leq 0.05$ for statistical significance. All statistical calculations were performed using

Table 6. Training efficiency* (% per jump) for plyometric training group with (PPT; $n = 8$) and without (NPPT; $n = 8$) a progressive increase in volume across time.

Vertical countermovement jump with arms	
NPPT	0.0014 ± 0.006
PPT	0.0055 ± 0.009
Horizontal countermovement jump with arms	
NPPT	0.0027 ± 0.0059
PPT	0.0029 ± 0.0041
Right leg horizontal countermovement jump with arms	
NPPT	0.0017 ± 0.0051
PPT	0.0051 ± 0.0058
Left leg horizontal countermovement jump with arms	
NPPT	0.0077 ± 0.0065
PPT	0.0077 ± 0.0056
20-cm drop jump reactive strength index	
NPPT	0.012 ± 0.028
PPT	0.016 ± 0.020
Maximal kicking velocity	
NPPT	0.0030 ± 0.001
PPT	0.0035 ± 0.001
10-m sprint time	
NPPT	−0.00042 ± 0.0025
PPT	−0.00053 ± 0.0014
Change of direction speed test time	
NPPT	−0.0039 ± 0.0025
PPT	−0.0031 ± 0.0021
Yo-Yo intermittent recovery level 1 test	
NPPT	0.0061 ± 0.0024
PPT	0.0054 ± 0.0027

*Efficiency was calculated as percentage change of performance variable divided by the total volume of jumps per leg completed during the 6 weeks of plyometric training.

STATISTICA statistical package (version 8.0; StatSoft, Inc., Tulsa, OK, USA). In addition to this null hypothesis testing, data were also assessed for meaningful significance using an approach based on the magnitudes of change. Threshold values for assessing magnitudes of SE (changes as a fraction or multiple of baseline SD) were 0.20, 0.60, 1.2, and 2.0 for small, moderate, large, and very large, respectively (14). Magnitudes of differences in training effects between groups were evaluated as follow (14): if the confidence interval overlapped thresholds for substantial positive and negative values, the effect was deemed unclear. The effect was otherwise clear and reported as the magnitude of the observed value with a qualitative probability, as above. Performance measurement reliabilities were determined using the intraclass correlation coefficient (ICC). A coefficient below 0.40 was considered poor, 0.40 to 0.59 fair, 0.60 to 0.74 good, and 0.75 to 1.00 excellent (21). We obtained excellent ICC for the different performance measurements, ranging between 0.85 and 0.99.

Results

Before training, no significant differences were observed between groups in descriptive or anthropometric variables (Table 1), and no significant changes were observed after intervention in any group. Before training, no significant differences were observed between groups in CMJA (i.e., vertical, horizontal, bilateral, and unilateral), RSI20 (Table 3), MKV, 10-m sprint, CODS, or Yo-Yo IR1 (Table 4) test performance.

No statistically significant changes over time were observed in the CG, except for a significant ($p \leq 0.05$) improvement in CODS performance (Table 4). PPT showed a statistically significant ($p \leq 0.05$) increase in all jump performance test, with a small-to-moderate meaningful effect (Table 3). NPPT also showed a statistically significant ($p \leq 0.05$) increase in vertical CMJA, left leg horizontal CMJA, and RSI20, with a small meaningful effect (Table 3). In comparison with CG, only PPT showed a significantly ($p \leq 0.05$) higher performance improvement in all (except vertical CMJA) jump test (Table 3).

PPT showed a statistically significant ($p \leq 0.05$) increase in MKV, 10-m sprint, CODS, and Yo-Yo IR1 test performance, with a small-to-moderate meaningful effect (Table 4). NPPT also showed a statistically significant ($p \leq 0.05$) increase in CODS and Yo-Yo IR1 test performance, with a small meaningful effect (Table 4). Compared with CG, only PPT showed a significantly ($p \leq 0.05$) higher performance improvement in MKV and Yo-Yo IR1 test (Table 4).

Although no statistically significant differences in performance changes were observed between plyometric training groups, PPT showed higher meaningful improvement compared with NPPT in all jump performance measures (except vertical CMJA) (Table 5).

No significant differences were observed for training efficiency between PPT and NPPT in any of the dependent variables (Table 6).

Discussion

This study showed that PPT and NPPT ensured significant improvement in several explosive (i.e., vertical jump, horizontal jump, RSI20, CODS) and endurance (i.e., Yo-Yo IR1) performance measures. However, only PPT induced a significant increase in MKV and sprint performance. In addition, only PPT achieved significantly higher improvements in vertical jump, horizontal jump, MKV, and Yo-Yo IR1 compared with CG. More so, based on meaningful significance analysis, PPT achieved a greater increase in several explosive performance measures compared with NPPT and CG. Therefore, the study hypothesis is accepted. Although concern may exist regarding increased load and risk of fatigue, an increase in plyometric training volume-based load requires only 12 to 18 repetitions per week (16). In addition, young subjects possess high fatigue resistance and recovery capacity after high-intensity strength exercise (33). Therefore, an adequate progressive increase in plyometric training volume-based load would not negatively affect fatigue in young soccer players, and as our results show, should result in greater performance adaptations in explosive movements and aerobic endurance.

Both plyometric training groups showed a significant increase in vertical CMJA, horizontal CMJA, and RSI20 performance, with a small-to-moderate SE (Table 3). In this study, the magnitude of improvement was similar to that previously reported for analogous slow stretch-shortening cycle (SSC) (i.e., CMJA; SE = 0.43–0.59) (26) and fast SSC (i.e., RSI20; SE = 0.81–0.89) muscle actions (37) after plyometric training with young soccer players using interventions of similar duration or number of sessions and partially agreed with a previous study that applied an intensity-based progressive increase in plyometric load in young rugby players (42). Interestingly, only PPT showed a significantly ($p \leq 0.05$) greater performance improvement in CMJA and RSI20 performance compared with CG (Table 3). More so, PPT showed greater meaningful improvements than NPPT in all horizontal jump performance measures and RSI20 (Table 5). Because participants in this study were instructed to produce maximal intensity vertical height and horizontal distance for acyclic jumps, with minimum ground contact time for cyclic jumps (instructions intended to maximize reactive strength), it is plausible that these instructions have permitted an adequate stimulation of slow and fast SSC muscle performance. Considering the necessity to produce a high rate of force development in explosive jump actions during soccer games (25), the improvement observed in explosive jump performance could also induce some enhancements in physical parameters of game performance. The improvement observed could have been induced by various neuromuscular adaptations (23); however, because no physiological measurements were made, only speculations are possible. These results support the need for a progressive increase in plyometric training volume-based load during short-term interventions with young soccer players to induce greater performance adaptations in explosive movements requiring slow and fast SSC muscle actions.

To the best of our knowledge, this is the first study to compare the effect of progressive volume-based overload to constant volume-based overload during short-term plyometric training in MKV in young soccer players. Our results showed that only PPT achieved a statistically significant ($p \leq 0.05$) increase in MKV performance, with a small SE, and this performance improvement was significantly greater compared with CG (Table 4). These results suggest that plyometric training incorporating a progressive volume-based overload in the short-term may induce greater MKV performance improvements in young soccer players. Although differences in the type of training program applied make comparisons between different studies difficult, other studies have also reported significant increases in kicking performance after plyometric training in young soccer players (29,37). Increases in MKV performance may be attributed to increased strength and explosiveness of legs' extensor muscles (29), factors that are important during the instep kick in soccer (20); these adaptations have been attributed to neuromuscular adaptations (29). It may be that these neuromuscular and strength-explosive adaptations had an effect on the biomechanical factors related to kicking performance, such as maximum linear velocity of the toe, ankle, knee, and hip at ball contact (19), which may have cumulatively or individually contributed to a higher ball kicking velocity.

Regarding 10-m sprint performance, only PPT showed a statistically significant improvement (Table 4). Although previous plyometric interventions with young soccer players showed a positive impact on 10-m sprint performance during the in-season period (26,29,46), to the best of our knowledge, this is the first study to compare the effect of progressive volume-based overload with constant volume-based overload during plyometric training on 10-m sprint times in young soccer players. It has been shown that although vertical strength and explosiveness may be related with sprint performance in young male athletes (28), incorporation of horizontal drills during plyometric training probably played a more important role in sprint performance improvement (41), considering the importance of horizontal force production and application in sprint performance (32) and the principle of training specificity (41). This agrees with previous studies in which vertical-only plyometric training failed to improve sprint performance in young soccer players (37). Although NPPT also incorporates horizontal plyometric drills, the lower volume of training may have reduced the probability of achieving significant sprint performance adaptations (41). Also, the higher acceleration performance improvement (i.e., 10-m sprint) in participants from PPT may be related to their greater improvement in slow SSC muscle performance (i.e., CMJA) and transference to unilateral horizontal performance compared with NPPT (Table 5), because acceleration may be more dependent on a slower SSC muscle action and explosive production similar to the CMJ (4) and because unilateral horizontal jump performance may better predict sprint performance (27). Interestingly, although CG achieves a similar relative performance improvement compared with PPT (Table 4), the nonsignificant improvement in the former may be related to the fact that only 4 of 8 soccer players in the CG achieve a reduced 10-m sprint time, whereas all soccer players from the PPT achieve a reduction in the 10-m sprint time. These observations reinforce the value of a progressive volume-based overload explosive training program to enhance acceleration sprint ability of young soccer players during the in-season.

