**Universidade de São Paulo**
**Faculdade de Medicina de Ribeirão Preto**

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# Observação, Análise e Interpretação do Desempenho em Jogo no Futebol: Implicações para a Avaliação e Treinamento

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**Rodrigo Leal de Queiroz Thomaz de Aquino**

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RODRIGO LEAL DE QUEIROZ THOMAZ DE AQUINO

# **Observação, Análise e Interpretação do Desempenho em Jogo no Futebol:** Implicações para a Avaliação e Treinamento

Documento apresentado a Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo como parte dos requisitos exigidos para obtenção do título de Doutor em Ciências, na área de Reabilitação e Desempenho Funcional.

Área de concentração: Educação Física

Orientador: Prof. Dr. Enrico Fuini Puggina

Ribeirão Preto

2019

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Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo

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# DECICATÓRIA

Aos meus avós João Angélico e Dirce (*in memoriam*), que me cercaram de carinho, amor, experiências e me ensinaram a trilhar o caminho do bem.

Aos meus pais Carlos Eduardo e Christina Helena, pelo empenho, compromisso, dedicação e ensinamentos durante minha caminhada de vida.

A minha namorada, Isabella Alves, pela amizade, amor e equilíbrio.

Aos amigos, Professores, alunos, e profissionais do futebol por me oportunizarem o conhecimento por meio da convivência.

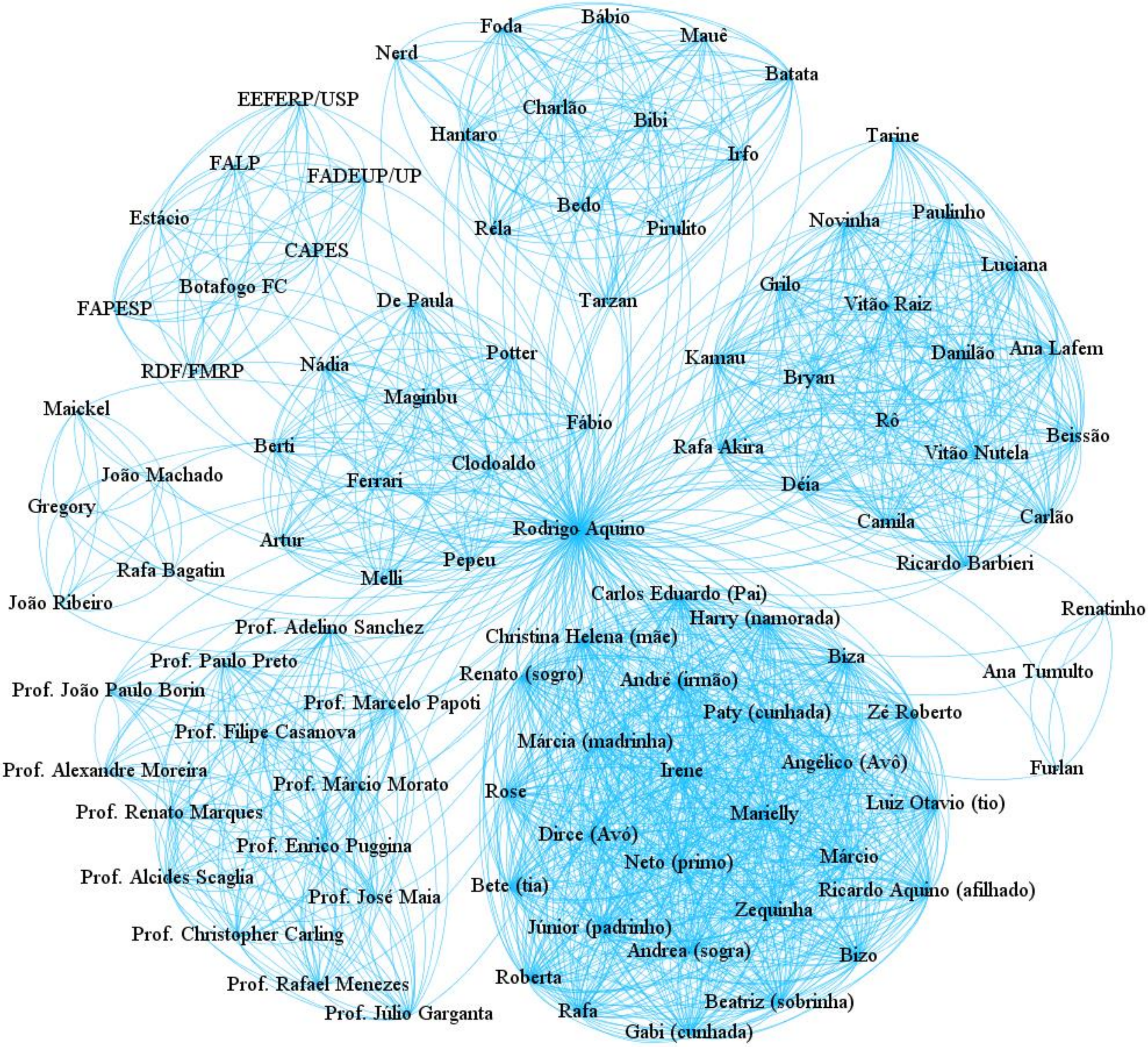
# AGRADECIMENTOS

Uma história vem a cabeça no encerramento deste ciclo. Os agradecimentos, aqui expostos em palavras, transcendem as pessoas que caminharam lado-a-lado durante minha trajetória de vida. Sentimentos emergentes, sejam eles bons ou ruins, impactaram diretamente as minhas decisões durante os últimos anos. Por isso, também agradeço ao plano sentimental e espiritual que não são mensuráveis objetivamente. Com certeza essas energias que circundaram meu corpo, minha alma e meus pensamentos foram essenciais para meu crescimento como ser-humano, o que impacta diretamente minha vida profissional.

Como defendo nesta tese, nossas decisões são emergentes da interação entre nós, o ambiente a qual estamos inseridos e a tarefa que cumprimos. Portanto, agradeço as decisões pouco resolutivas e por vezes menos apropriadas que contribuíram sobremaneira para o fortalecimento das minhas opiniões e crenças. De fato, o processo de doutoramento foi fundamental para potencializar minha capacidade de enxergar pistas no ambiente e resolver os problemas. Tal como estamos em constante interação com os elementos constituintes da vida, sejam eles humanos, materiais e espirituais, agradeço a estas esferas relacionais que contribuíram para minha visão mais sistêmica do mundo.

Não há significados em um conjunto de palavras para agradecer as pessoas das quais tive a oportunidade de compartilhar as alegrias e tristezas da vida profissional e pessoal. Por isso, gostaria de resumir todo o sentimento que estou transmitindo de dentro de mim para as teclas deste computador em três palavras: gratidão, fraternidade e humildade. Foram muitas as pessoas que viveram ao meu lado e colocaram um tijolo na construção desta tese. Porém, a sinergia e a inter(ação) destes tijolos emergiram discussões e conclusões imprevisíveis para mim.

Por fim, então, gostaria de representar esta rede de inter(ações) por meio de uma Figura. Nela, não me preocupei em elencar as pessoas mais ou menos importantes nesta rede da vida, mas sim, os canais de comunicação que me oportunizaram o conhecimento, a descoberta, o equilíbrio e o discernimento do bom e ruim. Meus sinceros e especiais agradecimentos cada um!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*Toda grande verdade começa como uma heresia. A história não ergue monumentos a cientistas que apenas repetem aquilo que é conhecimento comum; grandes ideias são grandes porque confrontam determinada ortodoxia reinante. Para que se possa entender aqueles que dão importantes contribuições ao pensamento humano, deve-se começar a análise com o estado da ciência no momento da descoberta.*

*Carl Biven*

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# RESUMO

A presente tese apresenta, discute e avalia criticamente o conteúdo e o contributo de uma seleção de trabalhos de pesquisa submetidos ou publicados em revistas internacionais no campo das ciências do esporte. Coletivamente, esses trabalhos contribuem para o campo da análise de jogo em jogadores jovens e adultos de futebol, com implicações para aperfeiçoar a avaliação e o treinamento. As pesquisas foram em parte moldadas pela experiência do autor na prática profissional e acadêmica, mas principalmente impulsionada por necessidades emergentes identificadas durante os anos de atuação prática e em parceria com profissionais atuantes em clubes de futebol. Um total de duas revisões sistemáticas (apresentadas na presente tese como introdução ao campo de estudo), sendo uma meta-análise, e três estudos de campo revisados por pares estão incluídos. Esta tese apresenta criticamente resultados e discussões sobre dois principais fluxos: (i) validação de testes físicos em ambiente de jogo, de acordo com as características gerais e exigências específicas das partidas; (ii) análise dos fatores contextuais e posicionais que afetam potencialmente o desempenho no futebol. Os trabalhos de pesquisa são apresentados em uma sequência conceitual dentro dos dois temas, em vez de uma ordem estritamente cronológica, para demonstrar a coerência e a sinergia dentro dos dois fluxos. Esta tese fornece uma reflexão crítica sobre a contribuição geral para o corpo atual de conhecimento científico e o impacto coletivo dos trabalhos que foi alcançado. As limitações dos estudos encontradas no decorrer do trabalho são discutidas como temas atuais, possibilitando um direcionamento para futuras pesquisas. Por fim, todo conhecimento produzido foi traduzido em forma de um e-book para maior acesso por diferentes recursos humanos.

**Palavras-chave:** análise de redes sociais; análise de jogo; ciências do esporte.

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# ABSTRACT


This thesis presents, discusses and critically evaluates the content and the contribution of a selection of research papers submitted or published to international peer-reviewed sports science journals. Collectively, these papers make novel insights to the field of match analysis in young and adults' soccer players, with implications for improving assessment and training. The researches were partly shaped by the authors' experience in professional and academic practice, but mainly driven by emerging and evolving needs-analyses identified within his work, identified during the years of practice and in partnership with professionals working in soccer teams. A total of two systematic reviews (presented in this document as an introduction to the field of study), one of them being a meta-analysis, and three original articles are included. These papers present critically comments on work in two main streams: (i) validation of physical fitness tests in a game context, according to general characteristics and specific requirements of the match; (ii) analysis of contextual and positional factors that potentially affect the soccer performance. The original research papers are presented in a conceptual sequence within the two themes, rather than a strictly chronological order to demonstrate coherence and synergy within the two collections. The document provides critical reflection on the general contribution to the current body of scientific knowledge and the collective impact of the work that has been achieved. The limitations of the studies found during the course of the work are discussed as current themes, allowing a direction for future research. Finally, all scientific knowledge produced was translated into an e-book for greater access by different human recourses.



**Key-words:** social network analysis; match analysis; sport sciences.

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# LISTA DE SIGLAS E ABREVIATURAS

**1T:** 1 Touch.

**2T:** 2 Touch.

**a.u.:** Arbitrary Units.

**AP:** Average Power.

**APHV:** Age from/to Peak Height Velocity.

**ASR:** Anaerobic Speed Reserve.

**CBF:** Brazilian Football (or soccer) Federation.

**CD:** Central Defenders.

**CG:** Control Group.

**CM:** Central Midfielders.

**CON-test:** Control Test.

**Ɛ:** Standart Error of the Estimate.

**ECL:** English Championship League.

**ED:** External Defenders.

**EI:** Exercise Intensity.

**EM:** External Midfielders.

**EPL:** English Premier League.

**ES:** Effect Size.

**F:** Female.

**F:** Forwards.

**FAPL:** English FA Premier League.

**FMS:** Soccer Match Simulation.

**FP:** Free Play.

**GKs:** Goalkeepers.

**GPS:** Global Positioning System.

**HIA:** High-intensity Activities.

**HIR:** High-intensity Running.

**HIS:** High-intensity Simulation.

**HPBPT:** High Percentage Ball Possession Teams.

**$HR_{MAX}$:** Maximum Heart Rate.

**IBGE:** Brazilian Institute of Geography and Statistics.

**IPMet:** Brazilian Institute of Meteorological Research.

**ITG:** Interval Training Group.

**LIR:** Low-intensity Running.

**LIST:** Loughborough Intermittent Shuttle Test.

**LPBPT:** Low Percentage Ball Possession Teams.

**LPM:** Local Position Measurements.

**LSPT:** Loughborough Soccer Passing Test.

**M:** Man.

**MAS:** Maximal Aerobic Sprint.

**MBI:** Magnitude-based Inference.

**MIR:** Moderate-intensity Running.

**MP:** Minimum Power;

**MRS:** Maximal Running Speed.

**MS-10m:** Maximum Speed 10 m.

**MS-30m:** Maximum Speed 30m.

**N° Sprints per minute:** Number of sprints per minute, frequency of runs at V7 accounted as function of individual playing time.

**NS:** Number of Sprints.

**OSCS:** Offensive Sequences Characterization System.

**PSE:** Percepção Subjetiva de Esforço.

**$PMS_{Abs}$:** Absolute Peak Match Speed.

**$PMS_{Rel}$:** Relative Peak Match Speed.

**PP:** Peak Power (Estudo 3).

**PRISMA:** Preferred Reporting Items for Systematic reviews and Meta-analyses.

**PT-test:** Physical and Technical Test.

**R1:** Recovery of 1 minutes.

**R2:** Recovery of 2 minutes.

**R3:** Recovery of 3 minutes.

**R4:** Recovery of 4 minutes.

**RAT:** Reactive Agility Test.

**RHIA:** Repeated High-intensity Actions.

**RMST:** Reactive Motor Skills Test.

**RPE:** Rating Perceived Effort.

**SAFALL-FOOT:** System of Assessment of Functional Asymmetry of the Lower Limbs in Football.

**SD:** Standard Deviation.

**SE:** Sub-elite.

**$S_{MEAN}$:** Mean Speed.

**SPR:** Sprinting.

**SSCG:** Small-sided and Conditioned Games.

**SSG:** Small-sided Games.

**T1:** Before training.

**T2:** After training.

**TD:** Total Distance covered.

**TD-Yo-Yo IR1:** Total Distance covered during Yo-Yo Intermittent Recovery Test level 1.

**V1 (%):** Stopped, 0.00-0.40 km.h-1.

**V2 (%):** Walking, 0.41-3.00 km.h-1.

**V3 (%):** Low Intensity Running, 3.01-8.00 km.h-1.

**V4 (%):** Medium Intensity Running, 8.01-13.00 km.h-1.

**V5 (%):** High Intensity Running, 13.01-16.00 km.h-1.

**V6 (%):** Very High Intensity Running, 16.01-19.00 km.h-1.

**V7 (%):** Sprinting, > 19.01 km.h-1.

**V8 (%):** High Intensity Activities, V6 + V7.

**$V_{AVERAGE}$:** Average Speed.

**VHIR:** Very High-intensity Running.

**$V_{L4}$:** Running Speed at a blood lactate concentration of 4 $mmol \cdot L^{-1}$.

**$V_{MAX}$:** Maximal Speed.

**$\dot{V}O_{2\,MAX}$:** Maximum Oxygen Consumption Uptake.

**$\dot{V}O_{2\text{-}LAC3}$:** Oxygen Consumption Uptake corresponding to 3 $mmol \cdot L^{-1}$ lactate.

**$\dot{V}O_2VT$:** Oxygen Consumption Uptake at the Ventilatory Threshold.

**$VT_{2speed}$:** High-intensity Running based on second Ventilatory Threshold.

**$v\dot{V}O_{2MAX}$:** Intensity of Maximum Oxygen Consumption Uptake.

**YE:** Young Elite.

**Yo-Yo IR:** Yo-Yo Intermittent Recovery Test.

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# CAPÍTULO 1. VISÃO GERAL DA TESE

## 1.1 ESTRUTURA

A presente tese está estruturada conforme o modelo escandinavo e é composta por uma seleção de trabalhos de pesquisa submetidos ou publicados em revistas internacionais no campo das ciências do esporte. Entendemos que o que comumente é denominado "análise de desempenho" nos remete inicialmente a um processo de observação das medidas de interesse (nesta tese recorremos ao registro dos indicadores físicos e interações interpessoais), análise (de acordo com os procedimentos estatísticos e inferenciais necessários) e interpretação (que dá significado ao conjunto de dados e análises obtidas). Assim, coletivamente, os trabalhos apresentados nesta tese contribuem para o campo da observação, análise e interpretação do desempenho em jogo em jogadores jovens e adultos de futebol, com implicações para aperfeiçoar a avaliação e o treinamento.

Especificamente, organizamos as ideias em cinco estudos e um e-book. O Estudo 1 (Capítulo 2), revisitou sistematicamente a literatura disponível acerca da análise do desempenho técnico no futebol, tendo como destaque a necessidade emergente em abordagens de observação mais representativas ao jogo (e.g., análise de redes sociais). O Estudo 2 (Capítulo 3) contempla uma revisão sistemática e meta-análise sobre as relações entre os parâmetros obtidos em testes antropométricos e de aptidão física com o desempenho físico em jogo (i.e., demandas de corrida), recomendando para futuras pesquisas testes físicos integrados em contexto de jogo.

No Estudo 3 (Capítulo 4) propusemos um teste alternativo para descrever o desempenho físico de jovens jogadores (Sub-11 até Sub-20) utilizando um jogo reduzido denominado "6v6-SSGs". Os indicadores físicos observados contemplaram a carga externa (e.g., distâncias percorridas, acelerações, desacelerações) e interna (e.g., percepção subjetiva de esforço, frequência cardíaca média). A configuração de jogo reduzido utilizada (6v6-SSG) apresentou validade, reprodutibilidade e sensibilidade, o que o torna interessante para a comunidade científica e prática já que integra elementos tático-técnico-físicos.

Nos dois próximos Estudos (4 e 5) observamos as influências das variáveis contextuais ou situacionais da partida (i.e., níveis competitivos, fase da temporada, local, qualidade dos oponentes, resultado final) e dos fatores posicionais (i.e., posições de jogo, formações da equipe e de seus oponentes) sobre o desempenho de corrida e a interação entre os jogadores (i.e., análise de redes sociais).

Por fim, com o intuito de "traduzir" o conhecimento produzido para uma linguagem mais acessível, foi elaborado um e-book contemplando para além das principais ideias de cada estudo, outras abordagens de observação, análise e interpretação do desempenho em treino e jogo no futebol. Este livro está disponível na íntegra pelo link na seção de considerações finais (página 196).

Importa destacar que o conjunto de artigos apresentados retrata a minha trajetória acadêmica e profissional ao longo de quatro anos (2015-2019) em um clube de futebol. As problemáticas emergentes das minhas interações entre a comunidade científica e as comissões técnicas (i.e., treinador, preparador físico, fisiologista e analista de desempenho) resultaram nas reflexões metodológicas e nos planejamentos dos delineamentos experimentais dos estudos que serão apresentados.

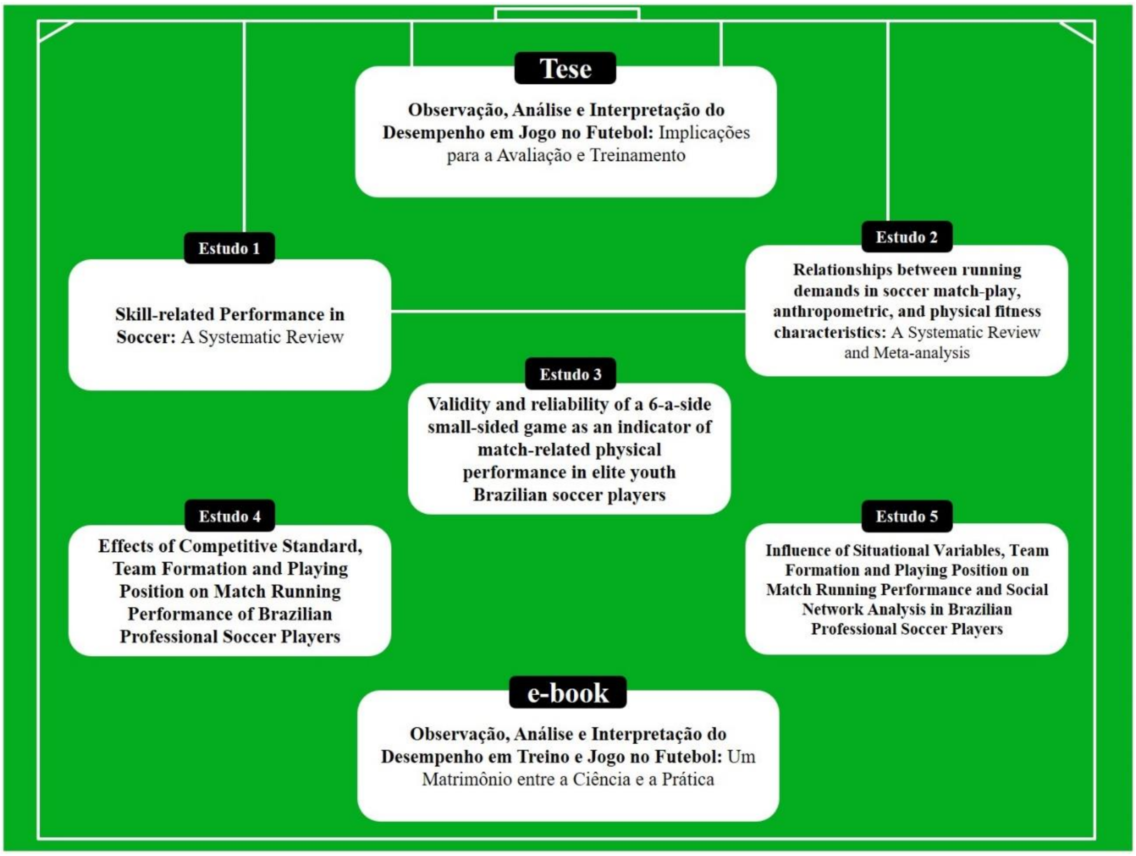


**Figura 1.** Estrutura geral da Tese.

## 1.2 CONTEXTUALIZAÇÃO

A produção científica sobre o futebol tem apresentado um crescimento vertiginoso no número de publicações nos últimos anos. Apenas como dados ilustrativos, inserindo os descritores "*brazilian*" E "*soccer*" no PubMed/NCI, podemos verificar que ~48% dos artigos foram publicados entre 2014-2019. Dentre as temáticas emergentes, a observação, análise e interpretação do desempenho em jogo – processo usualmente denominado pelos pesquisadores como análise de jogo – recebe um destaque notório (~52%). Porém, o que é análise de jogo?

A análise de jogo reporta-se ao estudo do treino e da competição, de modo a quantificar e qualificar a efetividade das suas ações, em todos os seus aspectos (e.g., tático-técnico-físico), salientando os fatos e os comportamentos relevantes que contribuem para otimizar o rendimento esportivo, identificando e caracterizando as tendências evolutivas e servindo como um processo de controle e avaliação da prestação dos jogadores e equipes. Ou seja, é utilizada para investigar o comportamento multidimensional das equipes no que diz respeito às diferentes escalas, a partir do nível individual (micro) para o nível coletivo (macro) (CARLING; WILLIAMS; REILLY, 2005; GROOM; CUSHION; NELSON, 2011). De fato, a análise de jogo contribui para que os processos de tomada de decisão sobre o desempenho dos jogadores e equipes sejam mais assertivos e sequencialmente permite o fornecimento de *feedbacks*, como parte do processo de *coaching*. Além disso, podemos destacar nas últimas décadas o desenvolvimento de equipamentos portáteis (*Global Positioning System*) e sistemas de análise de vídeo baseados em visão computacional e processamento de imagens (e.g. ProZone®, Amisco® Pro, DIVIDEOW, Sportscode), o que tem melhorado a acessibilidade aos recursos para análise objetiva de eventos esportivos em situação real de disputa

(CARLING; WILLIAMS; REILLY, 2005) e como resultado, as pesquisas frequentemente utilizam-se destes dados (MACKENZIE; CUSHION, 2013).

O futebol, caracterizado como um esporte complexo, dinâmico e aleatório, onde os jogadores e o ambiente interagem a todo o momento, é composto pela indissociabilidade entre os aspectos tático-técnicos e físicos (JÚLIO; ARAÚJO, 2005). A literatura científica é abrangente na sistematização do conteúdo acerca dos meios e métodos de avaliação do comportamento tático no futebol, principalmente nos últimos anos (GONZÁLEZ-VÍLLORA et al., 2015; RIBEIRO et al., 2017). No que tange aos meios e métodos para avaliação do desempenho técnico e físico, frequentemente, os pesquisadores têm recorrido a avaliações de maneira descontextualizada do jogo.

De fato, os estudos de revisão sistemática e meta-análise desta tese, apresentados nos Capítulos 2 e 3 como elementos introdutórios ao campo de estudo, fundamentam esta reflexão e direcionam para futuras pesquisas a proposição e utilização de abordagens multivariadas, utilizando-se de múltiplas variáveis em contexto de jogo para buscar um melhor entendimento do fenômeno. Portanto, os três estudos experimentais subsequentes foram motivados e convergem para a produção e utilização de alternativas para a resolução desses problemas vigentes.

O Estudo 1 desta tese (texto na íntegra disponível no Capítulo 2), revisitou sistematicamente 60 artigos empíricos acerca da análise do desempenho das ações técnicas no futebol obedecendo as orientações do *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA). Destes, 24 artigos utilizaram testes para avaliação técnica fora do contexto de jogo (*dribbling, shooting, passing*: e.g., RUSSEL; BENTO; KINGSLEY, 2010, 2011), embora não se perceba como esta abordagem descontextualizada interage com as outras (i.e., aspectos físicos e tático-técnicos específicos do jogo) ou como ela se adapta à estrutura do jogo (AQUINO et al., 2016a). Isso devido a esses testes isolados não abrangerem variáveis de percepção crítica (e.g., informação contextual ambiental) que os jogadores normalmente usam para controlar suas ações durante os jogos (GIBSON, 1979; SCARANTINO, 2003; TRAVASSOS et al., 2012; PASSOS et al., 2014), o que sugere um comprometimento na validade ecológica das conclusões dessas pesquisas (RÉ et al., 2014).

Os estudos selecionados nesta revisão que analisaram o desempenho técnico em contexto de jogo recorreram prioritariamente à análise notacional[1] (e.g., CARLING; DUPONT, 2011; HARPER et al., 2014). Contudo, o recurso unicamente a esta abordagem também parece não ser a forma mais condizente para diferenciar entre o desempenho menos do mais eficaz (BORRIE; JONES, 1998; BORRIE; JONSSON; MAGNUSSON, 2002; MACKENZIE; CUSHION, 2013). Por exemplo, durante um jogo, um passe para trás executado por um jogador de meio-campo a um jogador de defesa, resultando em manutenção da posse de bola, é conotado como bem-sucedido igualmente a um passe que gerou uma situação de finalização executado por um jogador de meio-campo a um jogador de ataque. De fato, o exemplo exposto evidencia dois cenários distintos de jogo que em grande parte das pesquisas são conotados com o mesmo resultado (i.e., passe bem-sucedido).

O Estudo 2 desta tese (texto na íntegra disponível no Capítulo 3) contemplou uma revisão sistemática e meta-análise sobre as relações entre os parâmetros obtidos nos testes antropométricos e de aptidão física com o desempenho de corrida durante os jogos de futebol (i.e., verificação da validade de constructo dos testes fora de contexto de jogo). Vinte e sete estudos empíricos foram incluídos também de acordo com as orientações do PRISMA. A amostra foi composta por 991 jogadores (964 homens e 27 mulheres), sendo

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[1] Análise notacional consiste na observação e na análise quantitativa/qualitativa das ações técnicas e táticas cumpridas durante o jogo (JÚLIO; ARAÚJO, 2005). Quantitativamente registra-se o número de ações executadas pelos jogadores e suas respectivas durações. Em relação à análise qualitativa, o objetivo é verificar o resultado da ação de acordo com a sua eficácia (CARLING; WILLIAMS; REILLY, 2005).

687 jovens (Sub-13 até Sub-18) e 304 profissionais (faixa etária: 22-28 anos). Três principais achados foram emergentes: (i) dados antropométricos (e.g., massa corporal total, % de gordura, massa magra) apresentam pequena associação com o desempenho de corrida durante os jogos em jogadores profissionais. Portanto, sugerimos que estas variáveis não devem ser utilizadas para fins de relação ou predição das demandas físicas em jogo; (ii) embora os parâmetros obtidos por testes incrementais em esteira (e.g., $v\dot{V}O_{2MAX}$, distância total percorrida) demonstrarem forte associações com as demandas de corrida na partida, a variedade de protocolos usados nos estudos não permite ainda a utilização de procedimentos de meta-análise e reduz a força de quaisquer conclusões; (iii) os resultados da meta-análise demonstram a forte capacidade do *Yo-Yo Intermitent Recovery* teste para prever as distâncias totais percorridas (nível 2 melhor que nível 1) e as atividades de alta-intensidade (nível 1 melhor que nível 2) durante as partidas.

Para além dos principais resultados expostos, ambas as revisões de literatura acima descritas destacaram a necessidade de futuras investigações em dois principais fluxos: (i) validação de testes físicos em ambiente de jogo, de acordo com as características gerais e exigências específicas das partidas; (ii) análise dos fatores contextuais e posicionais que afetam potencialmente o desempenho em jogo no futebol.

Face ao enquadramento conceitual e a linha de raciocínio apresentada, as problemáticas centrais desta tese consistem em:

*Será um jogo reduzido válido e reprodutível para avaliar o desempenho físico de jogadores de futebol?*

*Como os fatores contextuais e posicionais afetam o desempenho em jogo de jogadores de futebol?*

Para responder a primeira problemática central, o Estudo 3 (texto na íntegra disponível no Capítulo 4) propôs um teste alternativo para avaliação do desempenho físico utilizando um jogo reduzido denominado “6v6-SSGs”. O desenho experimental foi dividido em três experimentos. Experimento A: cinquenta e um jovens jogadores das categorias Sub-11 até Sub-20 foram submetidos ao “6v6-SSGs” (i.e., testar a sensibilidade do protocolo para diferenciar o desempenho físico em diferentes grupos-etários). Experimento B: trinta e dois jogadores foram randomizados para também jogarem partidas competitivas oficiais (i.e., verificar a validade de constructo). Experimento C: trinta e cinco jogadores foram randomizados para refazerem o protocolo proposto “6v6-SSG” (i.e., análise da reprodutibilidade). A carga externa foi obtida por meio das métricas de desempenho de corrida (e.g., distância total percorrida, acelerações/desacelerações) e os parâmetros de carga interna foram calculados através da percepção subjetiva de esforço (PSE) e da frequência cardíaca média. As abordagens estatísticas mostraram aumentos progressivos em todos os parâmetros de acordo com as categorias (Sub-11 < Sub-13 < Sub-15 < Sub-17 < Sub-20). Mesmo controlados pela idade cronológica, todos os parâmetros de carga mostraram fortes correlações entre o “6v6-SSG” e os jogos competitivos, com exceção da PSE. Coletivamente, o “6v6-SSG” indicou boa reprodutibilidade (i.e., baixo coeficiente de variação, erro típico; alto coeficiente de correlação intraclasse). Portanto, este estudo sugere que o “6v6-SSG” é uma ferramenta alternativa para avaliar o desempenho físico em jogadores de futebol, com a potencialidade de envolver elementos tático-técnicos.

A segunda pergunta norteadora foi abordada nos Estudos 4 e 5 (disponíveis na íntegra nos Capítulos 5 e 6, respectivamente), contribuindo para o campo da análise de jogo, especialmente na observação e interpretação das influências: (i) das variáveis contextuais ou situacionais da partida (i.e., níveis competitivos, fase da temporada, local, qualidade dos oponentes, resultado final); (ii) dos fatores posicionais (i.e. posições de jogo, formações da equipe e de seus oponentes).

A presente tese também avançou na utilização de uma abordagem de análise mais contemporânea (especificamente no Capítulo 6 – Estudo 5). Esta abordagem é denominada análise de redes sociais (i.e., *social network analysis*: RIBEIRO et al., 2017). Em síntese, a análise de redes sociais avalia a interação interpessoal entre os jogadores. Embora outras formas de interações sejam importantes (e.g., mudança de posição de jogo), os passes bem-sucedidos (i.e., que permitem a manutenção da posse de bola) entre os colegas de equipe podem ser considerados a forma mais presente de interação durante as partidas de futebol (GRUND, 2012). Por meio desta análise é possível a obtenção de métricas individuais e globais (Tabela 1).

**Tabela 1.** Métricas globais e individuais, definições e os respectivos indicadores de desempenho oriundos da análise de redes sociais nos esportes coletivos (CUMMINGS; CROSS, 2003; WATTS; STROGATZ, 1998; PASSOS et al., 2014; FREEMAN, 1979; BORGATTI, 2005).

| **Propriedades da rede** | | **Definição** | **Indicadores de Desempenho em Esportes Coletivos** |
|---|---|---|---|
| **Métricas Globais** | **Densidade** | Descreve o nível global de cooperação/interação exibido pelos companheiros | Essas medidas globais podem informar treinadores e analistas de desempenho sobre o nível do time e do nível de função organizacional, se for baseada em um nível de sistema homogêneo, onde todos os jogadores interagem com a mesma proporção |
| | **Centralidade** | Centralidade reflete a extensão em que as interações são igualmente distribuídas entre todos os jogadores | Essas medidas globais podem informar treinadores e analistas de desempenho sobre nível de função a organização da equipe, se baseia em um nível de sistema heterogêneo, caracterizado pela forma proporção desigual de interações e a existência de "jogadores-chave" específicos |
| **Métricas Individuais** | ***In Degree Centrality*** | Indica a importância de um vértice (e.g., do jogador) em um grafo. Degree centrality consiste no número de laços incidentes sobre um nó | Essas métricas podem informar sobre quantos passes cada jogador recebe de forma eficaz |
| | ***Out Degree Centrality*** | | Essas métricas podem informar sobre quantos passes cada jogador passa a bola para seus companheiros de equipe de forma eficaz |
| | ***Betweenness Centrality*** | O número de vezes que um vértice liga dois outros vértices através de caminhos mais curtos | Esses dados podem fornecer informações sobre a quantidade de *network* que um determinado jogador "controla" (e.g., jogador (es) responsáveis por ligar o setor defensivo com o setor meio-campo) |
| | ***Closeness Centrality*** | A soma das distâncias a partir de todos os outros vértices apresentadas em um grafo, sendo estas distâncias definidas como o comprimento dos caminhos mais curtos a partir de um vértice para outro | Essa métrica pode informar sobre o quão perto o jogador está para os outros, onde os jogadores com baixo *closeness score* possuem pouca proximidade dos outros, apresentando condições de receber fluxos (e.g. receber a bola ou mudar de posição com o jogador mais próximo), mais cedo |
| | ***Eigenvector Centrality*** | Mede a influência de um vértice no grafo | Argumenta-se que estas medidas de centralidade podem fornecer um *feedback* informativo valioso e relevante para treinadores, relativa à identificação de possíveis jogadores importantes que desempenham um papel crucial na organização e função das fases ofensivas determinadas da partida |

## 1.3 OBJETIVOS

Como objetivo geral, a presente tese tem por finalidade propor e testar abordagens de observação, análise e interpretação do desempenho em jogo em jogadores jovens e adultos de futebol.

### 1.3.1 OBJETIVOS ESPECÍFICOS

- Comparar a carga externa e interna durante um jogo reduzido (6v6-SSG) de acordo com diferentes categorias – Sub-11 até Sub-20 (i.e., sensibilidade). Relacionar esses parâmetros entre o protocolo proposto (6v6-SSG) e jogos oficiais (i.e., validade de constructo). Testar a reprodutibilidade do protocolo – 6v6-SSG (Estudo 3);
- Verificar os efeitos das variáveis situacionais (i.e., local da partida, da qualidade dos oponentes e o resultado do jogo) sobre o desempenho de corrida em uma equipe de futebol profissional brasileira. Examinar a contribuição relativa das variáveis situacionais da partida sobre a variância da frequência de atividades de alta intensidade durante as partidas (Estudo 4);
- Examinar os efeitos de variáveis independentes, incluindo o nível competitivo, a formação da equipe e as posições de jogo sobre o desempenho de corrida durante jogos oficiais. Verificar a contribuição relativa das variáveis independentes na variação no desempenho de corrida, em particular sobre a velocidade máxima e a frequência de atividades de alta intensidade (Estudo 5);
- Demonstrar os possíveis efeitos independentes e interativos das variáveis situacionais (incluindo a fase da competição), formação da equipe dos adversários e posição de jogo sobre o desempenho de corrida e a interação interpessoal em jogadores brasileiros de futebol durante partidas oficiais (Estudo 6).

## 1.4 DESAFIOS METODOLÓGICOS

Acerca das tecnologias que foram utilizadas para análise do desempenho de corrida nos artigos que serão apresentados, importa destacar alguns tópicos. Nosso grupo de pesquisa tem recorrido ao rastreamento computacional para essa finalidade (AQUINO et al., 2016a, 2016b, 2018). Entretanto, o tempo médio necessário desde o registro de um jogo (n=1 partida) até a obtenção das variáveis de interesse (distância total percorrida, velocidade média/máxima, número de *sprints* e distâncias totais percorridas em diferentes faixas de velocidade) para todos os participantes (n=10 jogadores) consistem em três meses (levando em conta uma carga horária de 20 horas semanais unicamente para esta atividade). Isso gerou alguns problemas práticos e operacionais na utilização desta tecnologia, apesar de ser apontada como uma ferramenta robusta, válida e com constante/baixo erro de medida (BARROS et al., 2007; RANDERS et al., 2010). Deste modo, nosso grupo de pesquisa obteve a aquisição de 12 equipamentos GPS (Sports®, QSTARZ, modelo BT-Q1300ST, 1-5 Hz, Taipei, Taiwan) e por meio de um estudo piloto verificamos um erro de medição constante e baixo (coeficiente de correlação intraclasse = 0,91; erro = 4%; nas análises das distâncias percorridas em alta intensidade durante o jogo [acima de 16.1 $km.h^{-1}$]), com tempo de processamento para a mesma coleta supracitada (i.e., n=1 partida; n=10 jogadores) de dois dias (quatro horas/dia).

Portanto, nos Estudos 3, 4 e 5, recorremos à tecnologia GPS. Isso facilitou o dia-a-dia em termos de coleta de dados, tratamento e síntese das informações obtidas para posterior *feedback* aos treinadores. Além disso, a metodologia de análise da interação interpessoal (i.e., análise de redes sociais – utilizada no Estudo 6) foi cuidadosamente aprendida e explorada durante o período dos meus estudos em Portugal, sob supervisão do Prof. Dr. Júlio Garganta e demais colegas, como o Prof. Dr. João Cláudio Machado e Dr. João Ribeiro

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# CAPÍTULO 2. ESTUDO 1

# SKILL-RELATED PERFORMANCE IN SOCCER: A SYSTEMATIC REVIEW

**Shortened title:** Performance Analysis in Soccer

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**Abstract**

The aim of this study was to evaluate and organize systematically the available literature on skill-related performance in young and adult male soccer players, in an attempt to identify the most common topics, ascertain the weaknesses and elucidate the main contributions of the scientific papers on this issue. A systematic review of Institute for Scientific Information (ISI) Web of Knowledge database was performed according to Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA) guidelines. The following keywords were used: football and soccer, each one associated with the terms: technical analysis, technical performance, technical activity, technical skill, technical demands, technical profiles, technical characteristics, technical actions, technical scores, technical ability, motor skills and skill acquisition. From the 2830 papers, only 60 were reviewed, of which 75% were published in the last five years (i.e., 2011-2015) and 53.3% were performed with professional or seniors' players (above the U-20 category). Regarding the 41 papers that analyzed the skill-related performance in the match, 48.8% evaluated the performance in small-sided and conditioned games. Considering 27 papers that used validated instruments, 88.9% evaluated the technical actions outside the match context (e.g. dribbling, shooting tests). Future research should pay attention to the definition/classification of the skill-related variables under investigation in match context and propose tests for measured skill-related performance in soccer, considering the representativeness task design allies the players' possibilities of action to the situation of the match.

**Key-words**: Ecological approach; technical performance; representative design; team sports.

## Introduction

The pursuit of sporting success constantly leads the coaches, performance analysts and sports researchers to explore methods to evaluate and promote performance. In this sense, match analysis investigates the performance of teams with regard to the different scales of analysis, from the individual level (micro) towards the collective level (macro). Moreover, it provides informational knowledge regarding the development of the training process as well as the competitive outcomes, considering various features displayed by teams in competitive matches [1]. It is a foundation for decision-making processes on the performance of players and sequentially enables the provision of feedbacks as part of the coaching process. However, accurate feedback on the actual performance of the players requires testing with representative task design of the actual match's demands (i.e., generalization of task constraints in experimental designs to the constraints in sports; see more details in Brunswik [2]).

Theoretical principles of ecological dynamics revealed that the most relevant information for decision-making and the regulation of action in dynamic environments is emergent during continuous performer-environment interactions [3]. In this approach, the environment provides information that directly influences the behavior of the agent (i.e., player) [4]. This information perceived by the players enhances the possibilities of action (i.e., affordances). Therefore, the responses to the constraints imposed by match context materialize through the execution of technical actions in order to achieve a certain objective [5]. These actions endue an adaptive character as a function of time and space in which they performed. The ability to perform a technical action influences the possibilities for the player to choose the best option in the match situation. During the matches is required from the player the interdependency between knowing "how to do" (efficiency), obtaining the result according to the purpose of the action (efficacy) and the capability to adjust according to different match scenarios (adaptation) [6]. Thus, a successful technical action in team sports is sustained by a decision-making process that results from the exploitation of the possibilities of action (i.e., affordances) that emerge from the interaction between the player and the environment [7]. From the foregoing, it is clear the importance of the development and evaluation of technical actions in team sports (e.g., soccer).

With the advancement in the production of scientific knowledge related to skill-related performance in soccer, notational analysis assumed an important role [8]. Notational analysis comprises the observation and the quantitative/qualitative analysis of the technical and tactical actions fulfilled during the match [9]. Quantitatively records the number of actions performed by players and their respective duration. Regarding qualitative analysis, the objective is to verify the result of the action according to its effectiveness [1]. Other forms of notational analysis focused on the actions and movements scrutinized by players that promote the emergence of different match patterns [9]. On the other hand, another approach studied in the analysis of skill-related performance in soccer refers to the analysis of technical actions outside of match context related to the efficiency of the players and teams [10-12]. This approach of evaluation has been described to conceive the identification and development of talents, as well as to allow the distinction between different levels of experience (e.g., [13-16]), although it is not clear how this dimension interacts with others or how it adapts to play structure [17]. Vilar et al. [18] argued that the skill-related tests outside match context (e.g., dribbling, passing, shooting) were not representative of competitive performance because these tests not include critical perceptual variables that players usually use to control their actions during the match.

To date, a few review articles have explored the skill-related performance in sports (i.e., ecological dynamics approach to skill acquisition [7]) and specifically in soccer [19-21]. While one of these reviews focused in to examine the validity, reliability and sensitivity of the tests used to measure skill-related performance outside soccer match context (i.e., juggling, heading, wall-volley, dribbling, shooting, passing, multi-faceted tests: [19]), others addressed critically [20] and systematically [21] the match performance analysis as a whole – without dividing by skill-related thematic categories and without considering both in- and out-game context. Thus, the aim of this study was to evaluate and organize systematically the available literature on skill-related performance in young and adult male soccer players, in an attempt to identify the most common topics, ascertain the weaknesses and elucidate the main contributions of the scientific papers on this issue.

## Methods

The sample of this study comprised 60 exploratory papers (see Supplemental File [Table 1]), indexed in the scientific journals of databases belonging to the Institute for Scientific Information (ISI) Web of Science. A systematic review conducted in accordance with the guidelines proposed by PRISMA (Preferred Reporting Items for Systematic reviews and Meta-analyses) statement.

Three evaluators conducted separately the analysis process on 19$^{th}$ of February, 2016, through the descriptors: football and soccer, each one associated with the terms: technical analysis, technical performance, technical activity, technical skill, technical demands, technical profiles, technical characteristics, technical actions, technical scores, technical ability, motor skills and skill acquisition. All search procedures were performed according to ethical guidelines (protocol number: 61884716.9.0000.5659).

Inclusion criteria comprised: i) scientific papers published up to 2015; ii) exploratory paper; iii) conducted with male soccer players; iv) performed with players of all positions and functions, excluding the goalkeepers; v) English language; vi) have relevant data for the evaluation of technical actions. If there was some disagreement among the evaluators regarding the inclusion of a particular paper, the final decision would be performed by the senior evaluator, due to more experience on this issue [21]. To organize the results, the papers grouped according to the main topics of skill-related performance that emerged from a detailed analysis and according to the methodological strategies used.

**Results and Discussion**

In the beginning of the search process found 2830 papers. In sequence, the duplicate papers have been removed (1785). The next stage comprised the reading of the title, abstract and keywords. Thus, over than 954 papers removed due to some criteria: another issue, other sports, without full text online, inadequate sample (e.g., women, referees, and goalkeeper), review paper and another language. After these exclusions, 91 full texts were read, allowing to realize that 31 of them were not relevant to this review. Finally, from the 2830 initial papers researched, only 60 obeyed to all the inclusion criteria (Figure 1). For each paper were recorded, the authors (year of publication), participants, aims, methods and the main findings related to technical actions (Table 1).

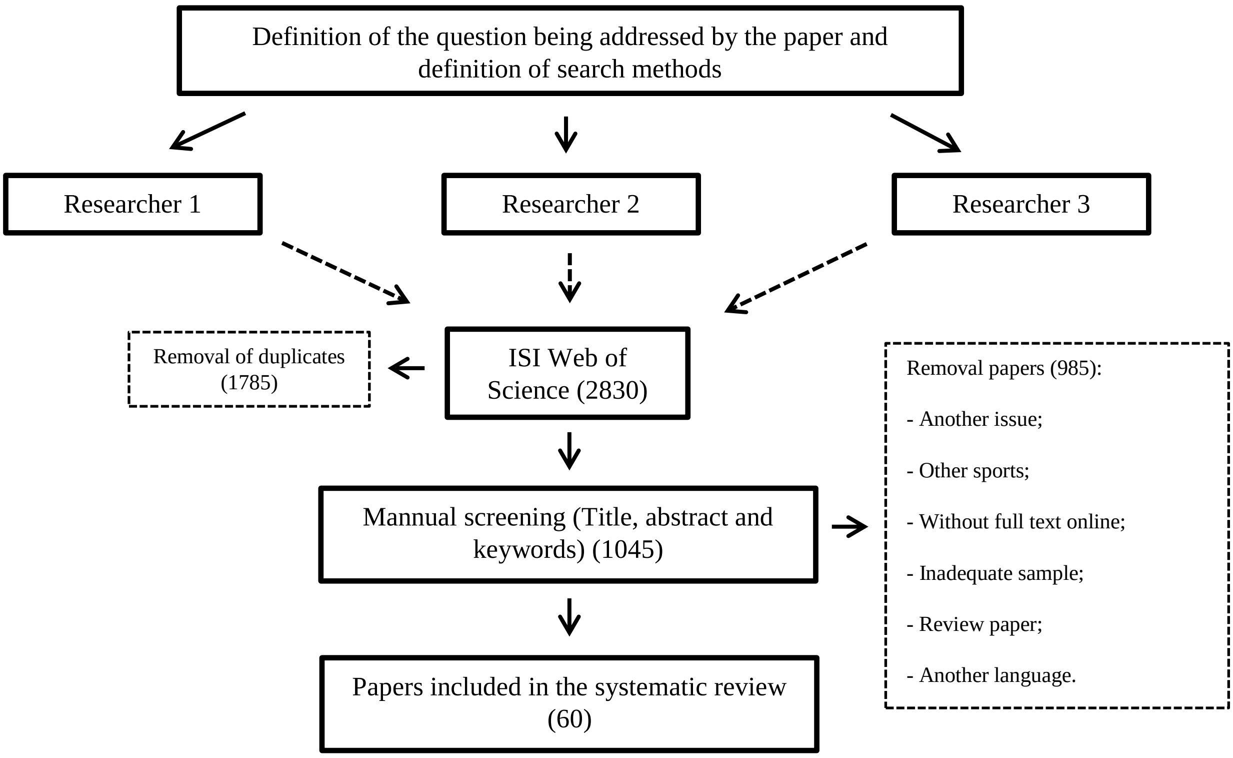


**Figure 1.** Systematic review process for the paper research.

Regarding the chronological analysis of published papers, it was found that before 2010, 15 papers (25%) were relevant to the scope of this review. The remaining 45 grouped papers (75%) were published in the last five years (2011 - thirteen papers; 2012 - three papers; 2013 - eight papers; 2014 - 12 papers; 2015 - 9 papers), which highlights the recent substantial growth of skill-related performance in soccer. Considering the age group of the participants, 32 papers (53.3%) performed with professional or seniors' players (above the U-19 category). The other 28 papers (46.7%) were performed with young players (U-20 or lower category), which shows a certain equivalence.

Additionally, 41 papers conducted skill-related performance in match context, through which 20 used small-sided and conditioned games (SSCG) (48.8%) and 21 friendly and official games (51.2%). From the 60 recruited papers, 27 carried out an analysis of technical actions by manipulating validated instruments, being three of these instruments (11.1%) employed in match context, such as: Team Sport Assessment Procedure (TSAP; [22]), System of assessment of functional asymmetry of the lower limbs in Football (SAFALL-FOOT; [23]), Offensive Sequences Characterization System (OSCS; [24]); and 24 (88.9%) without match context, such as: reactive motor skills test (RMST; Bullock et al., [25]), dribbling, shooting, heading, Loughborough passing tests [10-12, 26].

After a detailed analysis of each paper, a categorization system was carried out, contemplating two levels of analysis [21, 27]: The first level encompassed the topic of analysis (descriptive or comparative) and the second level comprised the skill-related variables employed in the analysis (Figure 2).