In relation with CODS, the control group and the plyometric training groups achieved a statistically significant and meaningful increase in performance. There are important differences between CODS tests used among studies, which make a comparative analysis difficult with our results; however, other studies have found a significant improvement in CODS performance after plyometric training (26) and soccer training (37). The improvement in CODS performance may be related to an improved RSI20 (30,47), explosive-development improvements (34), or an increase in eccentric strength of the lower limbs, which can impact changes of direction performance during the deceleration phase (43). The increase in CODS performance observed in the CG may be related to the fact that soccer coaches use technical and tactical drills that focus on the player's agility (6); also, this increased performance suggests that participants were not submitted to a poor soccer stimulus, highlighting the positive impact of plyometric training on other variables of young soccer players performance. Interestingly, although all groups achieved a significant increase in CODS performance, only PPT showed a higher meaningful increase compared with CG (Table 5), suggesting that progressive volume-based overload during plyometric training induces a greater CODS performance.

Our results showed that both plyometric training groups achieve a statistically significant ($p \leq 0.05$) increase in Yo-Yo IR1 test, with a small SE (Table 4). Plyometric training in young soccer players has shown not to induce a significant increase in the aerobic outcomes such as $\dot{V}O_2max$ (29) or lactate threshold (11), but still has a meaningful effect on a intermittent recovery endurance performance test with repeated changes of direction (i.e., Yo-Yo IR1) (46). An increase in running economy (24) associated with increased musculotendinous stiffness (44) and neuromuscular explosive improvements after plyometric training may be the underlying mechanisms behind this improvement in young soccer players (2), and these adaptations can occur independent of changes in $\dot{V}O_2max$ (29) or lactate threshold (11). A novel finding of this study was that PPT showed a significantly higher performance improvement in Yo-Yo IR1 test compared with CG (Table 4), suggesting that a progressive increase in volume during short-term plyometric training improves the recovery to intermittent efforts of soccer player's that are required during competitive games.

In conclusion, replacement of some low-intensity technical-tactical soccer drills during the in-season period with a short-term (i.e., 6 weeks) plyometric training intervention with a progressive increase in volume of jumps during this period in young soccer players would induce higher nonspecific and soccer-specific explosive and endurance performance improvements compared with a similar training program but without a progressive increase in volume.

Practical Applications

Replacement of some soccer drills with high-intensity plyometric exercises positively affected jump, sprint, kicking, CODS, and endurance performance in young soccer players during the in-season period. These adaptations can be achieved in the short-term and may potentially increase competitive performance and reduce the risk of injury of young soccer players (40). In addition, based on the present results, a progressive volume-based overload across time would be more advantageous to young soccer players. This volume-based progressive overload may induce meaningful improvements in explosive performance and intermittent aerobic capacity when compared with a nonprogressive plyometric training; and although a progressive increase in volume would involve a greater total training volume, the same training efficiency can be achieved. Finally, although plyometric training can induce improvements in explosive and endurance performance in young soccer players, this training strategy should incorporate other explosive exercises (e.g., sprints), intermittent endurance exercises, and technical and tactical-oriented training methods to optimize game performance.

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ARTÍCULO 7

Effects of In-Season Low-Volume High-Intensity Plyometric Training on Explosive Actions and Endurance of Young Soccer Players

Rodrigo Ramírez-Campillo,[1] César Meylan,[2,3] Cristian Álvarez,[4] Carlos Henríquez-Olguín,[5] Cristian Martínez,[6] Rodrigo Cañas-Jamett,[7,8] David C. Andrade,[9] and Mikel Izquierdo[10]

[1]Department of Physical Activity Sciences, University of Los Lagos, Osorno, Chile; [2]Canadian Sport Institute Pacific, Vancouver, Canada; [3]Canadian Soccer Association, Ottawa, Canada; [4]Family Health Center of Los Lagos, Health Promotion Program, Los Lagos, Chile; [5]Laboratory of Exercise Sciences, MEDS Clinic, Santiago, Chile; [6]Physical Education Department, University of La Frontera, Temuco, Chile; [7]Laboratory of Physiology, Department of Biological Science, Faculty of Biological Sciences, Andrés Bello University, Viña del Mar, Chile; [8]Kinesiology School, Faculty of Rehabilitation Sciences, Andrés Bello University, Viña del Mar, Chile; [9]Cellular Physiology Laboratory, Biomedical Department, Faculty of Health Science, University of Antofagasta, Antofagasta, Chile; and [10]Department of Health Sciences, Public University of Navarre, Tudela, Spain

Abstract

Ramírez-Campillo, R, Meylan, C, Álvarez, C, Henríquez-Olguín, C, Martínez, C, Cañas-Jamett, R, Andrade, DC, and Izquierdo, M. Effects of in-season low-volume high-intensity plyometric training on explosive actions and endurance of young soccer players. *J Strength Cond Res* 28(5): 1335–1342, 2014—Integrating specific training methods to improve explosive actions and endurance in youth soccer is an essential part of players' development. This study investigated the efficiency of short-term vertical plyometric training program within soccer practice to improve both explosive actions and endurance in young soccer players. Seventy-six players were recruited and assigned either to a training group (TG; $n = 38$; 13.2 ± 1.8 years) or a control group (CG; $n = 38$; 13.2 ± 1.8 years) group. All players trained twice per week, but the TG followed a 7-week plyometric program implemented within soccer practice, whereas the CG followed regular practice. Twenty-meter sprint time (20-m), Illinois agility test time, countermovement jump (CMJ) height, 20- (RSI20) and 40- (RSI40) cm drop jump reactive strength index, multiple 5 bounds distance (MB5), maximal kicking test for distance (MKD), and 2.4-km time trial were measured before and after the 7-week period. Plyometric training induced significant ($p \leq 0.05$) and small to moderate standardized effect (SE) improvement in the CMJ (4.3%; SE = 0.20), RSI20 (22%; SE = 0.57), RSI40 (16%; SE = 0.37), MB5 (4.1%; SE = 0.28), Illinois agility test time (−3.5%, SE = −0.26), MKD (14%; SE = 0.53), 2.4-km time trial (−1.9%; SE = −0.27) performances but had a trivial and nonsignificant effect on 20-m sprint time (−0.4%; SE = −0.03). No significant improvements were found in the CG. An integrated vertical plyometric program within the regular soccer practice can substitute soccer drills to improve most explosive actions and endurance, but horizontal exercises should also be included to enhance sprinting performance.

Key Words agility, explosive strength, stretch-shortening cycle, vertical jump

Introduction

Soccer is an intermittent sport, which requires different physiological components. The capacity to produce varied powerful actions during a 90-minute game is associated with high aerobic capacity (41). However, the ability to produce an explosive single-bout effort is as important as aerobic power for success in soccer (9). This includes movements such as sprinting, jumping, changing direction, throwing, or kicking frequently occurring in soccer (41). Many of these activities not only require maximal power but also a high rate of power development considering the short period spent on the ground to produce power, such as sprinting or changing direction (<100 milliseconds) (1,26). Various studies demonstrated that youth elite and subelite players were found to be

Address correspondence to Mikel Izquierdo, mikel.izquierdo@gmail.com.

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faster, more agile, and more powerful than nonelite (16,45), whereas future international and professional players had superior explosive characteristics (i.e., speed, power) at youth level than future amateur players (21). These results support the fact that soccer-related explosive activities requiring power may not only be important qualities at youth level (16,45) but also at a later stage of a player's career (21) and need to be developed from a young age.

Plyometric exercises are commonly used to increase explosive actions in pubertal (42) and prepubertal (8,28,29) soccer players, with the advantage of being easy to integrate in soccer practice (space, time, equipment) and replicating the neuromuscular stimulus encountered in explosive soccer activities such as sprinting and jumping (12). Previous studies demonstrated that high intensity plyometric exercises, such as drop jumps, can be used safely and effectively from the beginning of training in young population (4) and soccer players (42). Generally, the high intensity requirements of drop jump training imply a reduced volume in training (4,7) and therefore may require less time to complete than other plyometric modes, while inducing comparable training adaptations to slow stretch-shortening cycle (SSC) training (42). The ability to continue improving explosive action during in-season is a challenge because of the limited time available for isolated training, when the emphasis is mostly placed on technical development in youth soccer (27). Meylan and Malatesta (28) demonstrated that in-season high volume plyometric training (~100–120 ground contact/session) can increase explosive performance, but it remains unknown if a low-volume high-intensity training may induce similar changes in sprinting, jumping, and change of direction. Such approach may appear relevant to the time constraint that coaches may encounter for both physical and technical development of players.

Apart from sprinting, jumping, and change of direction, explosive training may also be beneficial to other soccer-specific athletic requirements such as ball kicking or endurance. Previous studies (29,48) investigating kicking velocity or distance demonstrated the efficiency of explosive training to improve this quality, but improvement in aerobic performance remained controversial. Some studies in explosive training in youth soccer players did not demonstrate any improvement in $\dot{V}O_2max$ (29) or lactate thresholds (14), whereas others (48) demonstrated the efficiency of explosive training to improve Yo-Yo intermittent recovery test and submaximal running cost. Similarly, research in adult runners demonstrated that plyometric training may improve running time trial and economy but not $\dot{V}O_2max$ and lactate threshold (32,40,44). It is therefore of interest to identify if plyometric in youth players have a positive influence on middle-distance running time trial, considering its multiple facet requirement ($\dot{V}O_2max$, lactate threshold and running economy) (32), likely to affect aerobic performance in soccer (41).

Given the limitations of the current literature, the purpose of this study was to determine the effect of replacing some soccer drills with low-volume high-intensity plyometric training exercises on explosive actions and middle-distance time trial of young soccer players during in-season. It was hypothesized that the replacement of some soccer drills with plyometric exercises, with no additional training time in-season, would enhance explosive actions and aerobic performance to a greater extent than soccer training alone.