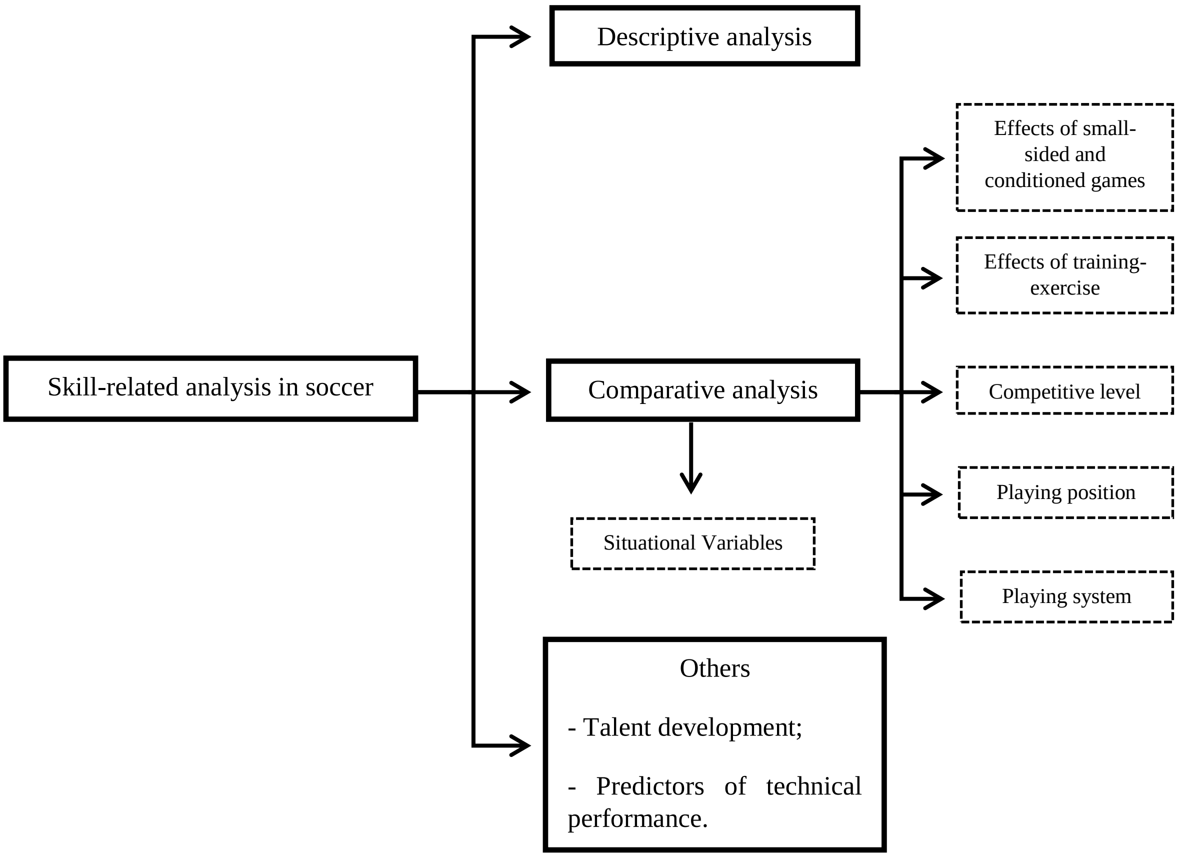


**Figure 2.** Issues of skill-related performance analysis in soccer (Adapted from Sarmento et al., [21]).

***Descriptive analysis***

The exploratory papers framed by the descriptive analysis usually aimed to verify the behaviour of technical actions during an official match. In general, the studies demonstrate that: i) teams with higher ball possession performed more passes (44%) compared to teams with less ball possession [28]; ii) occurred lower frequency of passes, successful passes and dribbles in the last 15 minutes of the match when compared to other match periods, i.e. 0-15 min, 15-30 min, 30-45 min, 45-60 min and 60-75 min [29-31]. Some studies of descriptive analysis aimed to assess the differences in skill-related performance along one or more seasons. Carling et al. [32] investigated the skill-related performance of a team in a sample of 190 matches for five consecutive seasons (2008-2013). The authors found that the team in the 2010/2011 season (champion) conceded fewer goals, especially during the second half of the season, showing an increase in the number of passes, percentage of completed passes, forward passes and percentage of completed forward passes across the seasons. Morgans et al. [33] verified the differences in skill-related performance during the whole season of the English Championship League, and concluded that successful passes were relatively stable throughout the season.

These papers resorted to notational analysis, having as the main skill-related variables: number of passes, successful passes, received passes, short passes, successful short passes, long passes, successful long passes, touches per possession, dribbling, shooting, clearances, events of tackles/tackled, headers, ball interceptions and crosses. However, there is a lack of transparency regarding the definitions/classifications of skill-related performance during in-game context. Considering the total papers that performed the analysis of the skill-related performance in the match (i.e. SSCG, friendly and official matches), 63.4% had no definitions/classifications for the analyzed variables (e.g. [29, 34-37]). Subsequently, it becomes difficult to compare the results derived from different studies, so that reproducibility can be ensured, an essential feature of scientific research, as exposed by O'Donoghue [38] (p. 36) "it is essential for system operators and the eventual consumers of the information generated by performance analysis to have a shared understanding of the variables used".

A positive example to this question refers to the study of Rampinini et al. [31], which provides the definitions of the skill-related variables under investigation, such as: "Short passes: number of short foot passes (length < 37m) performed by a player" and "Long passes: number of long foot passes (length > 37m) performed by a player". As stated by Mackenzie and Cushion [20] different interpretations of definitions (e.g., successful or unsuccessful pass) can generate different results and conclusions. Therefore, we proposed based on the literature research a definition of five offensives and two defensive skill-related performances for soccer players (Table 2).

Furthermore, the search for quantitative information that depicts the match (e.g. notational analysis), despite continuing to be an important approach, have the potential to augment its relevance when associated with methodologies that embrace the dynamics presented in the coordination of players actions across the match [9].

**Table 2.** Proposed definitions for skill-related performance in soccer based on literature search.

| Skill-related performance | | Definitions |
|---|---|---|
| **Offensives** | Goal attempts | To direct the ball into the opponent's goal, using any part of the body allowed by the rules of the game, in an attempt to make the ball to cross the line between the goalposts. Successful: results in a goal. Unsuccessful: does not result in a goal. |
| | Passes | Consists in transferring the ball from one player to another player of the same team, using the body parts allowed by the rules of the game. A long pass makes the ball travel more than 37 meters whereas a short pass travels less than 37 meters. Successful: the team maintains the possession of the ball. Unsuccessful: the team loses the possession of the ball. |
| | Carry or protect the ball | The action of carrying or protecting the ball happens when: i) the player in possession of the ball progresses with it, in any direction; and ii) the player player in possession of the ball makes one or more contacts with it without progressing on the field, and protects it from losing its possession to the opponent. Successful: the team maintains the possession of the ball. Unsuccessful: the team does not maintain possession of the ball. |
| | Received ball (Oriented/Not Oriented) | The action allows to receive and control the ball that was passed to him, in one of these two possible ways: i) oriented, allowing to continue to the next action in the possession of the ball; or ii) not oriented, not allowing to continue to further action. Successful: the team maintains the ball possession. Unsuccessful: the team not maintains the ball possession. |
| | Dodge/feint | A dodge/feint is observed when the player in possession of the ball overtakes the direct opponent in an attempt to: i) promote an offensive advantage for its team; and ii) create an imbalance in the opposing defence. Successful: the team maintains the possession of the ball. Unsuccessful: the team does not maintain possession of the ball. |
| **Deffensives** | Crosses | Action of the player who is to take the ball from the player in possession of the ball, impeding him to continue his action. Successful: the team wins the possession of the ball. Unsuccessful: the team does not win the possession of the ball. |
| | Interceptations | Anticipation of an attempt from the player in possession of the ball to pass or strike on goal, not allowing the ball to reach the destination. Successful: the team wins the possession of the ball. Unsuccessful: the team does not win the possession of the ball. |

### *Comparative analysis*

*Effects of small-sided and conditioned games (SSCG)*

Some practice effects induced by different task constraint manipulations (e.g., number of players or field dimensions) in SSCG on skill-related performance are often studied. In these investigations, the main findings consist of: i) decrease in the field size dimensions with the same number of players promotes an increase of technical actions [22, 34, 36, 37]. According to Hodgson, Akenhead and Thomas [37] "the smaller pitch size reduces the active playing area and requires players to make faster decisions and execute skills with higher frequency”; ii) decrease in the number of players prompts an increase of technical actions [36, 39, 40]. A possible explication of this refers to higher playing area can facilitate technical actions performed in more space (e.g., crosses, dribbling and shots); iii) when restrictions are applied in the number of ball touches during the SSCG, the restriction to one ball touch results in high level of difficulty regarding the performance of successful technical actions, wilts exercises without restrictions in the number of ball touches weak affects the realization of successful passes and loss of possession ball [41]. Dellal, Lago-Penas, Wong and Chamari [41] explain that the players have a reduced time to make decisions and to analyse the game, which explains the lower quality of their technical actions in one touch form as compared with the two touches and free play; iv) The application of SSCG promotes an higher frequency of technical actions compared to friendlies matches [42], probably due to smaller area per player such as aforementioned; v) the duration of the SSCG does not influence the number of technical actions per minute as well as the proficiency [43]. Two reasons can explain this behavior, being the first the fact of the authors normalized the data as number of technical actions per minute, and the second their used three bouts (i.e., previous study demonstrated decrease in technical action along the four bouts [44]; vi) SSCG with higher recovery time between sets promotes an increase in the number of technical actions [45]; vii) SSCG with the objective of maintaining ball possession contribute to an increase in the total number of successful passes and decrease in the number of shots, compared with SSCG whose objective comprehends the progression towards the goal [46], i.e., the players only progressed to goal-scoring situations when they are able to create safer options for the plays, resulting in fewer shots.

These results may help the coaches directly in the preparation of training sessions. For example, a coach who aims for his training session an increase in the technical actions might use SSCG with smaller dimensions (e.g., 30x20), smaller number of players (3v3), without limitations regarding the number of ball touches and exercises with higher recovery periods between sets (e.g. 3x4 min with 3-4 min of recovery). This topic of comparative analysis (e.g., effects of SSCG) represented the highest frequency of occurrence with 15 papers. This scenario can be explained by the growing interest in verifying the effects of these training tools in soccer [47]. Furthermore, it is considered that SSCG promote the increase of the number of actions with ball as well as the participation of all players during the matches [5]. A recent narrative review (Serra-Olivares et al. [48]) about tactical assessment of soccer training using representative tasks to measure the tactical expertise of young soccer players during SSCG is an important study that gives an overview of the ecological approach to training and the principles used for representative task design, providing relevant contribution and direction for future research into the assessment of tactical expertise in young soccer. Therefore, based on the ecological approach and the idea of representative task design, it is possible recommend for future research the development of measured skill-related performance using SSCG.

*Effects of training-exercise*

Several researchers have studied the effects of training and exercises on the skill-related performance of soccer players. The main conclusions of the studies on this subject are the following: i) passing and shooting performance declines after low and high intensity acute strength exercises [26, 49] and after simulated soccer match (induced fatigue protocol) [12]. The skill to pass and shot is based on inter-segmental coordination, therefore, following strength exercises muscle fatigue induces a negative effect on motor coordination [26]; ii) the use of non-preferred foot increases with analytical technical training [23]. According to the ecological dynamics approach, due the non-preferred foot was less stimulated during the daily practice, it is not perceptibly accessible (i.e., it is not a relevant option to make part of the decision-making and performed actions [23]). Therefore, the functional asymmetry of the lower limbs tends to reduce with the increase in specific training for non-preferred limb; iii) aerobic interval training (4x4 min at 90-95% of maximum heart rate - $HR_{MAX}$ – with three min of recovery between series) attenuated the deterioration in Loughborough Soccer Passing Test (LSPT) time after a simulated high running protocol [50]. Ten weeks of soccer training (continued running 70-80% of $HR_{MAX}$ + sprints + soccer specific activities) affect positively slalom dribble and lob pass in young soccer players [51]. Short-term training (plyometric + acceleration + dribbling + shooting) affect positively shooting speed [52]. This suggests that the trained players probably experienced less fatigue and, consequently, a lower impairment of skill-related proficiency; iv) significant improvement of soccer-specific technical skill level using a battery of tests proposed by the German soccer federation (i.e., juggling, passing, dribbling) was higher in SSCG (3vs.3 or 3vs.3 with joker player; 5x4 min with 3 min of active recovery) than high-intensity running training (5x4 min at 90% $HR_{MAX}$ – with three min of active recovery between series) [53]. Therefore, SSCG are more highly recommended training drills than generic (e.g., interval) training by engaging physical, technical and tactical aspects simultaneously [54].

*Competitive level*

The informational knowledge derived from researches that examine different competitive levels may provide useful and valuable insights for coaches that search for more appropriate conditions for helping their players to reach high performance levels [21, 55]. Almeida, Ferreira and Volossovitch [24] verified that high level youth soccer players performed more passes and had more ball possession in SSCG (i.e. 3vs.3; 6vs.6) than low level players. In addition, Dellal et al. [56] verified that amateur players completed less successful passes and exhibited less ball possession when compared with professional players, regarding various configurations of SSCG (i.e. 2vs.2; 3vs.3; 4vs.4). Furthermore, other researches performed in the same scope of analysis revealed the existence of differences in skill-related performance (e.g., shooting, slalom dribbling, ball control, LSPT) between competitive level, with advantage for elite players and elite teams [11, 57-60]. The experience is an aspect which influences the competitive performance that is directly related to the time of practice/competition in soccer [61]. Nevertheless, Almeida, Ferreira and Volossovitch ([24], p.102) complements "it seems that it does not require long periods of deliberate practice in order to verify differences in the collective performance comparatively to youngsters who only play the game for enjoyment and fun (i.e., deliberate play).".

*Playing position and playing system*

Another important issue that emerged from the comparative analysis of exploratory researches refers to the playing position and different systems. It observed some discrepancy regarding the designations adopted in different researches, according to tactical positions, which makes it difficult to compare the results between the studies. However, in general, one can distinguish three main tactical positions [21]: defenders, midfielders and forwards. In summary, the researches show that the forwards have a higher coefficient of variation (match-to-match) for performed passes, received passes and number of times that tackled compared with other positions; also exhibit higher coefficient of variation for tackles and interceptions than midfielders and defenders. The ability of forwards to hold up play will be affected by the number and quality of possessions won along with the aptitude and tactics of the opposition defenders, thus affecting the variability in performance. Midfielders performed higher successful passes ranging between 75-78% than forwards (71%) and defenders (63%) (i.e., this position frequently gain the ball in attacking area and are responsible to create finishing situations for the forwards, resulting in more passes) [62]. These results show that the frequency, variation and efficacy of technical actions vary according to the role and specific tactical position of each player on the field.

In addition, the literature is scarce from studies that analyzed skill-related performance and playing systems. In the course of this review, we noticed that only two studies reported these issues. Bradley et al. [63] highlighted that ball possession maintenance usually not differ between 1-4-4-2, 1-4-3-3 and 1-4-5-1 systems. However, the fraction of successful passes was higher in 1-4-4-2 system compared with 1-4-3-3 and 1-4-5-1 system, but the authors mentioned that caution is needed when interpreting the findings, as a relatively small number of matches (*n*=20) were analysed. Carling [35] found that, in general, the players perform more passes against teams in 1-4-4-2 system than in 1-4-2-3-1 system. Additionally, the same author reports the existence of more duels, those that result with the ball in an aerial trajectory as well as those derived, for example, from 1vs1 situations, against teams in 1-4-2-3-1 system when compared with 1-4-4-2 system. Finally, the author reports that occurs more one-touch-ball passes against teams in 1-4-2-3-1 system compared with 1-4-4-2, 1-4-3-3 and 1-4-5-1 systems (e.g., the higher frequency of one-touch passes against teams using a 4-2-3-1 formation suggests that players in the reference team could have benefited from performing one-touch passing drills in preparation for matches against this particular formation).

Clearly, there is a need to perform more studies emphasizing the playing system as well as those related with skill-related performance. Furthermore, it emphasizes the importance of describing how the players are positioned on the field in each playing system (e.g., 1-4-4-2 "diamond" or "square") and to analyse the differences in skill-related performance at each playing position in accordance with the team playing system (e.g., one defender in 1-4-4-2 system cannot perform the same functions and technical actions if the team plays in an 1-3-5-2 system).

*Match situational variables*

In soccer context, match location (home or away), quality of opponent (strong or weak) and match status (winning, drawing or losing) comprise the main situational variables that influence the performance of teams in competitive matches [64-66]. However, researches on the skill-related performance appear to disregard these situational variables. From the presented review, those consider the analysis according to the skill-related performance in official match context, 38.1% consider these situational variables (e.g. [65, 67, 68]). Lago-Peñas and Lago-Ballesteros [68] found that the teams playing at home have higher scored goals, shots in goal, attacking moves, crosses, assists, passes made, successful passes, dribbles made, successful dribbles, ball possession and gains of possession when compared with teams that played away. In addition, the visiting teams have greater loss of ball possession. Taylor et al. [65] found that the match location has significant influence on the frequency of clearances, crosses, dribbles, interceptions, shots and tackles. One explication for these performances is that home environment (i.e., social support of the crowd) is related to an increased functional aggressive response measured by more offensive than defensive behavior [69]. These authors [65] also reported that when teams were losing they showed an increase in ball possession and performed more crosses and dribbles (i.e., the teams try to "control" the match, creating more offensive situations), while when they were wining, performed more interceptions, clearances and aerial challenges. Regarding the quality of the opponents, these studies found no substantial differences in technical actions. Talyor et al. [65] used a symmetrical division based on the team’s final ranking and guided their analysis according to the dichotomy "strong opposition" versus "weak opposition", however, the authors considered that this division did not provide the sensitivity needed to detect any differences. The definition of the quality of the opponents according to k-means cluster analysis seems to be more robust [70-72].

***Others***

Other themes commonly addressed skill-related performance related to determination of predictor variables that intend to enhance the development and selection process of talented players. Malina et al. [73] and Matta et al. [74] found that the main predictors that explain the results of skill-related performance (e.g. dribbling, ball control, shooting) are: age, maturation, height, interaction of body height and body mass, years of training.

Studies that regard the process of selection of soccer players seek objective measures to assist in identifying supposedly talented players. Höner et al. [10] found that the technical actions, such as, dribbling and juggling differ between high- and low-level players. Huijgen et al. [16] studied multidimensional characteristics that distinguished selected and non-selected young players belonging to a talent development program in Netherlands, and found that 69% of selected players were correctly classified due to the evaluation of four domains (physical, technical, tactical and psychological). The main variable with discriminatory power in the technical domain comprises the dribbling test. Other studies support that dribbling, shooting, lob pass and juggling tests have high criterial validity [13-15, 60].

In this context, the understanding of talent is largely linked with the idea that innate assignments are responsible for “talent detection”, where is evident concern to find players with physiological, motor and psychological attributes above average [75]. However, as stated by Howe, Davidson and Sloboda [76], the conditions that lead to excellence are related with multidimensional characteristics in a multitude of factors, such as, early experience, preferences, opportunities, habits, structured and sustained training to promote increased sports performance, resilience and cultural aspects. Therefore, it becomes questionable the application of unrepresentative tests for “detecting” talents, the more so young players not "detected" as talents will be rejected by clubs and may leave practice earlier. In fact, the journey to sporting excellence derives not only from talent identification, but mainly elapses from a complex fusion of skills, capacities and competences [77] related to the development of potential talent in response to training and other environmental conditions [75].

**Limitations and recommendations for future research**

The main limitation of most studies mentioned in this review interferes with the principle of scientific reproducibility and the consistency of research findings [11, 12, 25], already demonstrated in previous review studies [20, 21]. Particularly, it comes from: i) the lack of definition/classification of the skill-related variables under investigation concerning match context (we proposed these definitions [see Table 2] based on the literature research); ii) the contextualization of the sample omitted and the influence of match situational variables (e.g. location, quality of opponent, status); and; iii) the absence of representative tasks design for measured skill-related performance.

Few revised papers (36.6%) defined clearly the skill-related variables under investigation in match context (e.g. [23, 30, 31, 78]). Mackenzie and Cushion [20] reported that the intensive use of notational analysis through data generated by computational software, can be considered as an explanatory factor that underpins this lack of definitions (e.g. AMISCO® Pro; GECASport®; ProZone®). Moreover, as already exposed, 38.1% of the papers comprehended in this review contemplated the effects of match situational variables on skill-related performance during the official matches (e.g. [65, 67, 68]). There seems to be little agreement with regard to the sample size necessary for a power generalization of the results found in this reviewed studies.

Regarding the representative design of the tests used for measured skill-related performance in soccer, we consider it necessary to return to some approaches. An important task in sports science and performance analysis is to understand the relationship between the skill acquisition and development of players, in order to achieve sporting excellence. Therefore, it is necessary to develop theoretical principles that guide the concession of skill acquisition programs, as well as to provide an informational base for the organization and implementation of evaluation tests concerning sports performance [7]. The ecological dynamics theory has revealed that the most relevant information for decision-making and regulation of action in dynamic environments (e.g., soccer) emerges from the continuous performer-environment interactions (see more details in [3]). The opportunities for action (e.g., *affordances*) constantly shape players intentions and interfere with decision-making processes by adjusting the key properties of the environment and organismic limitations inherent to each player [7, 79]. For example, performing a pass, dribble or shot in the course of a soccer match, emerges due to critical information regarding the relative positioning of the defenders, as well as the area of the field (e.g., identification of the opportunities for action to achieve the target performance). Thus, developing a rational basis to identify and manipulate the constraints acting on the players provides a basic principle for the development and implementation of tests to evaluate the skill-related performance in soccer (see [48]). For instance, 88.9% of the papers presented in this review evaluated skill-related performance through validated tests that performed outside the match context (e.g., [10-12, 25, 26]). However, these tests are not representative of the actual skill-related performance scrutinized by soccer players since these do not encompass critical perception variables (e.g., environmental contextual information) that players normally use to control their actions during the course of the matches [18], which could compromise the ecological validity of the conclusions obtained in these studies. To achieve this representation, skill-related performance tests should incorporate the same informational variables that specify match contexts (e.g., friendly or official matches) or in SSCG [80-82]. Furthermore, to ensure representativeness, the technical performance tests should not be limited to examining only the result of the action [20, 83], but also take into account the evaluation of representative tasks, which interact with each other and influence the behavior displayed by players at the time of carrying out the action (e.g., possibilities for action, the positioning of opponents and teammates, spatial references). As exposed by Hayes [84] (p. 4) “show me the results of notational analysis, not the notational analysis results”, *apud* Mackenzie and Cushion [20] (p. 655). Moreover, notational analysis does not measure the possibilities of action of the participants in relation to the selection of technical actions performed by players. For example, consider two match situations: i) the midfield player performs a pass to the defensive player, where the team maintain the ball possession; ii) the same midfield player performs a pass to the offensive player, which enabled a finish to the goal. In the technical analysis used in the reviewed studies, both situations labelled as successful pass. However, it understood that in situation (ii) the player's midfield pass to the offensive player resulted in the possibility of a goal, thus obtaining a score different from the pass performed in situation (i). Therefore, future researches should propose tests for measured skill-related performance in soccer, considering the representativeness contexts allies the players' possibilities of action to the situation of the match (see a positive example of tactical expertise assessment during SSCG in study of Serra-Olivares et al. [48]).

## Concluding remarks

The main purpose of this study was to evaluate and organize systematically the available literature on the skill-related performance in young and adult male soccer players. Furthermore, we identified the most common topics and examined the weaknesses as well as the main contributions of these studies to the technical performance. The emerging themes were i) descriptive analysis (e.g., characterizations of skill-related performance of championships); ii) comparative analysis (e.g., effects of SSCG, effects of training-exercise, competitive level, playing position and playing system, match situational variables); and iii) others (e.g., talent development, predictors of skill-related performance). This review has raised some methodological concerns regarding the use of scarce representativeness analysis for the skill-related performance of the players, such as, for example, dribbling, shooting and passing tests without match context. In addition, notational analysis can augment its relevance when associated with methodologies that consider the dynamics inherent to the coordination of players in match situations and consider representative task design combined the possibilities of action of the players each match situation. Other concerns evidenced in others studies were relate to the absence of clarification concerning the definitions/classifications of technical variables under investigation (see our proposed definition in Table 2) and omission of the context of the sample (e.g. location, quality of opponent, status). These limitations can compromise largely the reproducibility of the reviewed studies. Finally, given the limitations presented in this review, it is suggesting that future research may lead to a congruous understanding of the discussed topics, providing significant and substantial impact also on professional daily practice.

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**Table 1.** Exploratory papers published on skill-related performance in male soccer players.

| Authors | Sample | Aim | Methods | Main Findings |
|---|---|---|---|---|
| **Almeida, Ferreira, and Volossovitch [24]** | 28 U-15 male players were divided into two groups: Non-Experienced and Experienced | To analyse the interaction and main effects of deliberate practice experience and small sided and conditioned games (SSCG) format (3vs.3 and 6vs.6 + GKs) on the offensive performance of young soccer players | Offensive Sequences Characterization System was used. Duration of ball possession, number of players involved, number of ball touches, number of passes, number of shots and result of the offensive sequence | - "Experience level" had a significant effect on performance indicators that characterize the development of offensive sequences, especially in 6vs.6 + GKs |
| **Aslan [34]** | 10 male recreational soccer players | To determine the cardiovascular, perceived exertion and technical effects of altering pitch size and number of players in recreational soccer match-play | Four variations of SSCG (except for GKs, 5 a-side and 7-a-side on small and large pitches). Ball possession, dribbling, successful pass, unsuccessful pass, tackle and shooting | - The players performed more dribbling and successful passes, but fewer unsuccessful passes during 5-a-side games<br>- The number of ball possessions and unsuccessful passes was higher on a small pitch than on a large one |
| **Bradley et al. [63]** | 20 English FA Premier League matches (*n*=153 players) | To examine the effect of playing formation on high-intensity running and technical performance during elite soccer matches | Number of passes and percentage completion rate, passes received, touches per possession, dribbles, crosses, final third entries, possession won and lost, and total ball possession | - Overall ball possession did not differ between 1-4-4-2, 1-4-3-3 and 1-4-5-1 formations<br>- The fraction of successful passes was highest in a 1-4-4-2 compared with 1-4-3-3 and 1-4-5-1 formations |
| **Bradley et al. [85]** | FA Premier League (*n* = 190), Championship (*n* = 155) and League 1 (*n* = 366) | To compare the match performance and physical capacity of players in the top three competitive standards of English soccer | Number of passes, successful passes, forward passes, balls received, touches per ball possession, dribbles, tackles, interceptions, headers, crosses, shots, clearances and final third entries | - Technical indicators such as pass completion, frequency of forward and total passes, balls received and average touches per possession were 4–39% higher in the Premier League compared to lower standards |
| **Bradley et al. [28]** | Professional Players in the English FA Premier League (n = 810) | To examine the effects of high (HPBPT) and low percentage ball possession teams (LPBPT) on physical and technical profiles in elite soccer matches | Number of passes, successful passes, received passes, touches per possession, dribbles, shots, clearances, events of tackles/tackled, crosses, final-third entries, possession won and lost | - Players in HPBPT performed 44% more passes than those in LPBPT<br>- This trend was also evident for successful passes, received passes, touches per possession, shots, dribbles and final-third entries<br>- Technical indicators such as total passes and passes received were higher across all positions in HPBPT than LPBPT |

Note: GKs = Goalkeepers

**Table 1.** Continuation.

| Authors | Sample | Aim | Methods | Main Findings |
|---|---|---|---|---|
| **Bradley et al. [67]** | 54 English Premier League matches (*n* = 810 players) | a) To examine the influence of situational variables on ball possession in elite soccer. b) To quantify the variables that discriminate between high or low percentage ball possession teams (HPBPT and LPBPT) across different playing positions | Successful and unsuccessful passes, crosses, dribbles, shots, events of tackles/tackled, corners, goals, free kicks, fouls, fouled, interceptions and clearances. | - Possession was increased when losing than winning or drawing<br>- The variables that discriminated performance between HPBPT and LPBPT were different for various playing positions, although the number of successful passes was the most common discriminating variable |
| **Bullock et al. [25]** | 42 high-level amateur male soccer players | To evaluate the effect of 45 min of soccer-specific exercise in the reactive motor skills test (RMST), a novel test which measures sprint, passing and reactive agility (RAT) performance | Participants undertook 10 repetitions of the RMST before and after 45 min of soccer-specific exercise using the Loughborough Intermittent Shuttle Test | - The exercise protocol resulted in moderate decreases of sprint and RAT performance, but improved passing task time and passing accuracy |
| **Bush et al. [62]** | English Premier League (EPL) seasons (2005-06 to 2012-13) and consisted of 451 individual players across 3016 observations | To investigate match-to-match variability of physical and technical performances in EPL players and quantify the influence of positional and contextual factors | Number of passes attempted, passing success, number of passes received, interceptions, number of tackles completed per player and number of times the player was tackled, number of possessions won/lost, and average number of touches per possession | - Technical indicators such as tackles, possessions won, and interceptions illustrated substantial variability for attackers compared with all other positions<br>- Central defenders demonstrated large variability for the number of times tackled per match and passes attempted and received compared with other positions |
| **Bush et al. [86]** | Seven consecutive EPL seasons (2006-07 to 2012-13) of 1036 individual players across 22846 observations | To investigate position-specific evolution of physical and technical performance parameters in the EPL | Number of passes (short, medium, long), passing successful. | - Central players (central defenders and midfielders) illustrated the most pronounced increases in total passes and pass success rate whilst wide players (full backs and wide midfielders) demonstrated only small-moderate increases in total passes and pass success rate |
| **Carling [35]** | 45 French League 1 matches played over three competitive seasons (2007-08 to 2009-10) | To examine the influence of opposition team formation on physical and skill-related performance in a professional soccer team | Frequency of passes and forward passes, mean length of passes, percentage of passes played with one touch, frequency of ball possessions, mean time and number of touches per possession, and frequency of ground and aerial duels | - Players as a whole performed more passes versus a 4-4-2 than a 4-2-3-1 formation;<br>- More ground and aerial duels versus a 4-2-3-1 compared with a 4-4-2 formation;<br>- More one touch passes versus a 4-2-3-1 compared with a 4-4-2 formation and a 4-3-3/4-5-1 formation;<br>- The mean number of touches per possession was highest versus a 4-4-2 compared with a 4-3-3/4-5-1 and a 4-2-3-1 formation |
| **Carling and Dupont [29]** | 35 French League 1 matches and two UEFA Europa League matches over three seasons (2007-08, *n*=16; 2008-09, *n*=15; 2009-10, *n*=6) were used for analysis | To determine whether declines in physical performance in a professional soccer team during match play were associated with reductions in skill-related performance | Total number of passes, percentage of completed or uncompleted passes, number of ball possessions and possessions gained or lost, number of touches per possession, number of duels and percentage of duels won or lost | - Analysis of skill-related measures revealed no significant decline between halves, across 15-min intervals or in the 5-min period following that of peak high-speed activity compared with the match mean for other 5-min periods;<br>- Frequencies of passing, ball possessions, and duels were greater in the first 5-min than in the final 5-min period |

**Table 1.** Continuation.

| Authors | Sample | Aim | Methods | Main Findings |
|---|---|---|---|---|
| **Carling et al. [32]** | 38 league matches per season played over five consecutive seasons (2007-08 to 2012-13: 190 matches) | To investigate in a professional soccer team across five consecutive league seasons a squad management, injury and physical, tactical and technical match performance | Ball possession and possession in opponents' half, passes, forward passes, completed passes and forward passes, crosses and completed crosses, goal attempts and goal attempts on target, successful final third entries, free-kicks and 50/50 duels won/lost | - The team won both its highest number of points and conceded its lowest number of goals especially over the second half of this season<br>- The team won its highest number of matches directly via a goal from a substitute and scored and conceded a goal first on the highest and lowest number of occasions, respectively |
| **Clemente et al. [22]** | Male amateur soccer players from the Portuguese regional league (*n* = 10) | To examine the effect of differences in the number of players and scoring method on heart rate responses, time–motion characteristics, and technical/tactical performance during SSCG | Nine different SSCG (i.e., 3 formats × 3 scoring methods). Conquered Ball, Lost Ball, Neutral Ball, Pass, Successful Shot on Goal | - 2vs.2 induced significantly greater values of technical/tactical indexes |
| **Da Silva et al. [39]** | 16 male young soccer players completed two bouts of 3vs.3 (SSCG3), 4vs.4 (SSCG4), and 5vs.5 (SSCG5) training | To examine in young soccer players the effect of varying the number of players on exercise intensity (EI) and technical actions during SSCG | Involvement with the ball, crosses, headers, tackles, shots on goal, dribbling, passing, and target passing | - No effects of number of players were found in involvements with the ball, passes, target passes, tackles, and headers<br>- Significantly more crosses, dribbling, and shots on goal were observed during SSCG3 compared to during SSCG4 or SSCG5 |
| **Dellal et al. [87]** | 3540 professional soccer player's activities during the 2005-2006 season | To analyse the physical and technical activities of elite soccer players from the French First League, according to their playing positions | Percentage of successful passes, total duration of individual ball possession, and the number of ball touches per individual possession | - The players had the possession of the ball between 55.5sec and 74.2sec per match played;<br>- The players had no more than 2.2 ball touches per individual possession;<br>- Midfielders performed successful passes ranging from 75% to 78%, whereas lower values were found for the forwards (71%) and central defenders (63%) respectively |
| **Dellal et al. [88]** | 5938 observations of match performance were analyzed across Spanish La Liga (*n*=1896) and the English FA Premier League (FAPL) (*n*=4704) | To compare match performance in professional soccer players across two major European championships: Spanish La Liga and FAPL | Heading and ground duels, passing, time in possession, and ball touches | - La Liga players won more heading duels (49.32% vs. 48.68%) and performed the same proportion of successful passes (76.17%)<br>- FAPL wide midfielders had 20% more ball touches per possession than their La Liga counterparts |
| **Dellal et al. [56]** | International players (*n*=20) and amateur players (*n*=20) of the fourth French division | To examine the relationship between the playing level in soccer (i.e., amateur vs. professional players) and the physiological impact, perceptual responses, time–motion characteristics, and technical activities during various SSCG | Played 9 SSCG (i.e., 2 vs. 2, 3 vs. 3, and 4 vs. 4) in which the number of ball touches authorized by possession varied (1 ball touch authorized = 1T, 2 ball touches authorized = 2T, and Free Play = FP). Duels, percentage of successful passes, the amount of lost balls per possession, and the total number of possessions | - Across the various SSCG, amateurs completed a lower percent of successful passes and higher number of ball lost per possession |

**Table 1.** Continuation.

| Authors | Sample | Aim | Methods | Main Findings |
|---|---|---|---|---|
| **Dellal et al. [41]** | 20 international soccer players | To examine the influence of the number of ball touches authorized per possession on the physical demands, technical performances and physiological responses throughout the bouts within 4vs.4 SSCG | Three different 4vs.4 SSGs (4x4 min) in which the number of ball touches authorized per possession was manipulated (1 touch = IT; 2 touches = 2T; Free Play = FP). Number of duels, percentage of successful passes, number of ball losses, and total number of ball possessions | - The FP rule affected less the technical actions (successful passes and number of ball losses) as compared with IT and 2T forms<br>- SSCG played in IT form presented more difficulty to perform a correct technical action |
| **Dellal et al. [42]** | International players classified into five positional roles (*n*=40) | To compare the effects of common rule changes on technical and physical demands for elite soccer players in five playing positions during various 4-min SSCG in comparison to 11-a-side matches | Players completed three different SSCG 4 vs.4 (1 ball touch = 1T, 2 ball touches = 2T and Free Play = FP) as well as two friendly matches. Successful passes, total number of lost balls, dribbling, passing and total number of ball possessions | - Compared to match play, total numbers of duels and lost ball possessions were significantly greater within SSGs for all playing positions<br>- SSCG played with 1 or 2 ball touches the difficulty to perform technical actions, being more specific to match demands |
| **Draganidis et al. [26]** | 10 elite soccer players participated in three different trials: control, low-intensity resistance exercise | To determine the recovery rate of soccer skill performance following resistance exercise of moderate or high intensity | Loughborough Soccer Passing Test, long passing, dribbling, shooting and heading. | - Passing and shooting performance declined post-exercise following resistance exercise;<br>- Soccer skill performance is minimally affected by acute resistance exercise independent of intensity |
| **Fanchini et al. [43]** | 19 adult soccer players completed three bouts of a 3-a-side SSCG at three different bout durations: 2, 4, and 6 minutes | To examine whether the increase in bout duration would affect the exercise intensity and technical actions | Pass, successful pass, unsuccessful pass, tackle, header, turn, interception, dribbling, shoot, and shoot on target | - No effect of duration was found for number of technical actions per minute<br>- Duration did not influence the technical actions and proficiency |
| **Fernandez-Gonzalo et al. [89]** | 30 prepubescent young soccer players with the same experience in soccer training | To offer some insight into the factors contributing to success in this sport and to describe how physiological and technical performance evolves in young soccer players | 3 expert coaches with over 10 years of experience in young soccer. Each expert had to fill in a technical sheet for every subject by giving points from 1 to 100 to different technical parameters: shooting, passing, dribbling, ball control, heading, and tackling | - Among the technical skills measured, significant differences were found only in heading<br>- Besides, over 30% of the technical performance measured in this study can be explained with the physiological parameters |
| **Garcia et al. [36]** | 54 young soccer players (U-9 and U-14) | To quantify and analyse the offensive situations in different formats of SSCG | 54 SSCG played in three different formats (5vs.5, 7vs.7 and 9vs.9). Ball out of play, touches per game, touches per outfield player, touches per minute, defensive half, attacking half, attempts at goal, shots per minute, goals per minute, penalty area entries, unsuccessful dribbles, successful dribbles, unsuccessful passes, successful passes | - More touches of the ball and attacking play in the smaller game formats<br>- Higher frequency among the variables for attacking play in all age groups and playing surfaces in the smaller-sided games (5vs.5 and 7vs.7) than in the 9vs.9 format |

**Table 1.** Continuation.

| Authors | Sample | Aim | Methods | Main Findings |
|---|---|---|---|---|
| **Guilherme et al. [23]** | Young soccer players (*n*=71) were randomly divided into experimental group (*n*=35) and control group (*n*=36) | To ascertain whether a specific technical training programme for the non-preferred foot has implications in the increasing utilisation rate of the respective member during the game | System of assessment of functional asymmetry of the lower limbs in Soccer (SAFALL-FOOT). Interception/disarm, reception, passing, driving/protection, feint/dribble, shooting | - The use of the non-preferred foot increased significantly with the technical training programme in the experimental group and remained constant in the control group<br>- The use of the preferred foot decreased significantly in the experimental group and remained similar in control group |
| **Harper et al. [30]** | 18 matches involving professional European teams played between 2010 and 2014 | To examine the influence of prolonged durations of professional soccer match-play on markers of technical (i.e., skilled) performance | Technical actions observed during eight 15-minute epochs (E1: 00:00-14:59 min, E2: 15:00-29:59 min, E3: 30:00-44:59 min, E4: 45:00-59:59 min, E5: 60:00-74:59 min, E6: 75:00-89:59 min, E7: 90:00-104:59 min, E8: 105:00-119:59 min). Passing, dribbling, shooting, crossing | - The cumulative number of successful passes observed during E8 was lower than E1, E2, E3, E4 and E7<br>- The total number of passes made in E8 was reduced when compared to E1, E3, E4 and E7<br>- The cumulative number of successful dribbles reduced in E8 when compared to E1 and E3 |
| **Hodgson, Akenhead and Thomas [37]** | Eight university-level male soccer players | To quantify the time–motion characteristics and technical demands of SSCG played on small, medium and large pitches | SSCG comprising 4x4 min quarters (3 min recovery) on small (30x20m) medium (40x30m) and large (50x40m) pitch sizes. Pass, turn, dribble, shot, tackle, header, interception | - The small pitch imposed a greater technical demand on players (more passes, shots and tackles) compared to medium and large pitches |
| **Honer et al. [10]** | Highly selected players (the top 4% of their age groups, U12–U15) took part in the diagnostics at 17 measurement points between spring 2004 and spring 2012 (*n*=68.158) | To examine the reliability, differential stability and validity of the motor diagnostics conducted nationwide by the German soccer talent identification and development programme and provides reference values for a standardised interpretation of the diagnostics results | Sprint, agility, dribbling, ball control, shooting | - The diagnostics demonstrated satisfying factorial-related validity with plausible and stable loadings on the two empirical factors “speed” and “technical skills”<br>- The score, and the technical skills dribbling and juggling, differentiated the most among players of different performance levels and thus showed the highest criterion-related validity |
| **Huijgenet al. [15]** | Talented soccer players (*n*=131, 14-18 years). Professional (*n*=54) or amateur (*n*=77) | To investigate the relationship between the development of the technical skill dribbling | Shuttle Dribble Test | - The longitudinal results showed that during adolescence the talented players who ultimately became professional were on average 0.3s faster on 30m peak dribbling performance and on average 1 second faster on 3 × 30m repeated dribbling performance than the players who ultimately turned amateur |
| **Huijgen et al. [14]** | Talented soccer players aged 12-19 years (*n*=267) | To assess the development and determine the underlying mechanisms of sprinting and dribbling needed to compete at the highest level in young soccer | Shuttle Sprint and Dribble Test and the Slalom Sprint and Dribble Test | - Both dribbling and sprinting improved with age, especially from ages 12 to 14, but the time of development was different<br>- From ages 14 to 16, sprinting improved rapidly in contrast to dribbling |

**Table 1.** Continuation.

| Authors | Sample | Aim | Methods | Main Findings |
|---|---|---|---|---|
| **Huijgen et al. [16]** | Talented adolescent soccer players professional soccer clubs in the Netherlands (*n*=113) | To examine whether performance characteristics discriminated between selected and deselected players in talent development programmes | Four domains of multidimensional performance characteristics (physiological, technical, tactical, physical, psychological) were assessed by using a test battery consisting of soccer specific field tests and questionnaires. Peak shuttle dribble, repeated shuttle dribble and slalom dribble performance were measured by the ShuttleSDT and SlalomSDT | - The combination of the technical characteristic 'peak dribbling', the tactical characteristic 'positioning and deciding' and the physiological characteristic of 'peak sprinting' classified 69% of talented players correctly |
| **Impellizzeri et al. [50]** | 26 junior soccer players. Control group (CG) or aerobic interval training group (ITG) | To examine the effects of aerobic interval training on the declining in short-passing ability caused by a short bout of high-intensity intermittent activities | Loughborough Soccer Passing Test (LSPT) was measured before and 5-min after high-intensity simulation (HIS) | - The ITG, but not CG showed a reduced the worsening in LSPT penalty time after the HIS |
| **Juárez et al. [90]** | Young top-class soccer players (*n*=21) | To describe the kinematic pattern of the kicking movement of young top-class soccer players focusing in examining the linear joint markers velocity of the leg kick and the segments angular position | Maximal in step kicks performed were analyzed using a three dimensional motion capture system | - The maximum linear velocity of the hip, knee, ankle and toe joint markers were achieved consecutively during the kick, representing a typical proximal to distal kinetic chain |
| **Katis and Kellis [40]** | 34 young soccer players | To examine, first, the movement actions performed during two different SSCG and, second, their effects on a series of field endurance and technical tests | SSCG included three-a-side (3vs.3 players) and six-a-side (6vs.6 players) games consisting of 10 bouts of 4 min duration with 3 min active recovery between bouts Passing (short, long), heading, tackling, shooting, dribbling, gols. Dribbling test | - The number of short passes, kicks, tackles, dribbles and scoring goals were significantly higher during the 3vs.3 compared with the 6vs.6 game condition while players performed more long passes and headed the ball more often during the 6vs.6 |
| **Kelly and Drust [91]** | Eight young male soccer players | To examine the impact of changes in pitch size on heart rate responses and technical requirements of SSCG | SSCG on three different pitch sizes (SSCG1, 30x20 m; SSCG2, 40x30m; SSCG3, 50x40m). Games consisted of 4x4min of game play, interspersed by 2 min of active recovery. Pass, receive, turn, dribble, header, tackle, interception, shot, target pass | - The technical actions that changed as a result of changes in pitch size were the number of tackles (SSG1, 45±10; SSCG2, 15±4) and shots (SSCG1, 85±15; SSCG 2, 60±18; SSCG3, 44±9) |

**Table 1.** Continuation.

| Authors | Sample | Aim | Methods | Main Findings |
|---|---|---|---|---|
| **Koklu et al. [45]** | Young soccer players (*n*=12) | To investigate the effects of the length of recovery durations between bouts in 4x4min 3-a-side SSCG on time-motion analysis, technical actions and physiological responses of players | 4 different 3-a-side games in which the recovery durations between bouts were different (R1: 1 min, R2: 2 min, R3: 3 min, and R4: 4 min). Touches of the ball, total passes, successful passes, tackles | - SSCG-R1 induced lower successful passes, lower total passes when compared with others three conditions<br>- SSCG-R3 players performed more tackles and had more ball contacts (vs. R1 condition) and had more ball contacts (vs. R1 and R2 conditions). |
| **Lago-Penas and Lago-Ballesteros [68]** | 380 matches of the Spanish professional men's league | To identify the soccer match-related statistics that best discriminate home and visiting teams according to the team quality | The match-related statistics registered were divided into three groups: (i) variables related to goals scored; (ii) variables related to offense and (iii) variables related to defence | - Home teams have significantly higher means for goal scored, total shots, shots on goal, attacking moves, box moves, crosses, offsides committed, assists, passes made, successful passes, dribbles made, successful dribbles, ball possession, and gains of possession<br><br>- Visiting teams presented higher means for losses of possession and yellow cards |
| **Lizana et al. [46]** | 24 athletes assigned to 6-player teams | To investigate, through videogrammetry, if the technical and tactical principles promoted through the adoption of distinct rules from two distinct SSGs (Game 1: maintaining ball possession; Game 2: progression to the target) would actually be achieved | Number of passes, successful passes, number of shots, successful shots | - In Game 1, an average of (487±42) passes was performed, twice that of Game 2 (207±20 passes)<br>- The average number of shots using the feet in Game 1 (10±0.6) was lower than Game 2 (49±6 shots)<br>- In Game 1, the percentage of correct passes (85±2.3%) was higher than the values from Game 2 (79±2.0%)<br>- The total number of shots was lower in Game 1 |
| **Malina et al. [73]** | 69 players aged 13.2-15.1 years from three clubs that competed in the highest division for their age group | To estimate the contribution of experience, body size and maturity status to variation in sport specific skills of adolescent soccer players | Ball control with the body, ball control with the head, dribbling with a pass, dribbling speed, shooting accuracy and passing accuracy. Multiple linear regression analysis was used to estimate the relative contributions of age, stage of sexual maturity, height, body mass and years of formal training in soccer to the six skill tests | - Dribbling with a pass (21%; age, stage of maturity), ball control with the head (14%; stage of maturity, height, body height6body mass interaction), ball control with the body (13%; stage of maturity, years of training) and shooting accuracy (8%; stage of maturity, height; borderline significance) |
| **Matta et al. [74]** | 119 soccer players, 74 (U-15) and 45 (U-17) | To describe the association between chronological age, morphology, biological maturation and sport experience in relation to technical performance in young Brazilian soccer players | Data were analyzed using a multiple linear regression model. Ball control test, number of touches on the ball, dribbling test, kicking accuracy test | - Adiposity was negatively associated with technical performance regardless the age-category<br>- Weight was negatively associated with technical performance in U-15 and positively with the U-17 category<br>- U-17 biological maturation was negatively related to the dribbling test and positively associated with the ball control test<br>- Years of experience proved to be positively associated with technique taught to soccer player in the U-17 category |

**Table 1.** Continuation.

| Authors | Sample | Aim | Methods | Main Findings |
|---|---|---|---|---|
| **Miranda et al. [51]** | 30 young soccer players | To verify the influence of 10-week soccer training program on anthropometric, psychological, technical skills and specific performance parameters in young players | 10-week soccer training. The players were evaluated two times along the experiment (i.e. in T1 - before, and T2- after training). Slalom dribble, lob pass, juggling test | - 10-week soccer training program with similar characteristics of volume and intensity may lead to significant changes in slalom dribble and lob pass tests (T1vs.T2) |
| **Le Moal et al. [57]** | 87 players, aged 14–17 years. Elite (*n* = 44), Sub-elite (*n* = 22), and Non-elite (*n* = 21) | To examine the validity and reliability of the Loughborough Soccer Passing Test (LSPT) in adolescent soccer players | Two attempts of the LSPT were performed at baseline. Players then completed 10 attempts over 3 weeks to familiarize themselves with the test. Subsequently, 2 main trials, separated by 1 week, were performed; the mean of the 2 attempts was recorded as the performance score | - The LSPT seems to be a valid and reliable protocol to assess differences in soccer skill performance in adolescent players and can distinguish players according to their playing level |
| **Morgans et al. [33]** | 11 male professional outfield soccer players | To investigate if differences in physical and technical performance occurred across a season for 11 English Championship League (ECL) soccer players who played the majority of matches that season | Number of individual passes, individual passes completion, team possession, sprint and high-intensity running in possession of the ball | - Passes made and pass success rate per match were 55±3 and 85±1% respectively across the season<br>- Passes made and pass success rate were relatively stable and did not significantly differ across the season<br>- Collectively, the team kept possession of the ball for a median of 62% of total match time<br>- Maintaining possession during matches may reduce physical demands imposed on players and help preserve performance throughout the season |
| **Nassis et al. [92]** | The 2014 FIFA World Cup Brazil included 64 matches in temperate to tropical environmental conditions | To analyze performance data in relation to the environmental conditions to identify potential association | Environmental stress was estimated (low, moderate and high) for each match. Number of passes and the per cent of successful passes were recorded | - Number of passes was not different but the rate of successful passes was higher under high (76.8 ± 4.4%) than low (73.6±10.8 %) environmental stress |
| **Owen et al. [93]** | 15 male soccer players from a Scottish Premier League team | To examine the difference in heart rate (HR) responses and technical activities placed upon European elite players when exposed to 2-sided games differing in the number of players and playing area | Small (3vs.3 plus goalkeepers) and large (9vs.9 plus goalkeepers) sided games each lasting for 3x5 min interspersed with 4-minute passive recovery. Block, dribble, header, interception, pass, receive, shot, turn, tackle | - Technical performance analysis revealed a large practical difference between small (SSG) and large-sided games (LSG): less number of blocks, headers, interceptions, passes, and receives but more dribbles, shots, and tackles in SSG<br>- SSG induced significantly lesser total ball contacts per game, but significantly greater ball contacts per individual when compared to LSG |