Methods

Experimental Approach to the Problem

We examined the ability of an in-season short-term plyometric training program, implemented as a substitute for some soccer drills within the regular soccer practice, to improve physical performance compared with soccer practice alone. Two groups were formed from young male soccer players; one followed the modified soccer practice (training group [TG]) and the other followed the regular soccer practice (control group [CG]). Before and after a 7-week period, all players executed a battery of 8 tests related to explosive and endurance performance. This was a randomized controlled trial. The assigned groups were determined by a chance process (a random number generator on a computer) and could not be predicted. This procedure was established according to the "CONSORT" statement, which can be found at http://www.consort-statement.org.

Subjects

Initially 121 male soccer players between 10 and 16 years of age fulfilled the inclusion criteria to participate in the study. Subjects were recruited from 4 different soccer teams with similar competitive schedule (1 official competitive game per week) and soccer drills used during their 2 weekly training sessions. Soccer players fulfilled the following inclusion criteria: (a) more than 2-year background of systematic soccer training and competition experience, (b) continuous soccer training in the last 6 months, (c) no plyometric training experience in the last 6 months, (d) no background in regular strength training or competitive sports activity that involved any kind of jumping training exercise during the treatment. To be included in the final analyses, participants were required to complete all the familiarization sessions, training sessions, and complete all tests, which resulted in 76 players included for the final analyses. Subjects were randomly divided into a CG ($N = 38$) and plyometric TG ($N = 38$). Subject characteristics are provided in Table 1. Institutional review board approval for our study was obtained, and all subjects (and their parents or guardians) were carefully informed about the experiment procedures and about the possible risk and benefits associated with the participation in the study, and an appropriate signed informed consent/assent document has been obtained pursuant to law before any of the tests were performed. We comply with the human and animal experimentation policy statements guidelines of the American College of Sport Medicine. Sample size was computed according to

Table 1. Subject characteristics at the start of the 7-week period (mean ± *SD*).*

	Control group ($n = 38$)	Training group ($n = 38$)
Age (y)	13.2 ± 1.8	13.2 ± 1.8
Genital tanner stage	3.7 ± 1.0	3.7 ± 1.1
Pubic hair tanner stage	3.6 ± 1.1	3.6 ± 1.1
Body mass (kg)	47.4 ± 11.9	47.9 ± 10.0
Height (cm)	153 ± 12	154 ± 12
Body mass index ($m \cdot kg^{-2}$)	19.9 ± 2.3	19.9 ± 1.7
Session rating of perceived exertion	312 ± 123	334 ± 151
Soccer experience (y)	4.1 ± 1.8	4.4 ± 1.6

*No significant difference between groups and within groups before and after the 7-week period.

the changes observed in plyometric (i.e., reactive strength index) performance ($d = 0.3$ $mm \cdot ms^{-1}$; $SD = 0.35$) in a group of young adolescents submitted to the same training program applied in this study (4). A total of 8 participants per group would yield a power of 80% and $a = 0.05$.

Testing Procedures

Subjects followed a familiarization session of 90 minutes before testing to reduce any learning effects. Standardized tests were scheduled >48 hours after a competition or hard physical training to minimize the influence of fatigue and performed under similar weather, time, and field conditions before and immediately after the 7-week period over 2 days. On day 1, players characteristics (height, body mass, and self-assessed Tanner pubic hair and genital stage), and performance test were conducted in the following order: countermovement jump (CMJ), 20- (RSI20) and 40- (RSI40) cm drop jump reactive strength index, 5 alternated leg bounds test (MB5), 20-m sprint (20 m), and Illinois agility test. On day 2, maximal kicking test for distance (MKD) followed by a 2.4-km time trial were performed. All tests were administered in the same order before and after training in the same sporting clothes and recorded by the same investigators. In addition, all participants (and their parents or guardians) were instructed to have a good night's sleep (≥9 hours) before each testing day, to avoid drinking, or eating at least 2–3 hours before measurements. All participants were motivated to give their maximum effort during performance measurements. At least 2 minutes of rest was allowed between each trial to reduce fatigue effects. While waiting, the participants performed low-intensity activity to maintain physiological readiness for the next test. The best score of 3 trials was recorded for all performance tests apart for the single 2.4-km time trial. As in previous studies from our laboratory (4), high intraclass correlation coefficients were obtained for the different performance test varying between 0.81 and 0.98.

Subject Characteristics. Height was measured using a wall-mounted stadiometer (Butterfly, Shanghai, China) recorded to the nearest 0.5 cm, body mass was measured to the nearest 0.1 kg using a digital scale (BC-554 Ironman Body Composition Monitor; Tanita, Illinois, USA), and body mass index (BMI) was calculated ($kg \cdot m^{-2}$). Maturity was determined by self-assessment of Tanner stage (46).

Vertical Jump Tests. Testing included the execution of maximal CMJ, RSI20, and RSI40. All jumps were performed on a mobile contact mat (Ergojump; Globus, Codogne, Italy) with arms akimbo. Take-off and landing was standardized to full knee and ankle extension on the same spot. The participants were instructed to maximize jump height and minimize ground contact time during the RSI20 and RSI40 after dropping down from a 20- and 40-cm drop box, respectively. The reactive strength index was calculated as previously reported (49).

Multiple 5 Bounds Test. The multiple 5 bounds test (MB5) was started from a standing position and performed a set of 5 forward jumps with alternative left- and right-leg contacts to cover the longest distance possible. The distance of the MB5 was measured to the nearest 0.5 cm using a tape measure (28).

Twenty-Meter Sprint and Illinois Agility Test. The sprint time was measured to the nearest 0.01 seconds using single beam infrared reds photoelectric cells (Globus Italia, Codogne, Italy). The starting position was standardized to a still split standing position with the toe of the preferred foot forward and behind the starting line. Sprint start was given by a random sound, which triggers timing. The photoelectric signal was positioned at 20 m and set ~0.7 m above the floor (i.e., hip level) to capture the trunk movement rather than a false trigger from a limb. The Illinois agility test has been described, and its reliability addressed elsewhere (15). The timing system and procedures were same as the 20-m sprint, except that subjects started lying on their stomach on the floor with their face down.

Maximal Kicking Distance Test. After a standard warm-up, each player kicked a new size 5 soccer ball (Nike Seitiro, FIFA certified) (10) for maximal distance on a soccer field. Two markers were placed on the ground side by side to define the kick line. Participants performed a maximal instep kick with their dominant leg after a run up of 2 strides.

A 75-m metric tape was placed between the kicking line and across the soccer field. An assessor was placed near the region where the ball land after the kick to mark the point of contact and to measure the distance kicked. The distance was measured to the nearest 0.2 m. All measurements were completed with a wind velocity <20 km·h^{-1} (Chilean Meteorological Service, Santiago, Chile). Previous studies have reported a high reliability of similar soccer kicking test (23).

A 2.4-km Time Trial. After a warm-up of 2 laps and 4-minute rest, players performed 6 laps of a 400-m outdoor dirt track timed to the nearest second using a stopwatch. The wind velocity at all times was less than 9.9 km·h^{-1}, the relative humidity was between 50 and 70%, and the temperature was between 15 and 20° C (Chilean Meteorological Service). Motivation was considered maximal, as this test was conducted as part of the selection process.

Training Program

The study was completed during the mid-portion of their competition period. Before the competitive period, subjects completed 2 months of summer preseason training. The control group did not perform the plyometric training but performed their usual soccer training. A detailed description of the usual soccer training applied during the competition period is depicted in Table 2. To know the training load during the intervention, the session rating of perceived exertion (RPE) was determined (Table 1) by multiplying the soccer training duration (in minutes) by session RPE, as described previously in young soccer players (18). We used the Chilean translation of the 10-point category ratio scale (CR10-scale) modified by Foster et al. (11).

Before the initiation of the training period, the TG subjects were instructed on proper execution of all the exercises included in the program. During intervention, the TG removed the technical drills (i.e., ball control, ball pass, ball conduction and dribbling, ball kicking, ball heading exercises) and replace them with plyometric drills within the usual 90-minute practice twice per week for 7 weeks. This time frame or number of sessions are higher (3,22,42,43) or very similar (5,28) to those previously reported to induce significant explosive adaptations in young soccer players and youths (4). All plyometric sessions lasted 21 minutes and were performed just after the warm-up to ensure that the players were in a rested state and gain optimal benefits from the specific program, according to the training principle of priority (19). Plyometric drills included 2 sets of 10 repetitions of drop jumps from 20, 40, and 60 cm (i.e., 60 contacts) performed on a grass soccer field. Exercise intensity was determined as high (28) and exercise volume low (i.e., total ground contacts) (4). Although we did not increase the training volume during the 7-week period, as we used high intensity plyometric exercises performed with maximal effort, an adequate training stimulus was applied during each plyometric session, as previously demonstrated in young boys (4) and soccer players (22).

The rest period between repetitions and sets was of 15 (34) and 90 seconds (4), respectively, as previous research had demonstrated that this is an adequate rest interval for this type of training. The subjects were instructed to place their hands on their hips and step off the platforms with the supporting leg straight to avoid any initial upward propulsion or sinking, ensuring a drop height of 20, 40, and 60 cm. Participants were instructed to jump for maximal height and minimum contact time, every jump to maximize reactive strength (i.e., bounce drop jumps). As players did not have any history of formal plyometrics, all exercises were supervised, and particular attention was paid to demonstration and execution, giving maximal motivation to athletes during each jump. Training sessions were separated with a minimum of 48 hours (including games) to ensure that the players were always fresh to train (28). Aside from the formal training intervention, all participants attended their regular physical education classes.

Statistical Analyses

All values are reported as mean ± *SD*. Relative changes (%) in performance and standardized effects (SEs) are expressed with 90% confidence limits. Normality and homoscedasticity assumptions for all data before and after intervention were checked respectively with Shapiro-Wilk and Levene's tests.