**Table 1.** Continuation.

| Authors | Sample | Aim | Methods | Main Findings |
|---|---|---|---|---|
| **Radziminski et al. [53]** | 20 young soccer players (U-16) were divided into two groups (running group – RG, small-sided and conditioned games group – SSCGG) and completed two different 8-week training programs | To investigate the effects of high-intensity interval running and SSCG training programs on the physical capacity and the level of soccer-specific technical skills in young soccer players | Two training sessions a week (RG – 5x4 min running, with an active recovery period of 3 min; SSCGG - 3vs.3 games or 3vs.3 with a neutral player for 5x4 min, with an active recovery period of 3 min). Technical actions: battery of seven tests proposed by the German soccer federation (420 points in total) | - A significant improvement in soccer-specific technical skills level was noted only in the SSCGG |
| **Rampinini et al. [78]** | Young soccer players (*n*=16) | To examine whether the fatigue accumulated during match play or determined by short bouts of high-intensity intermittent activities affect short-passing ability in junior soccer players. Examine the influence of physical fitness as measured using the Yo-Yo Intermittent Recovery Test (YYIRT) on the changes in short-passing ability after a 5-min simulation of high intensity activities (HIS) | Loughborough Soccer Passing Test (LSPT). Players completed the LSPT in two sessions during the 1-wk control period, followed by two unofficial matches during which the LSPT was performed during and after the first and the second halves of the match. The change in LSPT performance was determined after 5 min of HIS | - A decline in LSPT performance was found during and after the match<br>- The accuracy of the LSPT decreased after the HIS<br>- A significant correlation was found between the YYIRT scores and the decline in LSPT performance (accuracy, total time, total time with penalties) after HIS |
| **Rampinini et al. [31]** | 416 individual matches from 186 professional soccer players | To examine the changes in technical and physical performance between the first and second half during official matches of Italian Serie A league. Compare the technical and physical performance of the players of the more successful teams (ranked in the first 5 positions) with the players of the less successful teams (ranked in the last 5 positions) | Short passes, Successful short passes, Long passes, Successful long passes, Crosses, Headers, Tackles, Dribbling, Shots, Shots on target | - The players from the more involvements with the ball, completed more short passes, successful short passes, tackles, dribbling, shots and shots on target compared to the less successful teams<br>- A significant decline between the first and second half was found for some technical scores |
| **Rebelo et al. [58]** | Elite (*n*=95) and non-elite (*n*=85) soccer players | Anthropometric characteristics, physical fitness and technical skills of under-19 (U19) soccer players were compared by competitive level and playing position (goalkeeper, central defender, fullback, midfield, forward) | Soccer-specific skills included ball control and dribbling | - Major differences were noted between elite and non-elite goalkeepers ball control<br>- Elite central defenders performed better than their non-elite counterparts in ball control tests |
| **Reilly et al. [60]** | 31 (*n*=16, elite; *n*=15, sub-elite) young soccer players (15-16 years) | To apply a comprehensive test battery to young players with a view to distinguishing between elite and sub-elite groups on the basis of performance on test items | Soccer-specific skills: shooting test and a slalom dribble test | - The elite players were better at dribbling the ball, but not shooting |
| **Rostgaard et al. [59]** | Young elite (YE, *n*=14) and sub-elite (SE, *n*=7) soccer players | To develop and examine a test for evaluation of the physical and technical capacity of soccer players | Players performed a physical and technical test (PT-test) consisting of 10 long kicks interspersed with intense intermittent exercise. A control test (CON-test) without intense exercise was performed. The test result was evaluated by the precision of the 10 kicks | - The YE-players performed better than the SE-players in both the PT-test and CON-test with no difference in the relative PT-test result<br>- Summed performance of the first 5 repetitions was higher than for the last 5 repetitions |

**Table 1.** Continuation.

| Authors | Sample | Aim | Methods | Main Findings |
|---|---|---|---|---|
| **Russel, Benton and Kingsley [11]** | 20 soccer player (*n*=10 professional; *n*=10 recreational) | To examine the reliability and construct validity of new soccer skills tests | Passing, shooting, and dribbling skills tests. Each trial consisted of 28 passes, 8 shots, and 10 dribbles | - Professional players performed better than recreational players in at least one outcome measure for all skills (reliability and validity of new soccer skill protocols) |
| **Russel, Benton and Kingsley [12]** | 15 academy soccer players completed a soccer match simulation (FMS) | To examine the effects of exercise-induced fatigue on soccer skills performed throughout simulated match play | Precision, success rate, and ball speed were determined via video analysis for all skills | - FMS influenced shooting precision and passing speed, such that shots taken after exercise were 25.5±4.0% less accurate than those taken before exercise and passes in the last 15 min were 7.8±4.3% slower than in the first 15 min<br>- Shot and pass speeds were slower during the second half compared with the first half<br>-Dribbling performance was unaffected by FMS |
| **Sinclair et al. [94]** | Academy-level soccer players (*n*=22) | To identify important technical aspects of kicking linked to the generation of ball velocity using regression analyses | Maximal instep kicks were obtained using a 10-camera motion capture system sampling at 500 Hz. Three-dimensional kinematics of the lower extremity segments were obtained. Regression analysis was used to identify the kinematic parameters associated with the development of ball velocity | - A single biomechanical parameter; knee extension velocity of the kicking limb at ball contact adjusted was obtained as a significant predictor of ball-velocity |
| **Stone and Oliver [49]** | Nine semi-professional soccer players | To examine the effect of fatigue, developed during prolonged high-intensity intermittent exercise, on the performance of soccer shooting and dribbling skill | Slalom dribble test and the Loughborough Soccer Shooting Test (LSST), before and directly following the performance of three 15-min bouts of a modified version of the Loughborough Intermittent Shuttle Test (LIST) | - The LIST slalom dribbling time increased significantly by 4.5±4.0%<br>- The mean total points scored during the LSST was significantly reduced by 7.6±7.0 points<br>- When fatigued the frequency of shots in the LSST achieving the highest score of 5 points was reduced by 47% while the frequency of shots achieving the lowest 0 point score increased by 85% |
| **Taylor et al. [65]** | 40 matches from the 2002-03 and 2003-04 domestic league seasons | To examine the effects of match location, quality of opposition, and match status on the technical aspects of performance within a single professional British soccer team | Aerial challenge, clearance, cross, dribble, interception, loss of control, pass, shot, tackle, times tackled, corner, free kick, throw-in | - The findings emphasize the need for notational analysts and coaches to consider the potential independent and interactive effects of match location, quality of opposition, and match status when assessing the technical components of soccer performance, particularly those relating to behavior occurrence |
| **Tessitore et al. [95]** | Young male soccer players (*n*=22) | To compare the heart rate (HR) responses and match analysis parameters of official 5-a-side young male soccer matches played over 2 pitch surface (i.e., clay vs. artificial turf) conditions | Type of action; the number of players involved in an action; the number of passes performed in a collective action; precision of the shots; lost balls; ball interceptions; dribblings; and tackles | - The similar HR responses and technical-tactical patterns observed on the 2 surfaces indicate that young match play is not affected by differences in pitch surface |

**Table 1.** Continuation.

| Authors | Sample | Aim | Methods | Main Findings |
|---|---|---|---|---|
| **Vaeyens et al. [13]** | Elite, sub-elite, and non-elite young players in four age groups: U-13 (*n*=117), U-14 (*n*=136), U-15 (*n*=138) and U-16 (*n*=99) | To determine the relationships between physical and performance characteristics and level of skill in young soccer players aged 12-16 years | Anthropometry, maturity status, functional and sport-specific parameters. Slalom dribble, lob pass, shooting accuracy, juggling test | - Elite players scored better than the non-elite players on several technical skills<br>- Running speed and technical skills were the most important characteristics in U-13 and U-14 players<br>- Cardiorespiratory endurance was more important in U-15 and U-16 players |
| **Vilar et al. [96]** | 15 amateur standard male soccer players | To examine the influence of pitch dimensions in SSCG in shaping opportunities for performers to maintain ball possession, pass to teammates and shoot at goal | 5vs.5 SSCG in three varying pitch conditions (28x14m, 40x20m and 52x26m). The values of interpersonal distance between all attackers and immediate defenders and the relative distances of defenders to intercept a shot and a pass were computed as dependent variables | - Existence of fewer opportunities to maintain ball possession on smaller pitches, compared to medium and larger pitches<br>- The different dimensions set to the pitch did not influence opportunities for players to shoot at goal, or to perform passes to other teammates |
| **Vilar et al. [97]** | 15 male young soccer players | To examine the effects of the numbers of players involved in SSCG (under-loading and overloading) on opportunities for maintaining ball possession, shooting at goal and passing to teammates during training | Three different conditions: 5vs.5, 5vs.4 and 5vs.3. interpersonal distance between an outfield attacker and nearest defender (ID), and the relative distance of a defender needed to intercept the trajectory of a shot (RDishot) or pass (RDipass) | - The mean ID values were significantly lower in 5vs.5 than in 5vs.4 and 5vs.3 conditions, and significantly lower in 5vs.4 than 5vs.3<br>- The mean values of RDishot were significantly higher in 5vs.3 than in 5vs.5 conditions<br>- The mean values of RDipass were significantly higher in 5vs.3 than in 5vs.5 |
| **Villarreal et al. [52]** | 26 young soccer players | To determine the influence of a short-term combined plyometric and sprint training (9 weeks) within regular soccer practice on explosive and technical actions of pubertal soccer players during the in-season | Two groups: control group (CG) (soccer training only) and combined group (CombG) (plyometric + acceleration + dribbling + shooting). Ball-shooting speed test | - Baseline-training results showed no significant differences between the groups in Ball-shooting speed test, however, meaningful improvement was found |

# CAPÍTULO 3. ESTUDO 2

# RELATIONSHIPS BETWEEN RUNNING DEMANDS IN SOCCER MATCH-PLAY, ANTHROPOMETRIC, AND PHYSICAL FITNESS CHARACTERISTICS: A SYSTEMATIC REVIEW AND META-ANALYSIS

**Shortened title:** Physical performance assessment in soccer

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AQUINO, R.; CARLING, C.; MAIA, J.; VIEIRA, L. H. P.; WILSON, R. S.; SMITH, N.; GARGANTA, J.; PUGGINA, E. F. Relationships between running demands in soccer match-play, anthropometric, and physical fitness characteristics: A systematic review and meta-analysis. **Sports Medicine**, Submetido para Publicação, 2019.

**Abstract**

*Background:* A large range of tests are presently used to determine characteristics of physical fitness in soccer players in both laboratory and field conditions. Researchers have subsequently attempted to associate fitness measures to match running performance (i.e., construct validity) and have observed contrasting findings. This information can aid practitioners to select the most valid tests to inform talent identification, player development programs, and physical conditioning interventions. A plethora of previous reviews have collated and appraised the literature on time-motion analysis, congested schedules, fatigue development, and situational variables, but none have solely examined the construct validity of fitness testing at youth and senior levels.

*Objective:* The aim of the present study was to systematically review the current literature that has investigated the relationships between anthropometric and physical fitness characteristics and match-play running demands in female and male soccer players at youth and senior levels.

*Methods:* The systematic review and meta-analysis were performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The following databases were examined: PubMed/NCBI, ISI Web of Knowledge, SciELO, and SPORTDiscus via EBSCOhost. In order to be included in the current study, papers had to be i) empirical in nature, ii) written in English, ii) published in a peer-reviewed scientific journal, iii) conducted in outfield players, iv) published/ahead of print on or before November 30$^{th}$, 2018, and vi) investigations relating anthropometric and physical fitness variables to match running demands (official and/or friendly matches; relationships expressed in correlation coefficients [r]),

*Results:* While a total of 12447 studies were initially identified, only 3562 titles and abstracts were screened. Following analysis, 27 articles were selected resulting in a sample of 991 players (964 male and 27 female) of which there were 687 youth (U-13 to U-18) and 304 professional players (range: 22.3-29.4 years). Of these studies, only three related anthropometric measures to running demands during the matches and showed poor relationships ($r^2$ = 4-36%). Incremental treadmill tests performed in laboratory settings showed large-to-very large correlations with total distance covered and/or high-intensity running activity during matches ($r^2$ = 20-50%). However, a range of protocols was used across studies, not enabling a meta-analysis to compare the results and draw firm conclusions. Regarding field tests, the Yo-Yo Intermittent recovery test (Yo-Yo IR) levels 1 and 2 were associated with high-intensity running activity across all studies with a mean effect size (Fisher-z value) of 0.79 and 0.68, respectively. A greater power of prediction was notably reported for level 1 compared to level 2. Both levels were also related to total distance covered (mean Fisher-z values of 0.63 and 0.82, respectively, level 2 > level 1).

*Conclusions:* This systematic review and meta-analysis collated scientific evidence that can aid sports science and coaching practitioners in understanding specificity, quality assessed, capacity to predict running demands during match-play, prescriptiveness, and overall characteristics of the anthropometric measures and physical fitness tests. This review also highlighted areas that requires further investigations, such as the possible influence of contextual factors (e.g., situational variables, competitive level, and team formation) when assessing the construct validity of a given test in relation to running performance, and the validity of more integrative tests combining match physical, tactical, and technical tasks (e.g., small-sided game).

**Key Points**

1) Anthropometric data cannot be used to associate and/or predict match running demands in professional players although youth players demonstrating advanced maturity might produce greater running outputs during matches, notably in midfielders and forwards.
2) While incremental treadmill tests demonstrate large to very-large associations to match-play running demands the range of protocols used across studies does not permit use of meta-analysis and reduces the strength of any conclusions.
3) The results of meta-analysis presented in this review demonstrate the strong capacity of the Yo-Yo Intermittent Recovery test to predict high-intensity running (level 1 better than level 2) and total distance covered (level 2 better than level 1) during match-play.

## 1 Introduction

At elite standards, physical performance of soccer players is routinely assessed for several purposes: to identify individual players' strengths and weaknesses, investigate the effects of training interventions, inform rehabilitation processes following injury, and profile and monitor development particularly in youth players [1]. Assessments of physical performance are traditionally conducted using laboratory based tests including incremental protocols performed on a treadmill [2], Wingate test on a cycle ergometer or a 30-s all-out running effort [3, 4], and maximal anaerobic oxygen deficit running tests [3]. Field-based assessments have also been developed in an attempt to assess endurance, muscular power, and sprinting performance under conditions more 'ecologically' in line with the real-world demands of match-play [5, 6]. Indeed, to ensure that data obtained from the field and laboratory tests are pertinent to performance, high ecological validity is necessary (generally considered construct validity: [7-9]). This validity can be assessed through evaluation of the potential associations between data derived from testing and that generated on physical outputs in match-play via time-motion analyses of locomotor activity.

Bangsbo and Lindquist [10] were the first to investigate the association between physical fitness and running demands during professional soccer match-play. Since this study, numerous investigations have been conducted. These generally show that total distance covered and peak velocity attained during endurance assessments [7, 11-14], and repeated sprint ability mean time [9, 15] are related to the total and high-intensity distance covered during matches (value range for r= -0.30 to 0.78). In contrast, additional research has shown that a number of physical fitness tests (e.g. countermovement jump, 5-m sprint time, aerobic fitness, repeated sprint ability) were unrelated to overall running output during soccer match-play [16, 17]. Similarly, such tests might not accurately depict a player's capacity to resist fatigue represented by drops in activity during competition [18]. Buchheit, Mendez-Villanueva [15] suggested that the association between physical fitness and match running performance was not as evident as perceived in earlier studies. This was notably due to correlation coefficients being partly position-dependent (e.g., trivial correlations for defenders and midfielders, large associations for forward positions).

Over the last two decades, several review papers have discussed physical performance in soccer match-play across professional [19-27] and amateur and elite youth levels [28-30]. These studies have generally focused on characterizing match demands and additionally discussed data acquisition techniques. However, none were dedicated specifically to collating the relationships between physical fitness characteristics and match-play running output. This information on the construct validity of physical fitness tests in relation to match running performance can aid practitioners to select the most valid tests to inform talent identification and player development programs and physical conditioning interventions [15].

The aim of this study is to systematically review the current body of evidence derived from original research investigations regarding the relationship between anthropometric and physical fitness characteristics with match running demands in youth and adult female and male soccer players.

## 2 Methods

### 2.1 Search Strategy

The systematic review and meta-analysis were performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [31]. All search procedures were conducted according to local University ethical guidelines (School of Physical Education and Sport, Ribeirão Preto-Brazil; protocol number: 61884716.9.0000.5659).

Two researchers separately conducted the literature search on November 30th, 2018. There was no restriction on year of publication. The following databases were examined: PubMed/NCBI (National Center for Biotechnology Information, United States National Library of Medicine), Institute for Scientific Information (ISI) Web of Knowledge, SciELO (Scientific Electronic Library Online) and SPORTDiscus via EBSCOhost. Initially, we checked titles, abstracts, and keywords separately for relevance in each database. The following descriptors were used: "soccer" and "football", each associated with the terms: "physical performance", "anthropometric measures", "field tests", "laboratory tests", "fitness assessment", "match running performance", "time-motion analysis", "match analysis", and "construct validity". Additional searches were performed on Google Scholar when full texts were not available in the mentioned databases and for articles found on ResearchGate™. Dedicated computer software (EndNote X7, Thomson Reuters ©, New York, NY, USA) was used for reference management, facilitating de-duplication and screening steps. In the case of disagreement between researchers (RA, LHPV), a senior researcher (CC) in this field determined whether the paper was included or not [32]. The full-text was then retrieved for relevant articles and reference lists screened for additional articles.

### 2.2 Selection criteria

In order to be included in the current study, papers had to be i) empirical in nature, ii) written in English, ii) published in a peer-reviewed scientific journal, iii) conducted in outfield players, v) investigations relating anthropometric and physical fitness variables to match running demands (official and/or friendly matches; relationships expressed in correlation coefficients [r]). Conference abstracts, dissertations, theses, narrative reviews, systematic reviews, meta-analyses, and articles published in non-peer reviewed journals were excluded. A flow chart of the literature search and selection is presented in Figure 1. Two researchers (RA, LHPV) separately conducted the literature search to assess the risk of bias, according to the PRISMA recommendation [31]. Inter-rater agreement was evaluated by Cohen's kappa coefficient (*k*), and the agreement rate was $k = 0.96$.

### 2.3 Data extraction

Information on the characteristics of populations in the articles included: sample size, playing standard (i.e., professional, youth academy), playing position (central/external defender, central/external midfielders, and forwards), age, age group (e.g., U15, U17), height, body mass and maximal oxygen uptake ($\dot{V}O_{2MAX}$). In addition, methodological descriptors reported in each article were provided in detail. These included: anthropometric variables, laboratory/field tests, match analyses (i.e., number of matches, match context [official, friendly], technology [video-based time-motion, GPS, video-computerized, semi-automatic, image recognition system], and running categories based on speed thresholds). Field tests were characterized as tests performed in field conditions (e.g., Yo-Yo Intermittent Recovery Test [Yo-Yo IR]).

Finally, the magnitudes of the relationships (expressed as correlation and determination coefficients [r and $r^2$, respectively]) between anthropometric data, physical fitness and match running demands were extracted in each paper. In accordance with a previous systematic review [30], results presented as figures (e.g., column graphics) were run through a specific routine ('ginput.m' function) custom-written in the MATLAB® environment (The MathWorks Inc., Natick, USA) to perform a more accurate extraction of the data.

### 2.3 Methodological quality assessment

A methodological assessment was performed for each included paper according to previous studies [23, 30, 33]. Here, an adapted version of this scoring system was applied (Table 1). Seven questions (Q1 to Q7) were answered with a three-point scale ("yes" = 2 points; "maybe" = 1 point; "no" = 0), except for Q4. The sums of the points for all questions (0 – 14 points) represent the methodological quality rating. In addition, the values were converted into a percentage scale. The threshold for methodological quality scores considered to be appropriate was > 75% [31].

**Table 1.** Methodological quality assessment system (adapted from: Bishop, Tuner [33] [a]; Castellano, Alvarez-Pastor [23][b]).

| | Question | Answer | Score |
|---|---|---|---|
| Q1 | The aim(s) of the study(ies) is/are clearly set out | Yes = 2; Maybe = 1; No = 0 | 0 – 2 |
| Q2 | Characteristics of the participants are presented (level, country, position, age, height, body mass) | Yes = 2; Maybe = 1; No = 0 | 0 – 2 |
| Q3 | Match analysis information [including four items: i) number of matches; ii) match category (context); iii) technology and; iv) match running demands] | Yes = 2; Maybe = 1; No = 0 | 0 – 2 |
| Q4 | The reliability/validity of the time-motion system/equipment is: i) not stated; ii) mentioned (i.e., a citation of previous study(ies)) or; iii) measured under local conditions where data collections took place | Measured = 2; Mentioned = 1; Not stated = 0 | 0 – 2 |
| Q5 | The duration of players recordings and/or inclusion criteria (an entire half-time, a whole match, a certain percentage, etc.) is clearly indicated | Yes = 2; Maybe = 1; No = 0 | 0 – 2 |
| Q6 | Results detailed (e.g. mean and standard deviation, correlation/determination coefficients) | Yes = 2; Maybe = 1; No = 0 | 0 – 2 |
| Q7 | Conclusions insightful (clear, practical applications, and future directions) | Yes = 2; Maybe = 1; No = 0 | 0 – 2 |
| Total | | | 0 – 14 |

Note: Strict rules applied to Q2 (0 – 2 items described = 0; 3 – 4 items described = 1 point; 5 – 6 items described = 2 points); Q3 (0 – 1 item described = 0; 2 – 3 items described = 1 point; 4 items described = 2 points); and Q6 (none information = 0; mean and standard deviation and correlation coefficients (r) = 1; also included determination coefficients = 2).

[a] Effects of inter-limb asymmetries on physical and sports performance: a systematic review, Chris Bishop, Anthony Turner and Paul Read, Journal of Sports Sciences, Published online 02 Aug 2017, Taylor & Francis Ltd publisher, reprinted by permission from Copyright Clearance Center Inc on Taylor and Francis's behalf.

[b] Reprinted by permission from Springer Nature Terms and Conditions for Rights Link Permissions Springer Nature Customer Service Center GmbH: Springer Nature publisher, Sports Medicine, Evaluation of Research Using Computerised Tracking Systems (Amisco® and Prozone®) to Analyse Physical Performance in Elite Soccer: A Systematic Review, Juan Castellano, David Alvarez-Pastor and Paul S. Bradley, Copyright Springer International Publishing Switzerland, 2014.

### 2.4 Statistical analysis

This study concatenated correlation coefficients from seven datasets that assessed the total distance covered and nine datasets that assessed high-intensity running distance during match-play. The correlation coefficients were used as effect sizes in a meta-analysis across each of these datasets. The random-effect DerSimonian-Laird (DSL) approach was employed [34]. In this approach, correlations are first transformed using Fishers z-transformation. However, after fitting this model these z-values were transformed back to the correlation coefficient to plot effect sizes. The 'metacor' package [35] within R [36] was utilised to perform the meta-analysis. A network creation for bibliometric analyses using the software Gephi (version 0.9.2) was performed according to that employed in a previous study [37].

## 3 Results

### 3.1 Search results

An initial search resulted in 12447 articles (Figure 1). Following removal of duplicates, inspection of title/abstracts, and review of the full-text articles for inclusion in the systematic review and meta-analysis, a total of 27 studies fulfilled all criteria. Studies excluded were those that did not meet individual criteria, or examined other team sports (e.g., futsal, rugby) and unsuitable populations (e.g., referees).