Table 2. Usual soccer training session of young soccer players during intervention.

Exercise	Duration (min)
Technical drills (ball control, ball pass, ball conduction and dribbling, ball kicking, ball heading)	20
Tactical drills (defensive drills, offensive drills, corner kicks situations, penalty kicks)	20
Small-sided games with or without goal keeper and with or without change of soccer rules (e.g., one touch pass, only heading goals)	20
Simulated competitive games	30

Table 3. Baseline performance measures (mean ± *SD*) and training effect (90% confidence limits) after the 7-week period.*

Variables	Control group (n = 38)			Training group (n = 38)		
	Baseline	Training effect (%)	Effect size	Baseline	Training effect (%)	Effect size
Countermovement jump (cm)	26.6 ± 4.7	2.2 (0.4 to 3.9)	0.12 (0.02 to 0.22)	27.0 ± 5.8	4.3† (3.2 to 5.3)	0.20 (0.15 to 0.25)
RSI20 (mm·ms^{-1})	1.01 ± 0.38	−2.7 (−6.5 to 1.3)	−0.07 (−0.17 to 0.03)	1.04 ± 0.40	22.2† (17.6 to 26.9)‡	0.57 (0.46 to 0.68)
RSI40 (mm·ms^{-1})	1.02 ± 0.35	−2.4 (−6.7 to 2.2)	−0.07 (−0.2 to 0.06)	1.04 ± 0.40	16.0† (12.5 to 19.5)‡	0.37 (0.29 to 0.44)
5 multiple bounds (m)	8.71 ± 1.20	0.1 (−0.4 to 0.6)	0.01 (−0.03 to 0.04)	9.00 ± 1.24	4.1† (2.9 to 5.4)	0.28 (0.19 to 0.36)
20-m sprint time (s)	4.39 ± 0.48	3.7† (2.2 to 5.2)	0.35 (0.21 to 0.48)	4.32 ± 0.57	−0.4 (−1.1 to 0.3)	−0.03 (−0.08 to 0.02)
Illinois agility test time (s)	20.1 ± 2.7	3.5† (2.9 to 4.2)	0.25 (0.20 to 0.30)	20.3 ± 2.8	−3.5† (−4.2 to −2.8)§	−0.26 (−0.31 to −0.21)
Maximal kicking distance test (m)	30.9 ± 7.4	−1.6 (−3.0 to −0.1)	−0.06 (−012 to 0.00)	32.7 ± 7.7	13.5† (10.6 to 16.4)‡	0.53 (0.42 to 0.63)
2.4-km time trial (min)	10.7 ± 0.8	−0.3 (−0.8 to 0.2)	−0.04 (−0.10 to 0.03)	10.6 ± 0.8	−1.9† (−2.6 to −1.2)	−0.27 (−0.37 to −0.18)

*RSI20 = 20 cm drop jump reactive strength index; RSI40 = 40-cm drop jump reactive strength index.
†Denotes significant difference vs. baseline value ($p < 0.01$).
‡Denotes significant difference vs. control group ($p < 0.01$).
§Denotes significant difference vs. control group ($p \leq 0.05$).

To determine the effect of intervention (i.e., plyometric training) on explosive strength adaptations, a 2-way variance analysis with repeated measurements (2 groups × 2 times) was applied. When a significant F value was achieved across time or between groups, Tukey's post hoc procedures were performed to locate the pairwise differences between the mean values. The α level was set at $p \leq 0.05$ for statistical significance. All statistical calculations were performed using STATISTICA statistical package (Version 8.0; StatSoft Inc., Tulsa, OK, USA). In addition to this null hypothesis testing, these data were also assessed for clinical significance using an approach based on the magnitudes of change. Threshold values for assessing magnitudes of SEs (changes as a fraction or multiple of baseline *SD*) were 0.20, 0.60, 1.2, and 2.0 for small, moderate, large, and very large, respectively (17). The effect was deemed unclear when the chance of benefit (a standardized improvement in performance of >0.20) was sufficiently high to warrant use of the intervention, but the risk of impairment was unacceptable. Such unclear effects were identified as those with an odds ratio of benefit to impairment of <66, a ratio that corresponds to an effect that is borderline possibly beneficial (25% chance of benefit) and borderline most unlikely detrimental (0.5% risk of harm). The effect was otherwise clear and reported as the magnitude of the observed value (17).

Results

Before and after training, no significant difference were observed between the intervention and control group in height, body mass, BMI, or maturity status (Table 1). Also, no significant change within the groups was observed after the training period.

There was no significant difference between groups at baseline in all performance measures. Differences between groups became significant in RSI20 ($p < 0.01$), RSI40 ($p < 0.01$), MKD ($p < 0.01$), and agility ($p \leq 0.05$) after the 7-week period (Table 3).

After training, the TG demonstrated a significant ($p < 0.001$) and small increase in CMJ, RSI20, RSI40, and MB5, whereas no significant changes were observed in CG (Table 3). The training program did not induce a significant change in sprint performance for the TG, whereas the CG exhibits a significant ($p < 0.001$) and small increase in 20-m time (Table 3). The training program had a beneficial impact on the Illinois agility test time, resulting in a significant ($p < 0.001$) and small decrease for the TG. In contrast, the CG achieves a significant ($p < 0.001$) and small increase in the Illinois agility test time (Table 3).

After intervention, a significant ($p < 0.001$) and small change was observed in MKD performance for the TG, whereas no significant change was observed in the CG (Table 3). After intervention, a significant ($p < 0.001$) and small change was observed in 2.4-km performance time for the TG, whereas no significant change was observed in the CG (Table 3).

For the CMJ, RSI20, RSI40, MB5, 20-m sprint time, Illinois agility test time, MKD, 2.4-km time trial, 88, 93, 95, 81, 32, 95, 70, and 88%, respectively of subjects from the TG were responders to training.

Discussion

This study indicated that 7 weeks of plyometric training induced significant and small to moderate improvements in CMJ, RSI20, RSI40, MB5, Illinois agility test time, MKD, and 2.4-km time trial performances. These results show that the combination of soccer drills and specific power training with no additional training time in-season optimize general and soccer-specific explosiveness and endurance performance in young soccer payers.

Although we used higher rigor to include subjects in the final analyses (i.e., completion of all training session) compared with the previous interventions in young subjects (13,47), the magnitude change in CMJ (SE = 0.20) and MB5 (SE = 0.28) in this study was smaller than previously reported for both the CMJ (SE = 0.50–0.87) (3,8,28,48) and MB5 (SE = 0.44–0.86) (8,28), after explosive training with young soccer players using interventions of similar duration or number of sessions as in this study. However, these discrepancy in training effect can be attributed to the training specificity, as the previous studies mentioned above used both slow and fast SSC (3,8,28,48), which the former being similar to CMJ and horizsontal stimulus (8,28). The greater magnitude in RSI20 and RSI40 (SE = 0.37–0.57) would support such contention considering the fast SCC of the current training program. In addition, Meylan and Malatesta (28), who did not include any drop jump training into their plyometric program, found no significant change in reactive strength. Considering the necessity to produce a high rate of power development in explosive actions (27), the improvement in RSI may have enhanced physical parameters of game performance. The improvement observed could have been induced by various neuromuscular adaptations, such as increased neural drive to the agonist muscles, improved intermuscular coordination, changes in the muscle-tendon mechanical-stiffness characteristics, changes in muscle size or architecture, and changes in single-fiber mechanics (24), but because no physiological measurements were made, only speculations are possibly.

The lack of improvement in 20-m sprint time after the current plyometric training demonstrated that other training stimulus may be necessary to enhance sprinting performance of young soccer players during the competitive period. A lack of change in 15-m sprint time after drop jump–based plyometric training has been previously reported in 17-year-old soccer players (42). As the training stimulus was only vertical in nature, this may had reduced the chances for soccer players to gain adaptations, considering the importance of horizontal force production and the application in sprint performance (30) and the principle of training specificity (33,36). Despite the lack of 20-m sprint improvement, a small reduction to complete the Illinois agility test was found in the TG. The current results are similar to those reported by Thomas et al. (42), where high intensity bounce drop jumps had a small positive effect on agility performance in young soccer players but only a trivial effect on 15-m sprint time. An increase in power development (31), reactive strength (49), and eccentric strength (39) may have contributed to the improvement in agility performance, whereas acceleration may be more dependent in a slower stretch-shorten cycle and rate of power production similar to the CMJ (6), which was not targeted in the current training program.

The improvement in kicking performance demonstrated that soccer-specific explosive actions of young male soccer players can be enhanced during the competitive period with a short-term plyometric training program implemented as a substitute for some soccer drills. An improvement in kicking performance after plyometric training has been previously reported in preadolescent (29) and adolescent soccer players (35). As players had more than a 2-year background of systematic soccer training and competition experience and given the lack of improvement in the CG, the positive change in kicking performance are unlikely to be related to the technical training over the short-term period of 7-week in this study. It had been suggested that an increased strength and power of legs' extensor muscles because of plyometric training may increase kicking performance in young soccer players, and these changes could be attributed solely to neuromuscular adaptations (29). It may be that these neuromuscular adaptations had an effect on the biomechanical factors related to kicking performance, such as maximum linear velocity of the toe, ankle, knee, and hip at ball contact (20), resultant in higher ball kicking velocity and hence MKD.

The TG exhibited a small reduction in 2.4-km time trial and became significantly fitter than the CG, despite no additional aerobic training. The change in neuromuscular ability in this study, especially the RSI, is likely to be transferred into a better running economy (37,38), which could potentially explain the positive change in the 2.4-km time trial of the TG (32,40). Previous explosive training in young soccer players did not induce improvement in $\dot{V}O_2max$ (29) or lactate thresholds (14) but was efficient at enhancing Yo-Yo intermittent recovery test level 1 performance (48). This discrepancy is likely related to the fact that the change in neuromuscular power after an explosive training can contribute to the change of direction during an intermittent test (e.g., Yo-Yo or 30-15 intermittent fitness test) with change of direction (2) or running economy (25,40) but has a limited influence on $\dot{V}O_2max$ or lactate threshold (40,44). Given the multi-directional nature of the game and necessity to cover long distances (41), explosive neuromuscular training should be considered as a complimentary method to aerobic conditioning in youth soccer players in addition to its anaerobic function.

Practical Applications

The replacement of technical exercises with low-volume high-intensity plyometric drop jump exercises was effective at improving several explosive actions and endurance capacity in youth soccer players, which may have high transference into game play performance. Thus, a twice-weekly short-term high intensity plyometric training program implemented as a substitute for some soccer drills within the regular in-season soccer practice can enhance explosive and endurance performance in young soccer players compared with soccer training alone. The reduced volume of plyometric training ensured minimal time allocated to non–soccer-specific training while maintaining continuous physical development of young players during the season. Considering that some young soccer teams (especially amateur teams) had limited time to train (e.g., 90 minutes, 2 times per week), the current findings may be relevant to programming plyometric training in this context.

Although concern has been expressed by some researchers regarding the injury risk during plyometric training, to the best of the author's knowledge, when adequate controlled plyometric training intervention had been applied, no important injuries had been reported. More so, plyometric training had been advocated as a preventive injury strategy and even as a rehabilitation tool. In fact, during our intervention, the relative high intensity of the training program did not result in any injuries, and it is important to notice that in the present investigation, subjects reported little subjective muscle pain after the training sessions (data not shown). However, practitioners need to be mindful of the players' movement competency before introducing drop jump exercises and place a considerable emphasis on coaching.

Also, in accordance to the concept of training specificity, drop jump training was most effective at improving tests replicating the training stimulus (RSI) and transferred to performance measures, where vertical neuromuscular power and reactive strength were relevant (CMJ, 5 MB, MKD, 2.5-km time trial). However, another or a complimentary training stimulus should be implemented to improve 20-m sprint time in young soccer players. Future studies should include training programs with multi-directional and unilateral-bilateral exercises, given the nature of sprinting and other explosive movement on the field (e.g., tackling, change of direction). Finally, short-term plyometric training program can also be considered as an intervention strategy to increase kicking ability and endurance in youth soccer players, but we recommend that this training method must be adequately incorporated in a comprehensive training program that develop the specific technical abilities critical to achieve adequate kicking performance (especially at young ages) and with an adequate aerobic conditioning program, to optimize training adaptations.

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ARTÍCULO 8

The Effects of Interday Rest on Adaptation to 6 Weeks of Plyometric Training in Young Soccer Players

Rodrigo Ramírez-Campillo,[1] César M.P. Meylan,[2,3] Cristian Álvarez-Lepín,[4] Carlos Henriquez-Olguín,[5] Cristian Martinez,[6] David C. Andrade,[7] Mauricio Castro-Sepúlveda,[8] Carlos Burgos,[5] Eduardo I. Baez,[9] and Mikel Izquierdo[10]

[1]*Department of Physical Activity Sciences, University of Los Lagos, Osorno, Chile;* [2]*Canadian Sport Institute Pacific, Vancouver, Canada;* [3]*Canadian Soccer Association, Ottawa, Canada;* [4]*Family Health Center of Los Lagos, Health Promotion Program, Los Lagos, Chile;* [5]*Laboratory of Exercise Sciences, MEDS Clinic, Santiago, Chile;* [6]*Department of Physical Education, Sport and Recreation, University of La Frontera, Temuco, Chile;* [7]*Cellular Physiology Laboratory, Biomedical Department, Faculty of Health Science, University of Antofagasta, Antofagasta, Chile;* [8]*School of Health, Duoc UC, Santiago, Chile;* [9]*Department of Sport and Recreation, University of Playa Ancha, Valparaiso, Chile; and* [10]*Department of Health Sciences, Public University of Navarre, Spain*

Abstract

Ramirez-Campillo, R, Meylan, CMP, Álvarez-Lepin, C, Henriquez-Olguin, C, Martinez, C, Andrade, DC, Castro-Sepúlveda, M, Burgos, C, Baez, EI, and Izquierdo, M. The effects of interday rest on adaptation to 6 weeks of plyometric training in young soccer players. *J Strength Cond Res* 29(4): 972–979, 2015—The purpose of this study was to determine the effects of short-term plyometric training interposed with 24 or 48 hours of rest between training sessions on explosive and endurance adaptations in young soccer players. A total of 166 players, between 10 and 17 years of age, were randomly divided into 3 groups: a control group (CG; $n = 55$) and 2 plyometric training groups with 24 hours (PT24; $n = 54$) and 48 hours (PT48; $n = 57$) of rest between training sessions. Before and after intervention, players were measured in squat jump, countermovement jump, 20 (RSI20) cm drop jump reactive strength index, broad long jump, 20-m sprint time, 10 × 5-m agility time, 20-m multistage shuttle run test, and sit-and-reach test. The plyometric training program was applied during 6 weeks, 2 sessions per week, with a load from 140 to 260 jumps per session, replacing some soccer-specific drills. After intervention, the CG did not show significant performance changes. PT24 and PT48 groups showed a small-to-moderate significant improvement in all performance tests ($p < 0.001$), with no differences between treatments. Although it has been recommended that plyometric drills should not be conducted on consecutive days, the study shows that plyometric training applied twice weekly on consecutive or nonconsecutive days results in similar explosive and endurance adaptations in young male soccer players.

Key Words maturity, explosive strength, competitive sports, strength training

Introduction

Soccer is an intermittent sport that requires different physiological components. The capacity to produce varied powerful actions during a 90-minute game is associated with high aerobic capacity (33). However, the ability to produce explosive single-bout effort is as important as aerobic power for success in soccer (12), such as sprinting, jumping, or changing direction (33). Plyometric training (PT) is commonly used to increase these types of actions in young soccer players (7,27,28,34), with the advantage of being easy to integrate in soccer practice (space, time, equipment), and replicating the neuromuscular stimulus encountered in explosive soccer activities such as sprinting and jumping (13). Additionally, PT in young soccer players may increase endurance performance (38). Therefore, PT may be advocated as an appropriate approach for enhancing soccer-related performance abilities. However, the characteristics of between-session recovery of a PT that generates optimal gains are not clear (31), especially in young soccer players.

Plyometric training frequency (31) or the rest interval between training sessions (26) may affect its outcome. In young soccer players, PT frequencies of 1 (24,36), 2 (14,19,24,27,28,32,34,40), and 3 (7) sessions per week have been applied effectively. Curiously, most studies in which explosive strength training was applied to this group of

Address correspondence to Mikel Izquierdo, mikel.izquierdo@gmail.com.

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athletes did not report the rest interval used between training sessions (7,14,19,24,34,40). It has been recommended that plyometric drills should not be conducted in consecutive days in youths (9,37) although no experimental evidence sustains these recommendations. In addition, several interventions in young soccer players used >72 hours (28,32) or >48 hours (27) of rest between PT sessions to allow for adequate recovery, suggesting that these time frames of rest would be necessary to induce adequate training stimulation in this population of young athletes. However, to the best of the authors' knowledge, no studies have evaluated the effect of the rest interval between PT sessions in explosive and endurance performance of young soccer players.

In adults, improved performance had been reported with PT frequencies of 4–5 sessions per week (15,31), suggesting that <24 hours of recovery between sessions may induce significant adaptations. In youths, the recovery capacity from high-intensity plyometric exercises has been reported to be higher than in adults, and <24 hours may be sufficient to recover from a previous explosive exercise stimulus (25). A higher level of flexibility (leading to less overextension of sarcomeres during eccentric exercise), slower muscle fiber-type composition, and a high level of habitual physical activity in youths may help explain their higher recovery ability after high-intensity PT (25). Therefore, because young athletes can recover from physical exertion faster than adults, especially from high-intensity exercise (11), one may hypothesize that 24 hours of rest between PT sessions could be viewed as an adequate recovery period to induce training adaptations in this population. Considering that from a practical and logistic point of view, some young soccer teams schedule training sessions on consecutive days, our research interest was to determine whether 2 PT sessions per week, with 24 or 48 hours of rest between these, would result in significant differences in explosive strength and endurance adaptations between the 2 recovery windows, as well as with no additional explosive training in young soccer players.

Methods

Experimental Approach to the Problem

We examined the ability of a twice weekly, in-season, short-term PT implemented with either 24 or 48 hours of rest between training sessions as a substitute for some soccer drills within regular soccer practice to improve physical performance compared with soccer practice only. Three groups were formed from young male soccer players; 1 group followed a twice weekly PT program with 24 hours of rest between training sessions (PT24), a second group followed the same twice weekly PT program but with 48 hours of rest between training sessions (PT48), and a third group followed their regular soccer practice (control group, CG). Before and after a 6-week period, all players executed a battery of 8 tests related to explosive and endurance performance. This was a randomized controlled trial. The assigned groups were determined by a chance process (a random number generator on a computer) and could not be predicted. This procedure was established according to the "CONSORT" statement, which can be found at http://www.consort-statement.org.