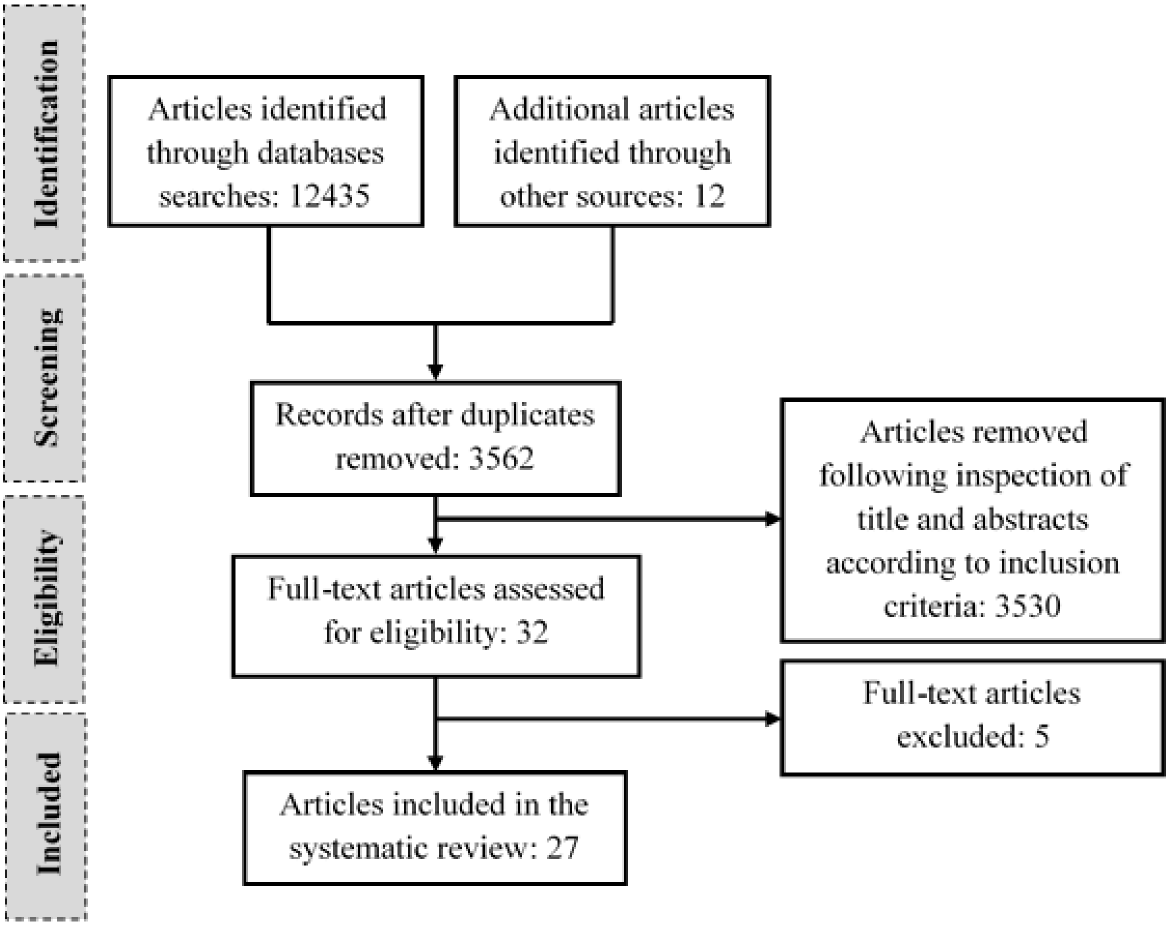


**Figure 1.** Flow chart of the literature search and articles selection.

### 3.2 Methodological quality

Quality ratings are shown in Table 2, with a mean score (standard deviation) of 11.0 (1.6), which is equivalent to 78.6% (11.2). Question 4 (Q4) presented the lowest individual mean, 1.0 (0.6), while questions 1, 6, and 7 presented the highest, 1.9 (0.3 to 0.4). Approximately two-thirds of the papers (63%; n = 17 publications) reached appropriate methodological quality scores (>75 %). Scores for the articles ranged from 57.1% (England and Denmark [38]) to several attaining 92.9% (one study in Qatar [39]; one in the United Kingdom [40]; one in Brazil [16]; and two in Italy [17, 41]).

**Table 2.** Results of methodological quality assessment of the 27 included studies.

| Included Studies | Year | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Total (∑) | Quality Score (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Doncaster, Marwood [40] | 2016 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 13 | 92.9 |
| Bellistri, Marzorati [41] | 2017 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 13 | 92.9 |
| Al Haddad, Simpson [39] | 2015 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 13 | 92.9 |
| Aquino, Palucci Vieira [16] | 2018 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 13 | 92.9 |
| Rago, Silva [17] | 2018 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 13 | 92.9 |
| Rienzi, Drust [51] | 2000 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 12 | 85.7 |
| Krustrup, Mohr [13] | 2003 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 12 | 85.7 |
| Buchheit, Mendez-Villanueva [15] | 2010 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 12 | 85.7 |
| Carling, Le Gall [18] | 2013 | 2 | 1 | 2 | 1 | 2 | 2 | 2 | 12 | 85.7 |
| Mendez-Villanueva, Buchheit [43] | 2013 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 12 | 85.7 |
| Buchheit and Mendez-Villanueva [46] | 2014 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 12 | 85.7 |
| Rebelo, Brito [14] | 2014 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 12 | 85.7 |
| Fernandes-da-Silva, Castagna [12] | 2016 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 12 | 85.7 |
| Bangsbo and Lindquist [10] | 1992 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 11 | 78.6 |
| Krustrup, Mohr [52] | 2005 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 11 | 78.6 |
| Castagna, Manzi [11] | 2010 | 2 | 2 | 2 | 2 | 0 | 2 | 2 | 11 | 78.6 |
| Aslan, Acikada [45] | 2012 | 2 | 2 | 2 | 0 | 2 | 2 | 2 | 11 | 78.6 |
| Rampinini, Bishop [9] | 2007 | 2 | 2 | 2 | 0 | 0 | 2 | 2 | 10 | 71.4 |
| Manzi, Impellizzeri [42] | 2014 | 2 | 2 | 2 | 1 | 0 | 2 | 2 | 10 | 71.4 |
| Rago, Pizzuto [49] | 2017 | 2 | 2 | 2 | 0 | 0 | 2 | 2 | 10 | 71.4 |
| Bradley, Carling [50] | 2013 | 2 | 0 | 1 | 1 | 1 | 2 | 2 | 9 | 64.3 |
| Bradley, Bendiksen [53] | 2014 | 1 | 0 | 1 | 1 | 2 | 2 | 2 | 9 | 64.3 |
| Abt and Lovell [48] | 2009 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 9 | 64.3 |
| Castagna, Impellizzeri [7] | 2009 | 2 | 2 | 1 | 1 | 0 | 2 | 2 | 9 | 64.3 |
| Sporiš, Dujić [54] | 2017 | 2 | 1 | 2 | 0 | 1 | 2 | 1 | 9 | 64.3 |
| Redkva, Paes [47] | 2018 | 2 | 1 | 1 | 0 | 2 | 2 | 1 | 9 | 64.3 |
| Bradley, Mohr [38] | 2011 | 2 | 0 | 1 | 1 | 0 | 2 | 2 | 8 | 57.1 |
| **Mean (standard deviation)** | **-** | **1.9 (0.3)** | **1.6 (0.7)** | **1.8 (0.4)** | **1.0 (0.6)** | **1.3 (0.8)** | **1.9 (0.4)** | **1.9 (0.3)** | **11.0 (1.6)** | **78.6 (11.2)** |

## 3.3 Research Paradigm

*3.3.1 General Information.* In total, there were 991 participants obtained from the 27 articles including 964 males and 27 females and 687 youth (U-8 to U-19), and 304 professional players (range of mean ages: 22.3–29.4 years). Of the total, 239 were defenders (i.e., central defenders, fullbacks, and/or external defenders), 257 were midfielders (i.e., central midfielders, external midfielders), and 158 were forwards. The mean sample size across studies was ~ 37 players per study (range: 9 to 180). General information regarding players is summarized in Supplemental File 1.

According to the yearly distribution frequency of publications, a progressive increase was observed over the current decade (2009–2018: 22 articles) compared to previous years (1992–2008: 5 articles). The majority of the studies were conducted on the European continent (70%), following by South America (7%), and Asia (4%). Five articles did not report the location where the investigation took place (19%). In addition, Figure 2 showed the network interaction between the 97 authors emergent from the topic reviewed in this study. The authors with the most interactions across publications were: P. Krustrup, M. Mohr, P. Bradley, J. Bangsbo, A. Gomez, M. Bendiksen, C. Castagna, F. Impellizzeri, C. Carling, A. Mendez-Villanueva, M. Buchheit, B. M. Simpson, C. Barnes, and P. Hood.

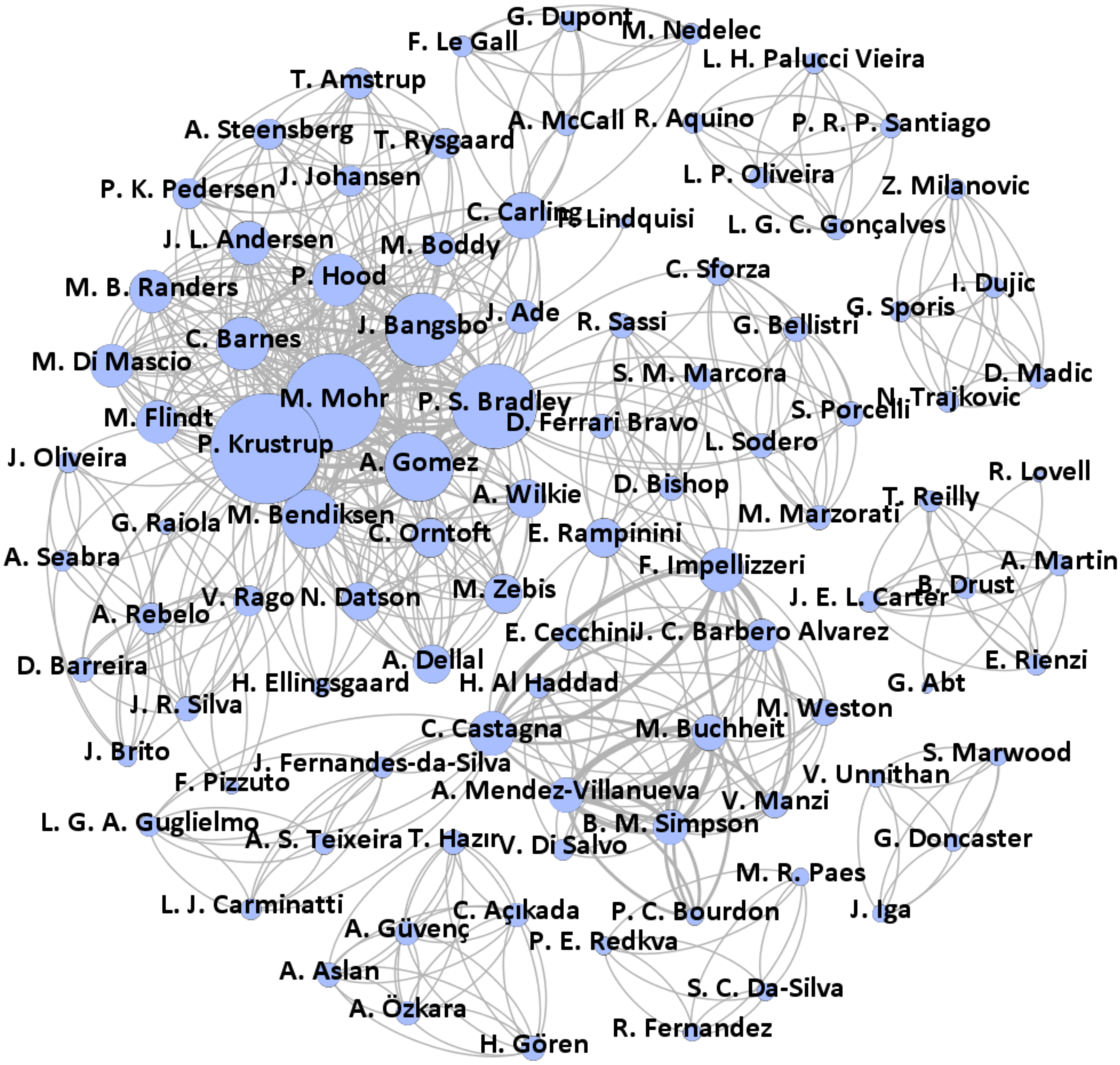


**Figure 2.** Clustered network of authorship within 97 authors that published on associations between match running demands and anthropometric and physical fitness characteristics.

*3.3.2 Match running demands.* The large majority of papers (26/27) assessed physical performance in match-play by measuring running variables such as total distance covered and distance covered at different running intensities. The remaining study [42] utilized the metabolic power approach which accounts for the increased energy expenditure when performing acceleration and deceleration actions (in watts per kilogram). Regarding sample size, studies analyzed from as few as 2 matches (e.g., [12]) to a maximum of 42 matches [15, 43]. Only three studies [15, 39, 43] respected the recommendation of Gregson, Drust [44] that a sample size of at least 80 players is required for studies on match-play running performance. Of the matches analyzed for physical performance, five were friendly [12, 40, 45-47] and the remainder were official in nature. Four studies included home [10, 42, 48] or away matches [16, 48].

With the exception of Manzi, Impellizzeri [42], all studies reported the total distance covered during matches. Running intensities were delimited differently among studies. For example, the lower and upper threshold values for high-intensity running (HIR) in youth players ranged from 13.00-16.00 $km{\cdot}h^{-1}$ [15, 16] to 19.00-22.00 $km{\cdot}h^{-1}$ [49], respectively. In professional players, values of > 14.4 $km{\cdot}h^{-1}$ [9, 38] to 19.8-25.1 $km{\cdot}h^{-1}$ [50] were observed. Only three papers [43, 45, 48] utilized personalized speed zone delimitations for individual players (speed zones derived from laboratory/field tests). Rienzi, Drust [51] did not report the intensities used to formulate zones.

*3.3.3 Analysis techniques.* Manual video-based time-motion analysis was used in six papers [10, 13, 14, 38, 51, 52] while nine used computerized video image recognition systems, such as ProZone® [9, 38, 48, 50], SICS® [42], DVIDEOW® [16], Amisco Pro® [18, 53], or Mathball Match Analysis Systems [45]. Twelve studies used GPS to assess match-play running performance. Of these, the sampling frequency of devices was either

1 Hz [7, 11, 39, 43, 46], 10 Hz [12, 40, 41], or 15 Hz [17, 49]. Furthermore, previous studies also investigated player accelerations and decelerations in match-play using the accelerometer incorporated into a GPS unit (100 Hz frequency; [7, 11, 17]). Further details on these issues are described in Supplemental File 2.

*3.3.4 Anthropometric testing.* Across studies, only three researchers related anthropometric data to match running performance [46, 51, 54]. In professional male players, Rienzi, Drust [51] showed that total body mass and muscle mass were both correlated with total distance covered during the matches ($r^2$ = 18-28%). Sporiš, Dujić [54] reported negative significant relationships between subscapular skinfold with total distance ($r^2$ = 14%), high-intensity running (13-18 $km \cdot h^{-1}$: $r^2$ = 15%), and sprinting (> 18 $km \cdot h^{-1}$: $r^2$ = 15%) in youth players. In elite youth players, Buchheit and Mendez-Villanueva [46] reported small correlations between match running performance and age, maturation status, and body size for central defenders ($r^2$ = 4-16%). In contrast, the majority of variables associated with high-intensity match running performance, including the frequency of single and repeated high-intensity actions (> 19.0 $km \cdot h^{-1}$), were correlated with maturation status and body size in both midfielders and forwards ($r^2$ = 9-36%).

*3.3.5 Laboratory-based tests.*

*Youth players:* Using data derived from an incremental treadmill test, Rebelo, Brito [14] found that players' $\dot{V}O_{2max}$ was moderately associated ($r^2$ = 20%) with match-play high-intensity running performance (13.0-18.0 $km \cdot h^{-1}$). Doncaster, Marwood [40] examined $\dot{V}O_2$ kinetics (i.e., oxygen uptake rates) during a step transition, work-to-work protocol (for more details see Nyberg, Fiorenza [55]), and observed a negative association ($r^2$ = 41%) with both total distance covered and high-intensity running (> 50% maximal linear speed).

*Professional:* In professional-standard players, match performance (i.e., distance covered) was associated with a number of physiological and field-performance test measures including blood lactate concentration, running time, and $\dot{V}O_{2max}$. Bangsbo and Lindquist [10] reported that total distance covered in matches by professional male players was moderately related to 3 mmol·L$^{-1}$ blood lactate concentration ($\dot{V}O_{2\text{-LAC3}}$), and mean $\dot{V}O_{2max}$ ($r^2$ = 40%) during a continuous treadmill test ($r^2$ = 33%). This finding was later supported by Krustrup, Mohr [13] in different professional players. Large correlations were reported between high-intensity running (18 km·h$^{-1}$) and distance covered in an incremental treadmill test or $\dot{V}O_{2max}$ obtained using a different protocol (∑0-90 min: $r^2$=67% and 65%, respectively) [52]. Using an alternative laboratory protocol, Abt and Lovell [48] found that high-intensity running — based on individual second ventilatory threshold ($VT_{2speed}$) — was negative moderately correlated to absolute $\dot{V}O_{2max}$ ($r^2$=46%). The distance run by players at high-intensity was related to absolute $\dot{V}O_{2max}$ regardless of whether an arbitrary defined high-speed zone used in the ProZone® match analysis software ($r^2$ = 50%) or individual $VT_{2speed}$ data ($r^2$=50%) were used. Importantly, the authors reported that the speed classed as high-intensity running using the individualized $VT_{2speed}$ approach (median: 15 km·h$^{-1}$) was 24% lower than the default arbitrary speed zone delimitation used by ProZone® (19.8 km·h$^{-1}$).

*3.3.6 Field-based tests.*

*Youth players:* Several field measures were linked to in-match running performance. Aquino, Palucci Vieira [16] observed moderate relationships ($r^2$ = 17-22%) between running profiles and the Zig-Zag (i.e., change-of-direction ability), running-based anaerobic sprint (i.e., RAST), and Yo-Yo IR level 1 tests. Players achieving higher performance in the Yo-Yo IR level 1 test covered more total distance ($r^2$=0.42) and ran more at high-intensities (> 13.0 km·h-1; $r^2$=59%) [7]. Specifically, performance in the Yo-Yo IR level 1 test was associated with high-intensity running (13.0-18.0 km·h-1; $r^2$=42%), sprinting (> 18.0 km·h-1; $r^2$=57%,), and all high-speed activity (> 13.0 km·$h^{-1}$; $r^2$=53%) [11]. Multistage fitness also correlated with high-intensity (13.0-18.0 km·$h^{-1}$) and sprinting (> 18.0 km·$h^{-1}$) distance and with these two variables combined ($r^2$ ranging from 49 to 56%). In contrast, performance in the Hoff Test (running test incorporating the ball) was only related to sprinting distance ($r^2$=49%) [11].

Rebelo, Brito [14] observed a stronger correlation between high-intensity running (13.0-18.0 km·$h^{-1}$) and values derived from the Yo-Yo IR level 1 ($r^2$=31%) compared to the Yo-Yo IR level 2 ($r^2$=20%) test. Fernandes-da-Silva, Castagna [12] reported moderate-to-very large associations between peak speed values derived from the Carminatti test and distance covered overall ($r^2$=22%) and that in high-intensity running (13.0-18.0 km·$h^{-1}$; $r^2$=43%), sprinting (> 18.0 km·$h^{-1}$; $r^2$=38%), and high-intensity and sprint activities combined (> 13.0 km·$h^{-1}$; $r^2$=60%).

Aslan, Acikada [45] observed moderate relationships between running speeds at fixed lactate concentrations and the total distance covered in competition ($r^2$ = 23-32%). Moreover, the magnitude of the coefficients gradually increased, starting from the running speed corresponding to an intensity > 4 mmol·$L^{-1}$ lactate and reached its highest level at the running speed corresponding to an intensity > 6.5 mmol·L$^{-1}$. However, the relationship between running speeds at fixed lactate concentrations and high intensity-running (> 18.0 km·h$^{-1}$) was not significant. In addition, no significant relationships were observed between $\dot{V}O_{2MAX}$ and total distance travelled.

Previous studies showed that field test (e.g., Yo-Yo IR1 and IR2) and running performance correlations were dependent upon player's position. For example, Buchheit, Mendez-Villanueva [15] reported the strongest correlations between fitness measures and forward positions while poor or non-significant associations were observed for central defenders, fullbacks, midfielders, and external midfielders. Only in forward players, maximal aerobic speed (MAS) was correlated with the total distance covered in matches ($r^2$ = 26%) [43].

Finally, Al Haddad, Simpson [39] reported that maximal sprinting speed was correlated with absolute peak match speed ($PMS_{Abs}$) ($r^2$ = 48%). These correlations varied according to age group; from moderate for U-17's ($r^2$ = 14%) to very large for U-14's ($r^2$ = 50%). These also varied across playing positions; partial correlations between maximal sprinting speed and $PMS_{Abs}$ (i.e., adjusted by age) were highest for external midfielders ($r^2$ = 49%) and lowest for central midfielders ($r^2$ = 16%).

*Professional:* In professional male players, match performance was also associated with a number of field test measures. For example, work by Bangsbo and Lindquist [10] showed that running time in a continuous exhaustion field test was negatively associated ($r^2$ = 46%) with the total distance covered in matches. Krustrup, Mohr [13] reported correlations between Yo-Yo IR level 1 and total distance covered ($r^2$ = 28%), high-intensity running (15-18 km·h$^{-1}$; $r^2$ = 50%), and total high-intensity activities (> 18 km·h$^{-1}$; $r^2$ = 33%). Rampinini, Bishop [9] reported an association between peak speed attained in an incremental field test and total distance covered ($r^2$ = 33%), high-intensity running (> 14.4 km·h$^{-1}$; $r^2$=43%), and very high-intensity running (> 19.8 km·h$^{-1}$; $r^2$ = 41%). The authors also observed an association between mean sprint time in a repeated sprint ability test and very high-intensity running ($r^2$ = 36%) and sprinting (> 25.2 km·h$^{-1}$; $r^2$ = 42%) distance.

As highlighted in youth players, the relationship between field-based fitness tests and match running performance was also dependent upon playing position in professional players. For instance, Bradley, Mohr [38] observed relationships between Yo-Yo IR level 2 performance and total distance covered ($r^2$ = 55%), high-intensity (> 14.4 km·h$^{-1}$; $r^2$ = 37%), and very high-intensity running activity (> 18.0 km·h$^{-1}$; $r^2$ = 31%) in match-play. However, these correlations were only significant in central defenders and forwards, and not midfielders and fullbacks. Positive correlations were observed between Yo-Yo IR level 2 performance and total distance and distance covered at high-intensity (19.8-25.1 km·h$^{-1}$) in both Premier League ($r^2$ = 37%, $r^2$ = 29%, respectively) and Championship ($r^2$ = 31%, $r^2$ = 41%, respectively) players [50].

According to the potential relationships between physical fitness and declines in match running performance, work by Carling, Le Gall [18] demonstrated that criterion measures from tests of aerobic fitness (maximal aerobic speed) and repeated sprint ability did not accurately depict a player’s capacity to resist fatigue (measured using decreases in running activity across match intervals) during professional male soccer competition ($r^2$ = 0.09-38%). Additional research is necessary to confirm this finding.

In professional female players, Yo-Yo IR level 1 results were related to the total distance covered ($r^2$ = 31%) and that travelled in high-intensity running during matches (∑0-90 min, $r^2$ = 57%; ∑30-45 and 75-90 min, $r^2$ = 69%) [52]. Bradley and colleagues [53] analyzed the same relationships (i.e. Yo-Yo level 2 x Match running performance) in female professional soccer players and reported moderate-to-large correlations with total and high-intensity running (> 15.0 km·h$^{-1}$) covered during matches ($r^2$ = 30%, $r^2$ = 49%, respectively). The authors also observed moderate associations with high-intensity activities at various speed zones (18.0-27.0 km·h$^{-1}$; $r^2$ = 34-42%).

*3.3.7 Meta-analysis*. According to the main findings of the reviewed articles, ~19% of the studies had "not fully reported", 26% "not reported", and 56% "reported" substantial relationships between anthropometric data and physical fitness with running demands during match-play (i.e., construct validity) (Table 3).

Due to an insufficient number of datasets, it was only possible to perform a meta-analysis for studies that related Yo-Yo IR level 1 and 2 performance to high-intensity running and total distance covered during match play. Yo-Yo IR level 1 was associated with a higher output in high-intensity running in all datasets, with transformed Fisher-z values ranging from 0.50 to 1.02 (Figure 3A). The mean effect size (Fisher-z value) was 0.79 and differed significantly from zero ($p < 0.001$). The Yo-Yo IR level 2 x high-intensity running presented transformed Fisher-z values ranging from 0.48 to 1.05 (Figure 3B), and the mean effect size was 0.68 ($p < 0.001$). These results leading to the rejection of no effect and leads to the conclusion that high-intensity running during match-play can be predicted in part from Yo-Yo IR level 1 and level 2 performance, with a greater power of prediction for the level 1 compared to the level 2. In contrast, Yo-Yo IR level 1 (z-value range: 0.51 to 0.78; z-value mean: 0.63; $p < 0.001$; r-value mean: 0.56; Figure 3C) presented a lower power of prediction for the total distance covered during the matches compared to Yo-Yo IR level 2 (z-value range: 0.51 to 0.95; z-value mean: 0.82; $p < 0.001$; r-value mean: 0.68; Figure 3D).