Subjects

Subjects were recruited from 2 different amateur soccer teams with similar competitive schedule (1 game per week) and similar soccer drills (2 sessions per week) resulting in similar soccer-specific weekly training load (session rating of perceived exertion) for all groups in the study design. Soccer players fulfilled the following inclusion criteria: (a) a background of more than 2 years systematic soccer training and competition experience; (b) continuous soccer training in the past 6 months, (c) no PT experience in the past 6 months, and (d) no background in regular strength training or competitive sports activity that involved any kind of jumping training exercise during the treatment. Initially, 189 subjects who fulfilled the inclusion criteria were chosen to participate in the study. To be included in the final analyses, participants were required to complete all the training sessions and attend all measurements sessions. As a result of these requirements, 23 subjects were removed from the study. Therefore, 166 male soccer players were included in the final analyses. The 166 subjects initially measured were divided into 3 groups: a CG ($N = 55$) and 2 PT groups with 24 hours (PT24; $N = 54$) or 48 hours (PT48; $N = 57$) of rest between training sessions. Mean values ± SD values for each group's characteristics are provided in Table 1.

Institutional review board approval for our study was obtained, and all subjects (and their parents or guardians) were carefully informed about the experiment procedures and about the possible risk and benefits associated with participation in the study, and an appropriate signed informed consent/assent document has been obtained pursuant to law before any of the tests were performed. We comply with the human and animal experimentation policy statements guidelines of the American College of Sport Medicine.

Testing Procedures

Subjects followed a familiarization period before testing to reduce any learning effects. Standardized tests during a period of 5 days were scheduled >48 hours after a competition or hard physical training and were completed in the same order, at the same time of the day, in the same indoor venue, with the same sport clothes, and by the same investigator before and immediately after the 6-week intervention period. In addition, all participants (and their parents or guardians) were instructed to have a good night's sleep (≥9 hours) before each testing day and to avoid drinking or eating at least 2–3 hours before measurements. All participants were motivated to give their maximum effort during performance measurements.

On day 1, players' characteristics (age, height, weight, self-assessed Tanner pubic hair and genital stage, soccer experience, and soccer-specific weekly training load) were assessed. On day 2, the squat jump (SJ) and countermovement jump (CMJ) tests were performed. The third day, the 20 (RSI20) cm drop jump reactive strength index and broad long jump (BLJ) test were assessed. The fourth day, 20-m sprint and running 10 × 5-m agility test were conducted. On the fifth day, the 20-m multistage shuttle run test (MST) and the sit-and-reach (SR) test were undertaken. At least 2 minutes of rest was allowed between each trial to reduce the effects of fatigue. While waiting, participants performed low-intensity activity to maintain physiological readiness for the next test. The best score of 3 trials was recorded for all performance tests, apart from the single MST.

Subject Characteristics. Height was measured using a wall-mounted stadiometer (Butterfly, Shanghai, China) recorded to the nearest 0.5 cm; body mass was measured to the nearest 0.1 kg using a digital scale (BC-554 Ironman Body Composition Monitor; Tanita, IL, USA); and body mass index was calculated ($kg \cdot m^{-2}$). Maturity was determined by self-assessment of Tanner stage.

Vertical Jump Tests. Testing included the execution of maximal SJ, CMJ, and RSI20. All jumps were performed on a mobile contact mat (Globus, Codogne, Italy) with arms akimbo. Take-off and landing was standardized to full knee and ankle extension on the same spot. The participants were instructed to maximize jump height and minimize ground contact time during the RSI20 after dropping down from a 20-cm drop box. The RSI20 was calculated as previously reported (41).

Broad Long Jump Test. The BLJ was used to assess maximal jump performance in the horizontal plain. The test was performed using a 5-m fiberglass metric tape laid on a wooden floor. Subjects were instructed to jump positioning (behind the starting line) their feet shoulders wide apart and to perform a fast downward movement (approximately 120° knee angle) followed by a maximal effort horizontal jump. Subjects were instructed to bend their knees after landing. Distance was measured from the starting line to the point where the heels of the subjects make contact with the ground after landing.

Twenty Meter Sprint Test. The sprint time was measured to the nearest 0.01 second using single beam infrared red photoelectric cells (Globus). The starting position was standardized to a still split standing position with the toe of the preferred foot forward and behind the starting line. Sprint start was given by a random sound that triggers timing. The photoelectric signal was positioned at 20 m and set approximately 0.7 m above the floor (i.e., hip level) to capture the trunk movement to avoid a false trigger from a limb.

Running 10 × 5-m Agility Test. The test was conducted as previously described (17). Markers were set at 5-m distance. The examinee was asked to run from one marker to another 10 times, with the fastest possible result and direction change. The examinee had to pass the marked space with both legs. The results were in seconds, determined with hand-held chronometer.

Twenty Meter Multistage Shuttle Run Test. The MST was conducted as previously described (1). Briefly, players ran back and forth between 2 lines, spaced 20 m apart, in time with the "beep" sounds from a compact disc. Each successful run of the 20-m distance was a completion of a shuttle. The beep sounded at a progressively increasing pace with every-minute of the test, and the athlete had to increase speed accordingly. The athlete was warned if he did not reach the end line in time once. The test was terminated when the examinee (a) could not follow the set pace of the beeps for 2 successive shuttles or (b) stopped voluntarily. The scores were expressed as the last minute that the athlete completed (20).

Sit-and-Reach Test. For the SR test, similar instruments and protocols were used as previously reported (23). Briefly, a scale calibrated in centimeters was placed on the top surface of a SR box. The test was performed by having athletes sitting on the floor. The athlete's feet were placed flat against the SR box, separated approximately by 40 cm. Players then slowly reached forward toward their toes, as far as possible, while keeping their knees, arms, and fingers fully extended, with palms down and placing their right hand over the left, with long fingers even, holding the position of maximal reach for 2 seconds. The precision of the measurement was 0.5 cm.

Treatment

The study was completed in autumn, during the mid-portion of their competition period. The CG did not perform the PT but performed their usual soccer training (technical-tactical exercises, small-sided games, simulated competitive games, and basic conditioning exercises). The PT groups performed plyometric drills as a substitute for some soccer drills within the usual 120-minute practice twice per week for 6 weeks. This time frame or number of sessions are higher (24,36), the same (24,34) or very similar (5,27) to those previously reported to induce significant explosive adaptations in young soccer players and youths (4). Plyometric volume was increased by 20% per week. Because players did not have any history of formal plyometrics, before beginning the training period they were instructed on how to properly execute all the exercises to be performed during this period. In addition, all training sessions were supervised, and particular attention was paid to demonstration and execution. Plyometric training sessions were separated with 24 hours for PT24 and with 48 hours for PT48. All plyometric sessions lasted approximately 30 minutes and were performed just after the warm-up. Aside from the formal training

TABLE 1. Descriptive data of the control group (CG), plyometric training 24-hour group (PT24), and plyometric training 48-hour group (PT48h).

	CG (*n* = 55)	PT24 (*n* = 54)	PT48 (*n* = 57)
Age (y)	14.0 ± 2.3	14.2 ± 2.2	14.1 ± 2.2
Height (cm)	160 ± 13.1	158 ± 12.4	159 ± 12.3
Body mass (kg)	52.1 ± 12.1	50.3 ± 12.1	51.8 ± 12.2
Body mass index ($kg\cdot m^{-2}$)	19.9 ± 2.0	19.8 ± 2.2	20.0 ± 2.1
Genital Tanner stage	3.9 ± 1.2	4.1 ± 1.1	3.9 ± 1.2
Pubic hair Tanner stage	3.8 ± 1.2	3.9 ± 1.1	3.9 ± 1.2
Soccer experience (y)	5.3 ± 2.0	5.0 ± 1.9	5.4 ± 2.4
Session rating of perceived exertion	432 ± 275	463 ± 229	451 ± 308

intervention, all participants attended their regular physical education classes. PT24 and PT48 completed the same amount of total jumps during intervention, used the same surface (grass soccer-field) and time of the day (afternoon) for training, with the same rest intervals between jumps and series. Half of the plyometric volume corresponds to cyclic and the other half to acyclic jumps. The combination of multilateral, multidirectional, cyclic, and acyclical plyometric drills was based on previous suggestions (6,27,31). The rest interval between series was of 120 seconds and between acyclic jumps was of approximately 15 seconds, as previously recommended (30). The same 13 exercises were completed by both the groups. All exercises were performed as a CMJ with arm swing (i.e., stretch shortening cycle involvement). In addition, both groups completed 2 sets of 10 repetitions of high-intensity bounce drop jumps from 20-cm high boxes. A detailed description of the 6-week training program is depicted in Table 2.

Statistical Analyses

All values were reported as mean ± *SD*. Relative changes (%) in performance and standardized effects (SE) are expressed with a 90% confidence limits. Normality and homoscedasticity assumptions for all data before and after intervention were checked, respectively, with Shapiro-Wilk and Levene tests. To determine the effect of intervention on performance adaptations, a 2-way variance analysis with repeated measurements (3 groups × 2 times) was applied. When a significant *F* value was achieved across time or between groups, Sheffe post hoc procedures were performed to locate the pairwise differences between the means. The α level was set at $p \leq 0.05$ for statistical significance. In addition to this null hypothesis testing, data were also assessed for clinical significance using an approach based on the magnitudes of change. Threshold values for assessing magnitudes of SE (changes as a fraction or multiple of baseline *SD*) were 0.20, 0.60, 1.2, and 2.0 for small, moderate, large, and very large, respectively (16).

RESULTS

Despite not pair-matching individuals based on an independent variable, there were no significant differences between groups' descriptive data (Table 1).

TABLE 2. Six-week plyometric training program.