**Table 3.** The main findings emerging from the articles addressed in this systematic review and meta-analysis.

| Included Studies | Main Conclusions | Do the studies indicate a construct validity of anthropometric data and physical fitness? |
|---|---|---|
| Bangsbo and Lindquist [10] | The interval field test can be used to evaluate long term, intermittent exercise performance and perhaps to test the endurance performance of soccer players | Yes |
| Rienzi, Drust [51] | Relationships between anthropometric data and match running performance are complex due to the interaction between the independent variables (e.g. team formation) that determine running demands during soccer match-play | No |
| Krustrup, Mohr [13] | The Yo-Yo IR 1 test was a valid measure of match running performance in soccer | Yes |
| Krustrup, Mohr [52] | The TD by HIR during match-play is closely related to the physical fitness and the Yo-Yo IR can be used as an indicator of the match running performance of elite female players | Yes |
| Rampinini, Bishop [9] | The results study gives empirical support to the construct validity of RSA and incremental running tests as measures of match running performance in top-level professional soccer players | Yes |
| Abt and Lovell [48] | A negative large relationship between absolute maximum oxygen uptake and the HIR calculated using second ventilatory threshold speed were observed | Not fully reported |
| Castagna, Impellizzeri [7] | The Yo-Yo IR1 test may be regarded as a valid test to assess match running demands and guide training prescription in male young soccer players | Yes |
| Castagna, Manzi [11] | The Yo-Yo IR1 and MSFT tests may be regarded as valuable tests to assess match running performance and subsequently guide training prescription in young soccer players | Yes |
| Buchheit, Mendez-Villanueva [15] | In highly trained young soccer players, the importance of physical fitness as a determinant of match running performance should be regarded as a function of playing position | No |
| Bradley, Mohr [38] | The Yo-Yo IR2 test was shown to be a sensitive tool that not only relates to match running performance but can also differentiate between intermittent exercise performance of players in various standards, stages of the season and playing positions | Yes |
| Aslan, Acikada [45] | It can be suggested that fixed blood lactate concentrations are not a valid predictor of physical performance in match play | No |
| Bradley, Carling [50] | Large magnitude and significant relationships were observed between Yo-Yo IR2 test performances and the TD and HIR | Not fully reported |
| Carling, Le Gall [18] | Criterion measures from tests of aerobic fitness and repeated sprint ability might not accurately depict a player's capacity to resist fatigue during professional soccer competition | No |
| Mendez-Villanueva, Buchheit [43] | There was a significant, negative, large-to-very large correlation between MAS and the distance run at speeds above MAS for all positions except forwards. The reduction in distance covered below MAS ($1^{st} > 2^{nd}$ half) was not related to a player's physical capacity | Not fully reported |
| Bradley, Bendiksen [53] | The Yo-Yo IE2 test is an indicator of the match running performance of female soccer players | Yes |
| Buchheit and Mendez-Villanueva [46] | The magnitude of the relationships between age, maturation and body dimensions and match running performance were position-dependent in young soccer players | Not fully reported |
| Rebelo, Brito [14] | The Yo-Yo IR1 test appears to be a valid indicator of HIR performance in young soccer players | Yes |
| Manzi, Impellizzeri [42] | The results provide evidence to the construct validity of aerobic fitness in male professional soccer | Yes |
| Al Haddad, Simpson [39] | Regardless of age and playing positions, faster players were likely to reach higher peak match speed (absolute) and possibly lower peak match speed (relative) | Yes |
| Fernandes-da-Silva, Castagna [12] | The study gives empirical support to the construct validity of novel field test (T-CAR) as an indicator of match running performance in young soccer players during pubertal years | Yes |
| Doncaster, Marwood [40] | Measures of oxygen uptake kinetics are related to match running performance | Yes |
| Aquino, Palucci Vieira [16] | The majority of field tests were not related to match running performance in high-level young soccer players | No |
| Bellistri, Marzorati [41] | Data demonstrate large magnitude relationships between match play measures (TD, HIR) and physical test performances (20-m shuttle run) | Yes |
| Sporiš, Dujić [54] | The study supports the conclusions that beside the anthropometry advantage, psychological and soccer-specific skills should be considered in the selection of soccer players | No |
| Rago, Pizzuto [49] | Match running performance correlate with the capacity to perform intermittent endurance exercise outside match context | Yes |
| Rago, Silva [17] | The majority of field tests (CMJ, 5-m sprint time, Yo-Yo IR1) were not related (unclear-moderate) to running demands during official matches | No |
| Redkva, Paes [47] | Better results in the Yo-Yo Intermittent Test correlate with TD, number of HIR and sprints during friendly matches. However, it may be concluded that there is no correlation between RSA and friendly match data variables | Not fully reported |

Note: Yo-Yo IR1 = Yo-Yo intermittent recovery test level 1; Yo-Yo IR2 = Yo-Yo intermittent recovery test level 2; TD = Total Distance covered; HIR = High-intensity Running; VHIR = Very High-intensity Running; RSA = repeated-sprint ability; MSFT = Multistage Fitness Test; MAS = Maximal Aerobic Speed.

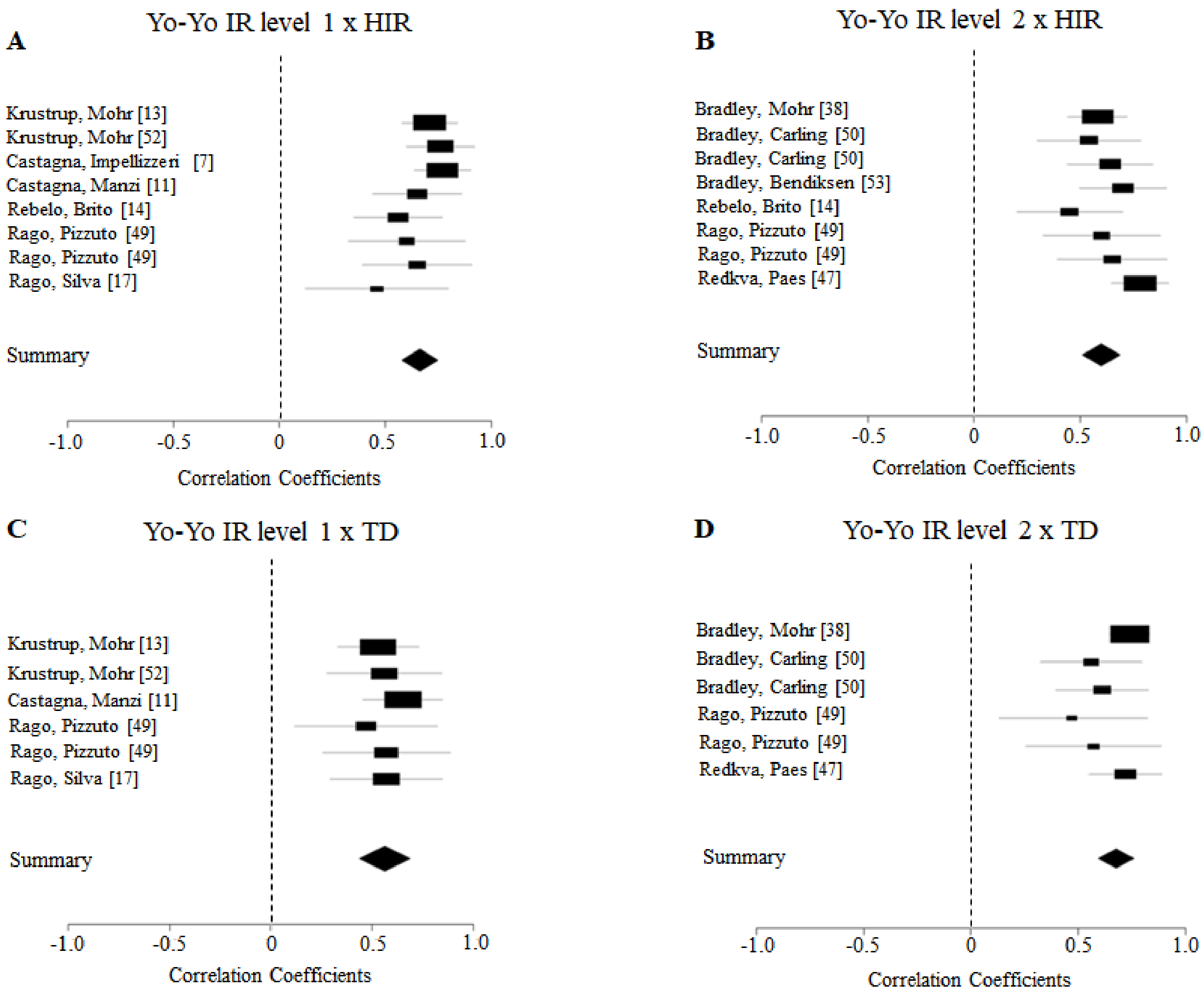


**Figure 3.** Meta-analyses of the effect of Yo-Yo Intermittent recovery level 1 (A and C) and level 2 (B and D) on high-intensity running and total distance covered during the matches. The box size is proportional to the weight given to each study, based on the sample size and variance. Grey lines represent the 95% confidence interval. The dashed grey line represents the null hypothesis. The summary statistic is represented by a black diamond. The width of the diamond represents the 95% confidence interval. Note: Yo-Yo IR = Yo-Yo Intermittent Recovery Test; HIR = High-intensity running; TD = Total Distance covered.

## 4 Discussion

The present systematic review and meta-analysis examined the current literature regarding associations between match running demands and anthropometric and physical fitness variables in soccer players. Main findings were: i) studies generally presented good methodological quality (mean: 78.6%); ii) three studies reported poor relationships between anthropometric measures and running demands during the matches ($r^2$ = 4-36%); however, one study highlighted the importance of considering maturation status when assessing youth players based on their match running performance; iii) six studies in youth and professional soccer players (male and female) employed incremental treadmill tests to assess physical fitness and presented large-to-very large correlations with total distance covered and/or high-intensity running activity during match-play; iv) regarding field tests, meta-analysis showed that Yo-Yo IR1 and IR2 outputs were associated with high-intensity running and total distance travelled in competition (Fisher-z value 0.63 to 0.82); v) only three articles examined the association between physical fitness and declines in running performance across match intervals and observed no substantial relationships [7, 18, 43]; vi) three papers used individually derived speed thresholds (derived from the results of laboratory/field tests) to determine running activity for each player [43, 45, 48]; vii) five studies reported that the relationship between physical fitness and match running performance was playing position-dependent (i.e., the magnitude of correlations expressed different values for defenders, midfielders, and forwards) [15, 38, 39, 43, 49]. Main results are discussed demonstrating their strengths and limitations, and where pertinent, recommendations are given for coaching and sports science practitioners.

### 4.1 Methodological quality

Overall, the reviewed studies presented high methodological quality ratings (approximately 80%). The questions with the greatest mean rating were Q1, Q6, and Q7, demonstrating that the studies' aims were clearly set out, results were detailed, and conclusions were insightful. In contrast, Q4 showed the lowest quality score demonstrating that important characteristics of the time-motion system/equipment used across studies were often insufficiently presented by the authors. Results from a previous study [30] corroborate these findings and future researches should therefore consider these methodological concerns.

### 4.2 Anthropometric testing

Only a few studies (~11% of all papers) investigated the relationships between anthropometric data and match running demands. Overall, the results showed poor associations. Buchheit and Mendez-Villanueva [46] did however highlight in elite youth players that the magnitude of the relationships between age, maturation, body dimensions, and match running performance were position-dependent. As discussed by the authors, while more data on technical and tactical skills are required to draw firm conclusions, the physical advantages of more mature youth players could translate into greater running outputs during matches, especially in midfielders and forwards (for example, high-intensity running distance was moderately-to-largely correlated to maturation status). Therefore, coaches and practitioners should take maturation status into account during the process of development of talented youth players (e.g., allocating more mature players to more physical demanding roles/positions: [46]). In contrast, the current literature does not support the use of anthropometric data to associate and/or predict match running demands in professional players and in our opinion, this observation questions its construct validity and the rationale for its use.

### 4.3 Laboratory-based tests

Incremental treadmill tests (e.g., MAS, $\dot{V}O_{2MAX}$) were employed in six studies and showed large to very-large associations to match-play running demands [10, 13, 14, 18, 48, 52]. However, a range of protocols was used across studies, as such no meta-analysis could be performed to compare results and hence draw conclusions. Indeed, Bentley, Newell [56] highlighted that modification of the stage duration during an incremental treadmill test can influence submaximal and maximal physiological responses (e.g., peak power output is reduced in incremental exercise tests with stages of longer duration). These discrepancies in protocols can influence the relationship of the variables to match running performance and the sensitivity of these results to soccer interventions. In future studies, sport science and coaching practitioners should consider these aspects when conducting incremental treadmill tests to associate and/or predict running performance and for the purposes of training prescription and analysis of the intervention. Ideally, expert-based consensus on protocols used would help enable consistency across the literature.

### 4.4 Field-based tests

The results of meta-analysis presented in this review demonstrate the strong capacity of the Yo-Yo IR to predict high-intensity running (level 1 better than level 2) and total distance covered (level 2 better than level 1) during match-play. In addition, the Yo-Yo IR is one of the few field tests that demonstrates similarity in the distance covered per minute by soccer players (mean duration: 14.7 min; mean distance covered: 1793 m [13];

estimated work-rate ≈ 122 m/min) to that observed during professional soccer matches (e.g., mean distance covered = 10860 m [57]; work-rate ≈ 121 m/min). Furthermore, values for session-RPE (rating of perceived exertion) appear to be quite similar (e.g., Borg 6–20 scale for age-matched players: following completion of the Yo-Yo IR level 1 = 14.18±1.4 arbitrary units [58]; following 90-min match-play = 14.5±1.6 arbitrary units [45]). These advantages (e.g., high specificity) demonstrate that Yo-Yo IR is a useful field test that can be used across the season (see Table 4).

**Table 4.** Specificity, quality assessed, capacity to predict running demands during match-play, prescriptiveness, and overall characteristics of the anthropometric measures and physical fitness tests emergent of the 27 reviewed studies.

| | Tests | Specificity | Quality Assessed | Capacity to predict running demands | Prescriptiveness | Overall |
|---|---|---|---|---|---|---|
| **Anthropometric testing** | Segmental lengths | Very low | -- | ↓ | + | Very poor |
| | Limb girths | Very low | -- | ↓ | + | Very poor |
| | Muscle mass | Very low | -- | ↑ | + | Very poor |
| | Chronological age | Very low | -- | ↓ | + | Very poor |
| | Age from/to peak height velocity | Low* | Maturation | ↑↑ | + | Poor |
| | Standing height | Very low | -- | ↓ | + | Very poor |
| | Height | Very low | -- | ↓ | + | Very poor |
| | Body Mass | Very low | -- | ↑ | + | Very poor |
| **Laboratory-based tests** | Incremental treadmill tests | Low | Aerobic power | ↑↑ | +++ | Good |
| | Running speed at fixed lactate concentration (e.g., 2mM, 4mM) | Low | Aerobic capacity | ↑↑ | ++ | Poor |
| **Field-based tests** | Yo-Yo IR level 1 | High | Aerobic power | ↑↑↑ | ++ | Very good |
| | Yo-Yo IR level 2 | High | Aerobic power | ↑↑↑ | ++ | Very good |
| | Vertical jump (i.e., countermovement and squat jump) | Medium | Lower limb explosive power | ↑ | + | Poor |
| | Repeated-sprint ability | High | Anaerobic power | ↑ | ++ | Good |
| | Multistage fitness test | High | Aerobic power | ↑↑ | ++ | Good |
| | Hoff test | Very high | Aerobic power and technical efficiency | ↑↑ | ++ | Good |
| | 5-m split time | High | Initial acceleration | ↑ | + | Poor |
| | 10-m split time | High | Initial acceleration | ↑ | ++ | Good |
| | 20-m split time | High | Maximal acceleration | ↑ | ++ | Good |
| | 30-m split time | High | Maximal running speed | ↑ | ++ | Good |
| | 40-m split time | Medium | Maximal running speed | ↑ | ++ | Poor |
| | Shorter version of the Vam-eval (see Rampinini, Bishop [9]) | High | Aerobic power | ↑↑ | ++ | Good |
| | Modifield version of the Vam-eval (see Buchheit, Mendez-Villanueva [15]) | High | Aerobic power | ↑ | ++ | Good |
| | Modifield Shutlle Run test (see Aslan, Acikada [45]) | High | Aerobic power | ↑↑ | ++ | Good |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Anaerobic speed reserve (see Mendez-Villanueva, Buchheit [43]) | High | Anaerobic power | ↓ | + | Poor |
| | Progressive long and short-stage running field test (see Manzi, Impellizzeri [42]) | High | Aerobic power | ↑↑ | ++ | Good |
| | Carminatti test | High | Aerobic power | ↑↑ | ++ | Good |
| | Zig-Zag test | High | COD ability | ↑ | + | Poor |

Note: Yo-Yo IR = Yo-Yo Intermittent Recovery Test; COD = Change-of-Direction; -- = Not applied; * = Only one study showed the importance of considering maturation status when assessing youth players based on their match running performance. In professional players, the current literature does not support the useful of anthropometric data to predict running demands during the matches; ↓ = Trivial to small; ↑ = Moderate. However, the number of datasets was insufficient to perform a meta-analysis and thus draw firm conclusions; ↑↑ = Large to very-large. However, the number of datasets was insufficient to perform a meta-analysis and thus draw firm conclusions; ↑↑↑ = Large to very-large. The number of datasets was sufficient to perform a meta-analysis and thus draw firm conclusions. + = Very poor. Can't be used to prescribe training; ++ = Poor. Limited to be used to prescribe training; +++ = Good. Can be used to prescribe training.

Despite these advantages, some concerns about the Yo-Yo IR should nevertheless be highlighted. This field test is incremental in nature and only 180º changes of direction are performed. Indeed, fluctuations in match demands are common [59] and random peak periods of intense activity occur potentially leading to temporary fatigue occurrence across the 90-min of match-play [57], further characterizing soccer as a non-incremental effort.

Recently attempts have been made to develop laboratory [60] and field protocols [61, 62] to simulate match-play conditions by recreating match-play running demands. Manouvrier, Cassirame [63] for example, proposed a soccer specific aerobic test ("Footeval") involving the ball. However, to date, the construct validity of these soccer-specific protocols has not been fully assessed. Similarly, the only study identified in this review that implemented a technical element was the Hoff test. However, this test is performed in a closed environment without the presence of teammates or opponents and presents lower values of reliability (i.e., test vs. retest) compared to Yo-Yo IR level 1 (Hoff test: ICC = 0.68 vs. Yo-Yo IR level 1: ICC = 0.98) [7].

On the basis of the above points, it seems that more ecologically valid field tests are needed to account for the interaction between match physical, technical, and tactical aspects. Related work has investigated the pertinence of a 6-a-side small-sided game as an alternative indicator of fitness [64]. However, physical performance during the 6-a-side game has not yet been associated with physical performance in an 11-a-side competitive match; therefore, construct validity is lacking and additional research is necessary.

### 4.5 Potential relationships between physical fitness and declines in match running performance

Only three of the reviewed studies addressed the relationship between physical fitness and declines in match running activity and observed no substantial relationships ($r^2$ = 0.09-38%) [7, 18, 43]. These results raise doubts on the capacity and pertinence of the physical fitness tests as valid indicators for predicting the ability to resist fatigue represented by a reduction in running output during the matches. Additional factors independent of physical fitness and related to match context may influence the between-half difference in running activities include: i) changes in tactics/playing formation [43]; ii) score-line [24, 65]; iii) effective playing time or time the ball is in play [66]; iv) influence of substitute players [67].

### 4.6 Speed thresholds

The diversity of speed thresholds used across the literature at youth and professional levels makes it difficult to objectively compare findings across investigations. Only three papers employed individually derived speed zone delimitations using the results from field or laboratory tests (e.g., MAS, maximal linear sprint speed) to determine running performance [43, 45, 48]. These studies suggest that individualizing speed thresholds provides a more accurate representation of match running outputs in soccer players [68]. For example, the use of individual speed thresholds can reduce the recognized high variability in individual and position-specific high-speed running activity between and within competitive matches compared to generic arbitrarily defined thresholds [69]. In addition, individual speed zone delimitations are frequently founded on the results from field or laboratory tests of MAS and maximal linear sprint speed. Caution though is necessary as the latter notably, has limitations for establishing match speed thresholds mainly due to peak match speeds potentially exceeding those derived from maximal sprint testing [70]. Therefore, the use of individual speed thresholds according to the percentage of peak match speed rather than maximal sprint testing would be pertinent [30].

### 4.7 Influence of playing position

Playing position and associated tactical roles should be taken into consideration when examining the relationship between physical fitness and match running performance [15]. Yet only five out of the 27 studies examined the association between physical fitness and match running performance relative to playing position [15, 38, 39, 43, 49]. Buchheit, Mendez-Villanueva [15] suggested that physical fitness is a limiting factor in players performing in forward positions. Ideally, future research should group and analyse players according to positional role to enhance assessment of the construct validity of a given test. However, in real-world settings this is difficult due to the small population sizes (e.g., single club) frequently used across studies.

### 4.8 Additional concerns

In this review, only three studies [15, 39, 43] included more than 80 players which is the sample size required to be able to make meaningful inferences of an intervention that utilizes match running performance as an indicator of change in performance [44].

In relation to the experimental designs used in the 27 papers, 19 (~ 70%) were apparently cross-sectional (e.g., [7, 10-12, 14, 16, 40, 48, 51]) while eight were longitudinal in nature [13, 15, 38, 39, 42, 43, 46, 50]. A problem related to the cross-sectional approach is that running performance and physical fitness can differ according to season stage (e.g., pre-season, competitive stages, and off-season periods) and the variations related to physical growth and/or training effects [71] as seen in professional

[57] and youth soccer players [72], respectively. The majority of studies did not verify possible alterations in running activity during match-play across the season in relation to changes in test outcomes. This is important as Buchheit and Mendez-Villanueva [46] used repeated assessments of player physical performance (e.g., data from games played between mid-December and the end of February were allocated to the January testing session) with poor relationships demonstrated. In addition, Buchheit, Simpson [71] verified that changes in running performance during match-play (e.g., repeated-sprint activity) did not necessarily match those in players' physical fitness profiles (assessed through incremental and maximal sprint speed field tests). The authors also suggested that results are position-dependent and the longitudinal improvement (~ 7 months) in match-play running performance could be more accountable to tactical and strategic aspects than changes in physical fitness. Unfortunately, conducting repeated assessments of player physical fitness across the same seasons especially at elite standards is challenging.

As mentioned earlier, numerous contextual issues can influence running performance in match-play. It is of our opinion that these must be better accounted for than currently is the case when relationships between anthropometric variables, physical fitness, and match running demands are investigated. In addition to those mentioned earlier, additional factors include: i) competitive level [73, 74]; ii) geographical location of league [75]; vi) situational variables (e.g., match location, quality of opponents, match outcome/status: [59, 76]); iii) match analysis systems [77, 78]; iv) environmental heat stress [79].

## 5 Conclusions

Overall, anthropometric data presented poor relationships to running demands at youth and senior levels. However, one study with elite youth players showed the importance of considering maturation status when assessing youth players based on their match running performance. Incremental treadmill tests performed in laboratory settings showed large to very-large correlations with total distance covered and/or high-intensity running activity during the matches. However, a range of protocols was used across studies thereby not allowing use of meta-analysis and reducing the strength of conclusions. In contrast, meta-analysis showed the capacity of the Yo-Yo IR to predict high-intensity running (level 1 superior to level 2) and total distance (level 2 superior to level 1) during match-play. According to the potential relationships between physical fitness and declines in match running performance, the results in three reviewed studies raise doubts on the capacity and pertinence of the physical fitness tests as valid indicators for predicting the ability to resist fatigue. In relation to the speed thresholds obtained during time-motion analysis, further studies should use individual speed thresholds according to the percentage of peak match speed rather than fitness testing performance when assessing the relationships between running demands, anthropometric and physical fitness characteristics. Future research using larger sample sizes to aid grouping of players according to positional role would enhance assessment of the construct validity of a given fitness test. Finally, contextual factors (e.g., situational variables, competitive level, and team formation) must be better accounted for when assessing the construct validity of a given test in relation to running performance.

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**Supplemental File 1.** General characteristics of the players.

| Articles | Participants | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sample Size (M/F) | Level | Country | Position | Age (years) | Height (cm or m) | Body Mass (kg) | $\dot{V}O_{2\,MAX}$ $ml \cdot kg^{-1} \cdot min^{-1}$ |
| Bangsbo and Lindquist [10] | 20 (20/0) | Professional | Denmark | Not reported | 2 groups<br>- 8 players: 22.3 ± 1.0<br>- 12 players: 24.9 ± 1.3 | 2 groups<br>- 8 players: 182.9 ± 1.3<br>- 12 players: 182.1 ± 1.5 | 2 groups<br>- 8 players: 76.3 ± 2.6<br>- 12 players: 74.9 ± 2.4 | 2 groups<br>- 8 players: 60.4 ± 1.1<br>- 12 players: 61.2 ± 1.6 |
| Rienzi, Drust [51] | 23 (23/0) | Professional | South American / England | 9 defenders, 10 midfielders, 4 forwards | South American<br>- 17 players: 29 ± 4<br>English<br>- 6 players: 28 ± 3 | 1.77 ± 0.4 | 74.5 ± 4.4 | Not reported |
| Krustrup, Mohr [13] | 37 (37/0) | Professional | Denmark | 9 central defenders, 7 fullbacks, 13 midfielders, 8 forwards | 26 (range: 22-32) | 181 (range: 169-183) | 75.4 (range: 67.5-90.1) | Not reported |
| Krustrup, Mohr [52] | 14 (0/14) | Professional | Denmark | 2 central defenders, 3 fullbacks, 5 midfielders, 4 forwards | 24 (range: 19-31) | 1.67 (range: 1.56-1.80) | 58.5 (range: 49.0-70.7) | 49.4 (range: 43.4-56.8) |
| Rampinini, Bishop [9] | 18 (18/0) | Professional | Not reported | 3 central defenders, 5 fullbacks, 7 central midfielders, 3 forwards | 26.2 ± 4.5 | 181.9 ± 3.7 | 80.8 ± 7.8 | Not reported |
| Abt and Lovell [48] | 10 (10/0) | Professional | England | Not reported | 27 ± 5 | 1.80 ± 0.06 | 79.1 ± 4.7 | 59 ± 4 |
| Castagna, Impellizzeri [7] | 21 (21/0) | Youth Academy | Italy | 7 defenders, 7 midfielders, 7 forwards | 14.1 ± 0.2 | 165 ± 5.1 | 52.5 ± 25 | Not reported |

Note: M = Man; F = Female.