	Set × repetitions					
Exercises*	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Cyclic horizontal left leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Acyclic horizontal left leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Cyclic horizontal right leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Acyclic horizontal right leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Cyclic vertical left leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Acyclic vertical left leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Cyclic vertical right leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Acyclic vertical right leg	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Cyclic bilateral vertical	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Acyclic bilateral vertical	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Cyclic bilateral horizontal	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Acyclic bilateral horizontal	2 × 5	2 × 6	2 × 7	2 × 8	2 × 9	2 × 10
Bounce drop jumps 20-cm	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10	2 × 10

*Denotes that the order of exercises execution was randomized each training session.

Table 3. Training effects (with 90% confidence limits) for the performance variables for the control group (CG; n = 55), plyometric training 24-hour group (PT24; n = 54) and plyometric training 48-hour group (PT48h; n = 57).

	Baseline mean ± *SD*	Performance change (%)	Magnitude of training effect
Squat jump (cm)			
CG	31.9 ± 6.1	−1.1 (−2.1 to −0.1)	−0.05 (−0.1 to 0.0)
PT24	31.2 ± 6.1	4.4 (3.6 to 5.2)*	0.22 (0.18 to 0.26)†
PT48	32.8 ± 7.0	3.8 (3.3 to 4.4)*	0.17 (0.15 to 0.20)
Counter movement jump (cm)			
CG	33.1 ± 6.4	−0.4 (−1.4 to 0.6)	−0.02 (−0.07 to 0.03)
PT24	32.6 ± 6.1	7.4 (6.3 to 8.5)*	0.37 (0.31 to 0.42)†
PT48	34.3 ± 6.9	8.0 (6.7 to 9.3)*	0.39 (0.33 to 0.45)†
20-cm drop jump reactive strength index (mm·ms^{-1})			
CG	1.31 ± 0.42	1.2 (−0.5 to 3.0)	0.03 (−0.01 to 0.08)
PT24	1.32 ± 0.40	12.2 (10.2 to 14.2)*	0.34 (0.29 to 0.39)†
PT48	1.37 ± 0.39	12.0 (10.0 to 14.0)*	0.39 (0.33 to 0.45)†
Broad long jump test (cm)			
CG	184.3 ± 29.1	−0.1 (−0.9 to 0.7)	−0.01 (−0.06 to 0.05)
PT24	184.1 ± 29.8	5.6 (3.4 to 7.9)*	0.33 (0.20 to 0.45)†
PT48	188.2 ± 30.0	5.3 (4.4 to 6.2)*	0.33 (0.28 to 0.39)†
20-m sprint time test (s)			
CG	4.32 ± 0.49	1.2 (0.7 to 1.6)	0.10 (0.06 to 0.14)
PT24	4.37 ± 0.46	−5.6 (−6.4 to −4,7)*	−0.52 (−0.60 to −0.44)†
PT48	4.26 ± 0.41	−5.1 (−5.7 to −4.4)*‡	−0.51 (−0.57 to −0.44)†
Running 10 × 5-m agility time test (s)			
CG	17.2 ± 1.1	1.8 (1.1 to 2.5)*	0.28 (0.18 to 0.38)†
PT24	17.4 ± 1.0	−3.3 (−3.8 to −2.8)*§	−0.63 (−0.72 to −0.53)‖
PT48	17.3 ± 0.9	−2.7 (−3.2 to −2.3)*‡	−0.57 (−0.67 to −0.47)†
20-m multistage shuttle run test (min)			
CG	8.5 ± 1.8	2.4 (1.2 to 3.6)	0.10 (0.05 to 0.16)
PT24	8.5 ± 1.6	10.3 (8.9 to 11.8)*	0.49 (0.43 to 0.56)†
PT48	8.9 ± 1.7	10.0 (8.3 to 11.7)*	0.49 (0.41 to 0.56)†
Sit-and-reach flexibility test (cm)			
CG	41.0 ± 4.8	−0.8 (−2.1 to 0.5)	−0.07 (−0.17 to 0.04)
PT24	40.3 ± 4.9	5.7 (4.4 to 7.1)*	0.44 (0.34 to 0.53)†
PT48	41.2 ± 5.2	4.7 (3.7 to 5.7)*	0.35 (0.28 to 0.42)†

*Denotes significant difference pre to posttraining $p < 0.001$. Values in brackets represent 90% confidence limits.
†Small standardized effect.
‡Denotes significant difference with the CG posttraining $p \leq 0.05$.
§Denotes significant difference with the CG posttraining $p < 0.01$.
‖Moderate standardized effect.

Before training, no significant differences were observed between groups in SJ, CMJ, RSI20, BLJ, 20-m sprint time, 10 × 5-m agility time, MST, or SR test (Table 3).

No significant change in the CG was observed, except for an increase in 10 × 5-m agility test time (i.e., reduced performance), with a small clinically significant change (+0.28 SE).

The 2-way variance analysis with repeated measurements (3 groups × 2 times) showed that after training both plyometrically trained groups demonstrated a statistically significant increase in SJ, CMJ, RSI20, BLJ, 20-m sprint, 10 × 5-m agility test time, MST, and SR performance, with no differences between groups. Also, the magnitudes of change analyses showed that the PT24 and PT48 groups achieve a similar small to moderate clinically significant change in SJ (+0.17; +0.22 SE), CMJ (+0.37; +0.39 SE), RSI20 (+0.34; +0.39 SE), BLJ (+0.33 SE), 20-m sprint (−0.51; −0.52 SE), 10 × 5-m agility test (−0.57; −0.63 SE), MST (+0.49 SE), and SR (+0.35; +0.44 SE) performance, respectively.

Discussion

This study suggests that 6 weeks of PT, with either 24 or 48 hours of rest between sessions, induced significant and small-to-moderate similar improvements in SJ, CMJ, RSI20, BLJ, 20-m sprint time, 10 × 5-m agility time, MST, and SR test performances in young male soccer players. Also, these results show that the combination of soccer drills and specific explosive strength training with no additional training time in-season is a meaningful stimulus to enhance explosive strength and endurance adaptations in young male soccer payers.

Although it has been recommended that plyometric drills should not be conducted on consecutive days in youths (7,37), and although some interventions in young soccer players used >72 hours (28,32) or >48 hours (27) of rest between PT sessions to allow for adequate recovery, suggesting that these time frames of rest would be necessary to induce adequate training stimulation in this population of young athletes, the study shows that PT applied twice weekly in consecutive or nonconsecutive days results in similar explosive and endurance adaptations in young male soccer players. It may be argued that the PT applied represented a low training load, therefore, a relatively short period of recovery (i.e., <24 hours) between training sessions to achieve performance adaptations was sufficient. However, during the first week of training players completed 140 jumps each session, including 1 legged jumps and BDJ, which can be considered high-intensity exercises (aside from the maximal voluntary intensity required to complete all jumps). In addition, each training week plyometric volume was increased by 20%, and during the sixth week of training athletes completed 260 jumps during each training session, a volume similar (7) or even higher (28,34) in comparison to the one used effectively in previous studies with young soccer players. Therefore, several possible mechanisms can be postulated to understand how this relatively short rest period between PT sessions allows significant explosive and endurance performance adaptations in the short term when PT was applied twice weekly in young male soccer players. Some of these are reduced susceptibility to muscle damage (compared with adults) and performance alterations, and higher ability to recover after PT (25); reduced proportion of fast twitch fibers (22); reduced relative power generation capacity related to maturation-dependent neuromotor factors (11); reduced body mass (38); greater muscle compliance (allowing rapid bone growth) (8); greater naturally anabolic-occurring processes (2); and adaptations achieved during training such as endurance capacity and, hence, an improved ability to recover from high-intensity exercise (35). Future studies must be conducted to elucidate the underlying mechanism that allows young soccer players to obtain significant performance adaptations with consecutive days of PT. Interestingly, it has been suggested that muscle function (i.e., jump ability, sprint performance) is probably the best indicator of muscle recovery after intense exercise, especially in athletes (8); hence, future studies in young soccer players may consider the evaluation of muscle function performance after PT sessions with different rest times between them to better understand the recuperation process in this population segment.

The PT24 and PT48 significantly increased jumping performance (SJ, CMJ, RSI20, and BDJ), with no difference between groups. Similar results have been reported in previous studies for SJ (7), CMJ (27), RSI (27), and horizontal jump performance (7) after PT intervention in young soccer players. The significant improvement in jump performance in SJ, CMJ, RSI20, and BDJ test confirms the effectiveness of the application of a PT stimulus in achieving explosive strength adaptations, which may improve players' performance. The improvement observed could have been induced by various neuromuscular adaptations, such as increased neural drive to the agonist muscles, improved intermuscular coordination, changes in the muscle-tendon mechanical-stiffness characteristics, changes in muscle size or architecture, and changes in single-fiber mechanics (26); but because no physiological measurements were made, only speculations are possible.

A significant and similar decrease in 20-m sprint time in the PT24 and PT48 suggested that PT may be a meaningful stimulus during the competitive period for the acceleration ability of young soccer players. These results agree with those previously reported (27). The horizontal nature of the PT stimulus in these studies may help to explain the increased acceleration sprint performance (31). In addition, the PT24 and PT48 significantly reduced their time to complete the running 10 × 5-m agility test, with no differences between groups. Previous studies in early and pubescent soccer players have reported reduced agility test times of −3.4% (6) and −3.1% (18), similar to the result of this study (−2.7 to −3.3%). It must be acknowledged that subjects from the PT24 and PT48 completed a training program with several plyometric exercises designed to induce short contact times; and a reduction in contact time with PT (29) may increase RSI, which may predict the ability to change directions while running (41). Contrary to the positive explosive adaptations observed in the PT24 and PT48, the CG exhibited a significant increase in their 10 × 5-m agility test time. These observations reinforce the value of an independent power-training program to enhance explosive actions of young soccer players.

To the authors' knowledge, a unique finding of this study was to report that a short-term PT program, implemented as a substitute for some soccer drills within regular in-season soccer practice, significantly enhances flexibility in young male players, and this improvement was similar in PT24 and PT48 groups. Similarly, previous results show that young people also increase flexibility after PT (10). Plyometric training has been advocated as a preventive injury strategy for young athletes (21), and as muscle flexibility is a risk factor for developing muscle injuries in male soccer players (39), these results may have important relevance. The increased flexibility may be explained by a possible reduction of the stiffness of the muscle-tendon complex and similar changes in the elastic behavior of adjacent joint subcomponents (26).

The PT24 and PT48 groups exhibited a significant increase in endurance performance (i.e., MST), with no differences between groups. Their relative increase in endurance performance was 4 times greater than that of the CG. The positive effects of PT on endurance performance in young soccer players have been previously reported (40). However, explosive training in young soccer players did not induce improvement in $\dot{V}O_2max$ (28) or lactate thresholds (14); therefore, the improvement in the MST may be related to neuromuscular power improvement useful for change of direction endurance test (3) or running economy adaptations (40). More studies must be conducted to clarify how PT influences endurance performance related to young soccer players.

In conclusion, PT24 and PT48 groups achieved similar small-to-moderate significant improvements in explosive and endurance performance after training. Therefore, when 2 PT sessions are performed per week, 24 or 48 hours of rest between these is adequate to induce significant explosive and endurance adaptations in young male soccer players.

Practical Applications

From a practical point of view, it must be considered that the PT applied induced explosive and endurance adaptations, which may have high transference into game-play performance. Thus, a twice weekly short-term high-intensity PT program, implemented as a substitute for some soccer drills within regular in-season soccer practice, can enhance explosive and endurance performance in young soccer players compared with soccer training alone, and these improvements can be achieved using 24 or 48 hours of rest between PT sessions. Considering that some young soccer teams schedule training sessions are on consecutive days, the current findings may be relevant to programming PT in this context.

Although concern has been expressed by some researchers with regard to the injury risk during PT, to the best of the author's knowledge, when adequate controlled PT intervention had been applied, no important injuries had been reported. In fact, PT had been advocated as a preventive injury strategy (21) and even as a rehabilitation tool. It is important to notice that in this investigation, no injuries were reported. More so, subjects reported little subjective muscle pain after the training sessions (data not shown). However, it is still unknown if consecutive days of PT may have a greater risk of injury occurrence over the course of a season in comparison to a periodized plan with greater between-days rest intervals, and precaution must be taken before implementing such regime with a long-term approach.

Also, it must be considered that although the results of the study demonstrated an increase in explosive and endurance ability after PT, it is recommended that this training method should be adequately incorporated in a comprehensive training program that develops the specific technical abilities that are critical to achieve adequate performance (especially at young ages), and with an adequate aerobic conditioning program to optimize training adaptations.

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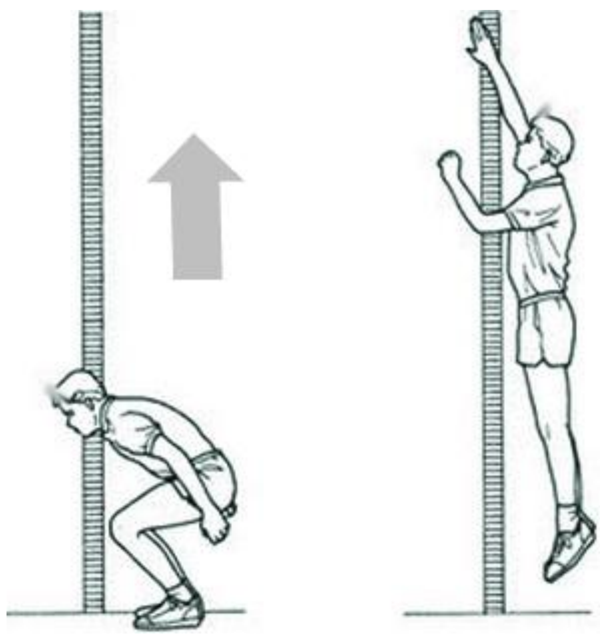
INSTRUMENTOS

Test de Salto VERTICAL

PROTOCOLO DE LA PRUEBA

- El atleta caliente durante 10 minutos.
- El atleta debe untarse en las yemas de sus dedos la tiza.
- Ubicamos un asistente para que este atento de los datos recolectados y al debido gesto técnico del test.
- El atleta se ubica en el espacio asignado lateral a la pared, manteniendo los pies restantes en el suelo, llega hasta lo más alto posible con una mano y marca la pared con la punta de los dedos (**Esta será H_a**)
- El atleta desde una posición cómoda realiza una flexión de piernas de 90° tomando un impulso; y salta tan alto como sea posible marcando la pared con la tiza en los dedos (**Esta será H_b**)mientras se este e esta posición preparaciones previas de salto es registro único.
- Las medidas auxiliares y registra la distancia entre H_a y H_b
- El atleta repite la prueba 3 veces y elije la mejor altura para calcular; hay descanso de 30" entre cada intento realizado con el fin de darle al atleta una debida preparación física, fisiológica y psicológica al siguiente salto.
- ***El asistente calcula el promedio de las distancias registradas y utiliza este valor para evaluar el rendimiento del deportista.***



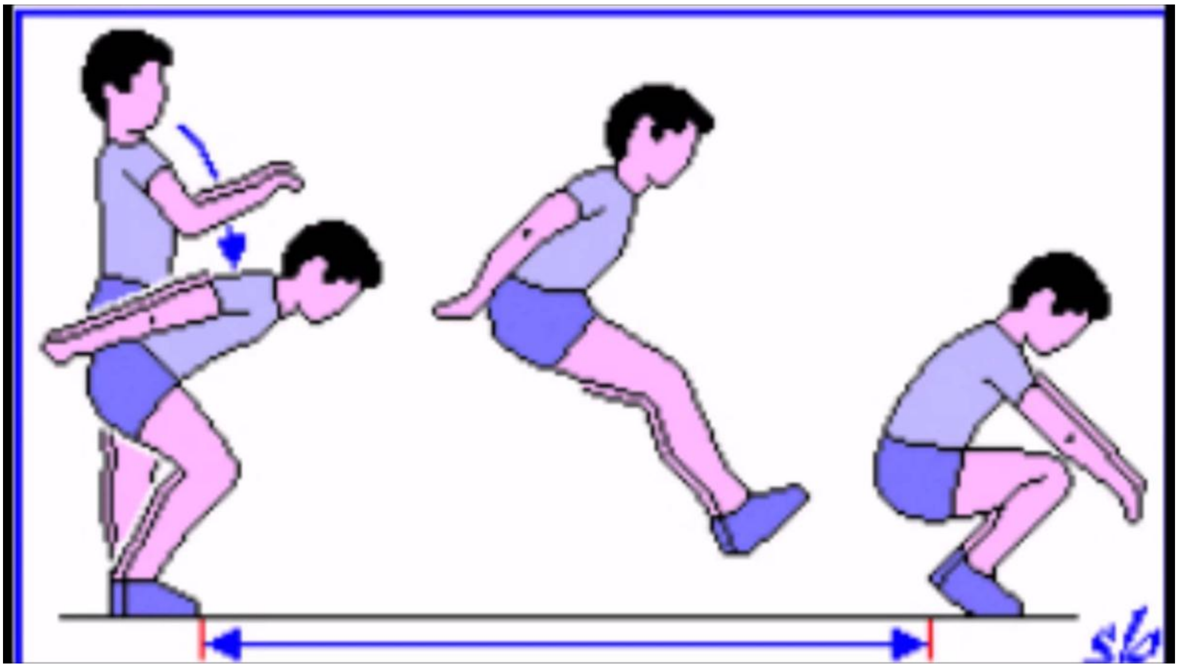
Test de Salto HORIZONTAL

Fuerza explosiva: salto horizontal con los pies juntos.

Esta prueba trata de **medir la fuerza explosiva del tren inferior**.

Una vez hechos los estiramientos y el calentamiento previo para hacer la prueba física, nos colocamos detrás de la línea de salto y en dirección a la que debemos saltar. Los pies podrán estar ligeramente separados. Una vez te hagan el señal para saltar, flexionas el tronco y las piernas. También es aconsejable balancear los brazos para posteriormente realizar un movimiento explosivo de salto hacia delante. La caída debe ser equilibrada, no se permite ningún apoyo posterior con los brazos.

La longitud saltada se medirá en centímetros, desde la línea de salto hasta la parte inferior del último pie, es decir, hasta el pie más retrasado a la caída.



Test de Sprint 10m, 20m, 30m, 40m

El **test de sprint** mide tu velocidad y rapidez de movimiento en una determinada distancia predefinida, normalmente 20 metros o 40 metros.

Cómo hacer un test de sprint

Para hacer un **test de sprints** necesitarás una persona que te cronometre y un espacio delimitado (20 o 40 metros según el tipo de sprint que vayas a hacer). Cuando la persona que cronometra te lo indique, recorre la distancia marcada lo más rápido posible. Cuando termines el sprint, anota los resultados en la calculadora para averiguar tu forma física.

Cómo interpretar los resultados del sprint

La calculadora te proporciona 3 resultados, en función de los datos introducidos:

- **Media**: Tiempo medio que suelen hacer las personas de tu mismo sexo y edad
- **Puntuación**: tu nota, según tus capacidades en comparación con la gente de tu mismo sexo y edad (sobre 100)
- **Valoración**: la evaluación de tu forma física (mala, pobre, en la media, buena o excelente).