**Supplemental File 1.** Continued.

| Articles | Participants | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sample Size (M/F) | Level | Country | Position | Age (years) | Height (cm or m) | Body Mass (kg) | $\dot{V}O_{2MAX}$ ml · kg$^{-1}$· min$^{-1}$ |
| Castagna, Manzi [11] | 18 (18/0) | Youth Academy | Italy | 6 defenders, 6 midfielders, 6 forwards | 14.4 ± 0.1 | 167 ± 4.8 | 53.6 ± 1.8 | Not reported |
| Buchheit, Mendez-Villanueva [15] | 99 (99/0) | Youth Academy | Not reported | 16 central defenders, 15 fullbacks, 13 midfielders, 13 external midfielders, 20 forwards | U13, U-14, U-15, U-16, U-17, U-18 | U-13 (150 ± 6), U-14 (159 ± 7), U-15 (161 ± 6), U-16 (163 ± 9), U-17 (170 ± 7), U-18 (171 ± 9) | U-13 (39.3 ± 5.1), U-14 (43.9 ± 5.2), U-15 (48.8 ± 9.8), U-16 (52.0 ± 7.2), U-17 (58.1 ± 4.7), U-18 (56.3 ± 7.5) | Not reported |
| Bradley, Mohr [38] | 68 (68/0) | Professional | England and Denmark | Not reported | Not reported | Not reported | Not reported | Not reported |
| Aslan, Acikada [45] | 32 (32/0) | Youth Academy | Turkey | 11 defenders, 15 midfielders, 6 forwards | 17.6 ± 0.58 | 1.78 ± 0.05 | 68.6 ± 5.62 | 51.76 ± 4.18 |
| Bradley, Carling [50] | 43 (43/0) | Professional | England | Not reported | Not reported | Not reported | Not reported | Not reported |
| Carling, Le Gall [18] | 9 (9/0) | Professional | France | Not reported | 26.1 ± 3.0 | 180.1 ± 8.2 | 78.1 ± 8.1 | Not reported |
| Mendez-Villanueva, Buchheit [43] | 103 (103/0) | Youth Academy | Not reported | 15 central defenders, 20 fullbacks, 19 midfielders, 24 external midfielders, 25 forwards | U13, U-14, U-15, U-16, U-17, U-18 | U-13 (149.2 ± 6.8), U-14 (158.3 ± 7.2), U-15 (161.3 ± 7.4), U-16 (164.2 ± 8.1), U-17 (171.5 ± 6.2), U-18 (171.1 ± 9.5) | U-13 (38.2 ± 5.4), U-14 (43.8 ± 5.1), U-15 (48.9 ± 10.1), U-16 (51.1 ± 6.9), U-17 (57.5 ± 4.8), U-18 (56.3 ± 7.5) | Not reported |
| Bradley, Bendiksen [53] | 13 (0/13) | Professional | England | Not reported | Not reported | Not reported | Not reported | Not reported |

Note: M = Man; F = Female.

**Supplemental File 1.** Continued.

| Articles | Participants | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sample Size (M/F) | Level | Country | Position | Age (years) | Height (cm or m) | Body Mass (kg) | $\dot{V}O_{2MAX}$ ml · kg$^{-1}$· min$^{-1}$ |
| Buchheit and Mendez-Villanueva [46] | 36 (36/0) | Youth Academy | Not reported | Not reported | 14.4 ± 0.4 | 163.4 ± 6.2 | 50.5 ± 6.9 | Not reported |
| Rebelo, Brito [14] | 30 (30/0) | Youth Academy | Portugal | 7 central defenders, 7 fullbacks, 8 midfielders, 8 forwards | 15.6 ± 1.4 | 169.5 ± 7.1 | 61.5 ± 12.5 | Not reported |
| Manzi, Impellizzeri [42] | 17 (17/0) | Professional | Italy | 5 defenders, 6 midfielders, 6 forwards | 28.2 ± 2.2 | 182 ± 7.1 | 80 ± 5.4 | Not reported |
| Al Haddad, Simpson [39] | 180 (180/0) | Youth Academy | Qatar | 24 central defenders, 31 external defenders, 30 central midfielders, 37 external midfielders, 33 forwards | U-13, U-14, U-15, U-16, U-17 | 161.5 ± 9.2 | 48.4 ± 8.7 | Not reported |
| Fernandes-da-Silva, Castagna [12] | 33 (33/0) | Youth Academy | Not reported | 7 central defenders, 6 external defenders, 5 central midfielders, 7 external midfielders, 8 forwards | 14.5 ± 0.6 | 168.0 ± 7.4 | 61.5 ± 9.5 | Not reported |
| Doncaster, Marwood [40] | 17 (17/0) | Youth Academy | United Kingdom | 5 defenders, 6 midfielders, 6 forwards | 13.3 ± 0.4 | 1.59 ± 0.11 | 48.9 ± 10.1 | Not reported |
| Aquino, Palucci Vieira [16] | 25 (25/0) | Youth Academy | Brazil | 11 defenders, 10 midfielders, 4 forwards | 15.2 ± 1.0 | 174.0 ± 8.5 | 64.1 ± 7.3 | Not reported |
| Bellistri, Marzorati [41] | 27 (27/0) | Youth Academy | Italy | Not reported | U8 (7.9 ± 0.1) U10 (10.1 ± 0.1) | U8 (1.33 ± 0.01) U10 (1.41 ± 0.01) | U8 (29.1 ± 1.2) U10 (34.1 ± 0.9) | Not reported |
| Sporiš, Dujić [54] | 37 (37/0) | Youth Academy | Croatia | Not reported | 18.4 ± 0.1 | 1.67 ± 4.8 | 53.6 ± 1.8 | Not reported |
| Rago, Pizzuto [49] | 29 (29/0) | Youth Academy | Italy | 12 defenders, 10 midfielders, 7 forwards | U-19 | 177.15 ± 5.30 | 71.96 ± 5.08 | Not reported |
| Rago, Silva [17] | 14 (14/0) | Professional | Italy | 5 defenders, 6 midfielders, 3 forwards | 27.6 ± 3.0 | 179.5 ± 5.0 | 76.8 ± 7.0 | Not reported |
| Redkva, Paes [47] | 18 (18/0) | Professional | Brazil | Not reported | 23 ± 3 | 177 ± 5 | 77.5 ± 8.9 | 56.8 ± 3.9 |

Note: M = Man; F = Female.

**Supplemental File 2.** Methods reported in 27 articles for assessing the association between anthropometric variables, physical fitness and match running demands.

| Articles | Anthropometric variables | Laboratory Tests | Field Tests | Match Analysis | | | |
|---|---|---|---|---|---|---|---|
| | | | | Number of Matches | Match Category (context) | Technology | Match Running Demands |
| **Bangsbo and Lindquist [10]** | Not related to match running demands | Incremental treadmill test | Intermittent endurance test<br>Interval field test<br>Continuous field test | Each of the 20 players was filmed by a separate camera during at least two complete matches | Official (home) | Video-based time-motion analysis | - Total distance covered<br>- Moderate-intensity running (MIR: 15 km·h$^{-1}$)<br>- High-intensity running (HIR: 18 km·h$^{-1}$)<br>- Sprinting (SPR: 30 km·h$^{-1}$)<br>- High-intensity distance (MIR + HIR + SPR) |
| **Rienzi, Drust [51]** | Segmental lengths, limb girths, body composition, muscle mass | Not reported | Not reported | Two players were filmed in each match (one from each side) for South American international matches and one player was filmed per match in the English Premier League | Official (not reported) | Video-based analysis | - Total distance covered<br>- Walking (intensity not reported)<br>- Jogging (intensity not reported)<br>- Cruising (intensity not reported)<br>- Sprinting (intensity not reported) |
| **Krustrup, Mohr [13]** | Not related to match running demands | Incremental Treadmill test | Yo-Yo Intermittent Recovery Test level 1 | 18 soccer matches in the National Premier League | Official (not reported) | Video-based time-motion analysis | - Total distance covered<br>- Standing (0 km·h$^{-1}$)<br>- Walking (6 km·h$^{-1}$)<br>- Jogging (8 km·h$^{-1}$)<br>- Low-intensity running (12 km·h$^{-1}$)<br>- Moderate-intensity running (15 km·h$^{-1}$)<br>- High-intensity running (HIR: 18 km·h$^{-1}$)<br>- Sprinting (SPR: 30 km·h$^{-1}$)<br>- High-intensity activities (HIR + SPR)<br>- Backward sprinting (10 km·h$^{-1}$) |

**Supplemental File 2.** Continued.

| Articles | Anthropometric variables | Laboratory Tests | Field Tests | Match Analysis | | | |
|---|---|---|---|---|---|---|---|
| | | | | Number of Matches | Match Category (context) | Technology | Match Running Demands |
| **Krustrup, Mohr [52]** | Not related to match running demands | Incremental treadmill test, running speed at 2mM lactate | Yo-Yo Intermittent Recovery Test level 1 | 4 soccer matches in the best Danish League | Official (not reported) | Video-based time-motion analysis | - Total distance covered<br>- Standing (0 $km \cdot h^{-1}$)<br>- Walking (6 $km \cdot h^{-1}$)<br>- Jogging (8 $km \cdot h^{-1}$)<br>- Low-intensity running (12 $km \cdot h^{-1}$)<br>- Moderate-intensity running (15 $km \cdot h^{-1}$)<br>- High-intensity running (HIR: 18 $km \cdot h^{-1}$): ∑ 0-90; ∑ epoch of 15-min (e.g., 0-15, 15-30, 30-45)<br>- Sprinting (25 $km \cdot h^{-1}$)<br>- Backward sprinting (10 $km \cdot h^{-1}$) |
| **Rampinini, Bishop [9]** | Not related to match running demands | Not reported | Vertical jump, incremental field test, repeated-sprint ability test | 2-3 soccer matches | Official (not reported) | Video-computerized, semi-automatic, image recognition system (ProZone®) | - Total distance covered<br>- High-intensity running ( > 14.4 $km \cdot h^{-1}$)<br>- Very high-intensity running ( > 19.8 $km \cdot h^{-1}$)<br>- Sprinting ( > 25.2 $km \cdot h^{-1}$) |
| **Abt and Lovell [48]** | Not related to match running demands | Incremental treadmill test | Not related to match running demands | 3 soccer matches | Official (2 home, 1 away) | Video-computerized, semi-automatic, image recognition system (ProZone®) | - Very high-intensity running ( > 19.8 $km \cdot h^{-1}$)<br>- After determining the second ventilatory threshold for each player, the associated treadmill speed at that point was taken as the high-intensity speed threshold ($VT_{2speed}$)<br>- After the distance run at very high-intensity running (> 19.8 $km \cdot h^{-1}$), the data were recalculated for each player using $VT_{2speed}$. |
| **Castagna, Impellizzeri [7]** | Not related to match running demands | Not reported | Yo-Yo Intermittent Recovery Test level 1 | Not reported | Official (not reported) | Global Positioning System (GPS, 1 Hz), triaxial built-in accelerometer (100 Hz) | Determined according to Castagna, D'Ottavio [80]<br>- Total distance covered<br>- Standing (0-0.4 $km \cdot h^{-1}$)<br>- Walking (0.4-3.0 $km \cdot h^{-1}$)<br>- Jogging (3.0-8.0 $km \cdot h^{-1}$)<br>- Moderate-intensity running (8.0-13.0 $km \cdot h^{-1}$)<br>- High-intensity running (HIR: 13.0-18.0 $km \cdot h^{-1}$)<br>- Sprinting (SPR: > 18.0 $km \cdot h^{-1}$)<br>- High-intensity activity (HIA: HIR+SPR) |

**Supplemental File 2.** Continued.

| Articles | Anthropometric variables | Laboratory Tests | Field Tests | Match Analysis | | | |
|---|---|---|---|---|---|---|---|
| | | | | Number of Matches | Match Category (context) | Technology | Match Running Demands |
| **Castagna, Manzi [11]** | Not related to match running demands | Not reported | Yo-Yo Intermittent Recovery Test level 1, Multistage Fitness test, Hoff test | 2-4 soccer matches | Official (not reported) | Global Positioning System (GPS, 1 Hz), triaxial built-in accelerometer (100 Hz). Both of the SPI Elite, GPSports, Canberra, Australia | Determined according to Castagna, D'Ottavio [80], such as aforementioned |
| **Buchheit, Mendez-Villanueva [15]** | Not related to match running demands | Not reported | Counter-movement jump, acceleration (10-m split time), peak running speed (40-m split time), repeated-sprint ability test, incremental field test | 42 matches against international club teams | Official (elite of the opposing teams and the same competition format) | Global Positioning System (GPS, 1 Hz, SPI Elite, GPSports, Canberra, Australia) | - Total distance covered<br>- Low-intensity running ( < 13.0 km·h$^{-1}$)<br>- High-intensity running (HIR: 13.1-16.0 km·h$^{-1}$)<br>- Very high-intensity running (VHIR: 16.1-19.0 km·h$^{-1}$)<br>- Sprinting (SPR: > 19.1 km·h$^{-1}$)<br>- High-intensity activities (HIA: VHIR+SPR) |
| **Bradley, Mohr [38]** | Not related to match running demands | Not related to match running demands | Yo-Yo intermittent Recovery Test level 2 | Not reported | Official (not reported) | Video-based time-motion analysis | - High-intensity running (> 14.4 km·h$^{-1}$)<br>- Very high-intensity running (> 18.0 km·h$^{-1}$) |
| **Aslan, Acikada [45]** | Not related to match running demands | Not related to match running demands | Modified Shuttle Run Test | 4 soccer matches | Friendly (not reported) | Video-computerized, image recognition system (Mathball Match Analysis Systems®) | - Total distance covered<br>- High-intensity running (> 18.0 km·h$^{-1}$) |

**Supplemental File 2.** Continued.

| Articles | Anthropometric variables | Laboratory Tests | Field Tests | Match Analysis | | | |
|---|---|---|---|---|---|---|---|
| | | | | Number of Matches | Match Category (context) | Technology | Match Running Demands |
| **Mendez-Villanueva, Buchheit [43]** | Not related to match running demands | Not reported | Maximal sprint speed (MSS: fastest speed over any 10-m sector measured during a maximal 40-m sprint), estimated maximal aerobic speed (MAS) during incremental running test, anaerobic speed reserve (ASR: MSS-MAS) | 42 matches against international club teams | Official (elite opposite international club teams) | Global Positioning System (GPS, 1 Hz, SPI Elite, GPSports, Canberra, Australia) | - Speed zone 1 (S1: < 60% of MAS)<br>- Speed zone 2 (S2: 61-80% of MAS)<br>- Speed zone 3 (S3: 81-100% of MAS)<br>- Speed zone 4 (S4: 101% of MAS to 30% of ASR)<br>- Speed zone 5 (S5: > 31% of ASR)<br>- Total distance covered (S1+S2+S3+S4+S5)<br>- Distance run at intensities below MAS (S1+S2+S3)<br>- Distance run at intensities above MAS (S4+S5) |
| **Carling, Le Gall [18]** | Not related to match running demands | Incremental treadmill test | Repeated ability sprint test | 33 soccer matches | Official | Video-computerized, semi-automatic, image recognition system (Amisco®) | Percentage difference between halves ($1^{st}$ x $2^{nd}$) for:<br>- Total distance covered<br>- High-intensity running (HIR: > 19.8 km·h$^{-1}$)<br>- Mean recovery time between HIR<br>- Percentage difference between the distance covered in HIR in the first 5- and 15-minute periods versus the final 5- and 15-minute periods respectively in normal time<br>- Percentage difference between HIR in a peak 5-minute period and the subsequent 5-minute period and for the latter compared to the mean for all other 5-minute periods |
| **Bradley, Carling [50]** | Not related to match running demands | Not related to match running demands | Yo-Yo Intermittent Recovery Test level 2 | Not reported | Official (not reported) | Video-computerized, semi-automatic, image recognition system (ProZone®) | - Walking (< 7.0 km·h$^{-1}$)<br>- Low-intensity running (7.2-14.3 km·h$^{-1}$)<br>- Moderate-intensity running (14.4-19.7 km·h$^{-1}$)<br>- High-intensity running (19.8-25.1 km·h$^{-1}$)<br>- Sprinting ( > 25.1 km·h$^{-1}$) |
| **Bradley, Bendiksen [53]** | Not related to match running demands | Not related to match running demands | Yo-Yo Intermittent Recovery Test level 2 | Not reported | Official (not reported) | Video-computerized, semi-automatic, image recognition system (Amisco®) | - Total distance covered<br>- Low-intensity running (< 12.0 km·h$^{-1}$)<br>- High-intensity running ( > 15.0 km·h$^{-1}$)<br>- High-intensity activities (18-27 km·h$^{-1}$)<br>- Sprinting (> 27.0 km·h$^{-1}$) |

**Supplemental File 2.** Continued.

| Articles | Anthropometric variables | Laboratory Tests | Field Tests | Match Analysis | | | |
|---|---|---|---|---|---|---|---|
| | | | | Number of Matches | Match Category (context) | Technology | Match Running Demands |
| **Buchheit and Mendez-Villanueva [46]** | Chronological age, age from/to peak height velocity (APHV), standing height, body mass | Not related to match running demands | Not related to match running demands | 19 soccer matches | Friendly (international) | Global Positioning System (GPS, 1 Hz, SPI Elite, GPSports, Canberra, Australia) | - Total distance covered<br>- Total distance covered > 16.0 km·h$^{-1}$<br>- Peak game speed<br>- Number of high-intensity actions (at least 1-s runs > 19.0 km·h$^{-1}$<br>- High-intensity actions (HIA: > 19.0 km·h$^{-1}$)<br>- Repeated high-intensity actions (RHIA) |
| **Rebelo, Brito [14]** | Not related to match running demands | Incremental treadmill test | Yo-Yo Intermittent Recovery Test level 1 and 2 | Each player was filmed and analyzed in two consecutive matches | Official (not reported) | Video-based time-motion analysis | Determined according to Castagna, D'Ottavio [80], such as aforementioned. The former activities were later divided into two locomotor categories: (1) low-intensity activities, encompassing standing, walking, jogging, moderate-intensity running and backwards running; and (2) HIA, consisting of HIR+SPR |
| **Manzi, Impellizzeri [42]** | Not related to match running demands | Not reported | Progressive long and short-stage running field test | 16 championship matches | Official (home) | Multi-camera video analysis system (25 Hz, SICS®, Bassano del Grappa, Italy) | Match physical performance was determined by metabolic power (in Watt per kilogram (Osgnach, et al., 2010)):<br>- Low-power (0-10 W·kg$^{-1}$)<br>- Medium-power (10-20 W·kg$^{-1}$)<br>- High-power (20-35 W·kg$^{-1}$)<br>- Very high-power (35-55 W·kg$^{-1}$)<br>- Max power ( > 55 W·kg$^{-1}$) |
| **Al Haddad, Simpson [39]** | Not related to match running demands | Not reported | Maximal sprinting speed (10-m split time during 40-m distance) | 1-7 times on each outfield player | Official (elite opposite international club teams) | Global Positioning System (GPS, 1 Hz, SPI Elite, GPSports, Canberra, Australia) | - The highest speed attained during the matches (i.e., absolute peak match speed; $PMS_{Abs}$) was recorded and was also expressed as a percentage of maximal sprinting speed (i.e., field test; $PMS_{Rel}$) |
| **Fernandes-da-Silva, Castagna [12]** | Not related to match running demands | Not reported | Carminatti test | 2 soccer games | Friendly (not reported) | Global Positioning System (GPS, 10 Hz, K-Gps, K-Sport, Montellabate, Italy) | Determined according to Castagna, D'Ottavio [80], such as aforementioned |

**Supplemental File 2.** Continued.

| Articles | Anthropometric variables | Laboratory Tests | Field Tests | Match Analysis | | | |
|---|---|---|---|---|---|---|---|
| | | | | Number of Matches | Match Category (context) | Technology | Match Running Demands |
| **Doncaster, Marwood [40]** | Not related to match running demands | The work-to-work kinetics protocol (two transitions for each change in workload [unloaded-moderate and moderate-severe]) | Not related to match running performance | 3 soccer matches | Friendly (same composition of players in the same positions) | Global Positioning System (GPS, 10 Hz, Catapult, Melbourne, Australia) | - Total distance covered<br>- High-intensity running (HIR: > 50% maximal linear speed)<br>- Very high-intensity running (> 70% maximal linear speed) |
| **Aquino, Palucci Vieira [16]** | Not related to match running demands | Not reported | Peak Running Speed, Zig-Zag test, Repeated-sprint ability, Yo-Yo Intermittent Recovery Test level 1 | 2 soccer matches | Official (away) | Video-computerized, semi-automatic, match analysis image recognition system (DVIDEOW®) | - Total distance covered<br>- Standing (0.00-0.40 $km{\cdot}h^{-1}$)<br>- Walking (0.41-3.00 $km{\cdot}h^{-1}$)<br>- Low-intensity running (3.01-8.00 $km{\cdot}h^{-1}$)<br>- Moderate-intensity running (8.01-13.00 $km{\cdot}h^{-1}$)<br>- High-intensity running (13.01-16.00 $km{\cdot}h^{-1}$)<br>- Very high-intensity running (VHIR: 16.01-19.00 $km{\cdot}h^{-1}$)<br>- Sprinting (SPR: > 19.01 $km{\cdot}h^{-1}$)<br>- High-intensity activities (VHIR + SPR)<br>- Peak Running Speed<br>- Number of sprints was defined as frequency of runs at V7 counted as a function of individual playing time |
| **Bellistri, Marzorati [41]** | Not related to match running demands | Not reported | Countermovement Jump, 20 m shuttle running, linear sprint performance (10, 20, 30 m) | 31 soccer matches | Official | Global Positioning System (GPS, K-Gps 10 Hz, K-Sport, Italy) | - Total distance covered<br>- U8: walking (<6.3 $km{\cdot}h^{-1}$), low-intensity running (6.4-8.4 $km{\cdot}h^{-1}$), moderate-intensity running (8.5-11.5 $km{\cdot}h^{-1}$), high-intensity running (HIR: 11.6-17.3 $km{\cdot}h^{-1}$), sprinting (SPR: > 17.3 $km{\cdot}h^{-1}$)<br>- U10: walking (<6.7 $km{\cdot}h^{-1}$), low-intensity running (6.8-9.6 $km{\cdot}h^{-1}$), moderate-intensity running (9.7-13.2 $km{\cdot}h^{-1}$), high-intensity running (HIR: 13.3-18.2 $km{\cdot}h^{-1}$), sprinting (SPR: > 18.2 $km{\cdot}h^{-1}$)<br>- High-intensity activities (HIR + SPR) |

**Supplemental File 2.** Continued.

| Articles | Anthropometric variables | Laboratory Tests | Field Tests | Match Analysis | | | |
|---|---|---|---|---|---|---|---|
| | | | | Number of Matches | Match Category (context) | Technology | Match Running Demands |
| **Sporiš, Dujić [54]** | Height, body mass, body fat percentage, triceps skinfold, subscapular skinfold, thigh skinfold, calf skinfold, supraspinal skinfold and abdominal skinfold | Not reported | Not reported | 3 soccer matches | Official | Not fully reported | - Total distance covered<br>- Walking (0.4 to 3.0 km·h$^{-1}$)<br>- Low-intensity running (3.0-8.0 km·h$^{-1}$)<br>- Moderate-intensity running (8.0-13.0 km·h$^{-1}$)<br>- High-intensity Running (13.0-18.0 km·h$^{-1}$)<br>- Sprinting (>18.0 km·h$^{-1}$) |
| **Rago, Pizzuto [49]** | Not related to match running demands | Not reported | Yo-Yo Intermittent Recovery Test level 1 and 2 | 4 soccer matches | Official | Global Positioning System (QStarz BT-Q1000XT, 15 Hz, Taiwan) | - Total distance covered<br>- Moderate-intensity running (MIR: 16-19 km·h$^{-1}$)<br>- High-intensity running (HIR: 19-22 km·h$^{-1}$)<br>- Very high-intensity running (VHIR: > 22 km·h$^{-1}$)<br>- High-intensity activities (MIR + HIR + VHIR) |
| **Rago, Silva [17]** | Not related to match running demands | Not reported | Countermovement jump, 5-m sprint time, Yo-Yo Intermittent Recovery Test level 1 | 4 soccer matches | Not fully reported | Global Positioning System (GPSports SPI Pro-X, 15 Hz, Canberra, Australia; 6 g tri-axial accelerometer sampling at 100 Hz) | - Total distance covered<br>- Moderate-intensity running (MIR: 16-19 km·h$^{-1}$)<br>- High-intensity running (HIR: 19-22 km·h$^{-1}$)<br>- Very high-intensity running (VHIR: > 22 km·h$^{-1}$)<br>- Maximum acceleration distance (> 3·s$^{2}$)<br>- Maximum deceleration distance (> -3·s$^{2}$) |
| **Redkva, Paes [47]** | Not related to match running demands | Not reported | Yo-Yo Intermittent Endurance Test , running-based anaerobic sprint test | Not reported | Friendly | Global Positioning System (QStarz®, Taipei, Taiwan) | - Total distance covered<br>- High-intensity running (actions between 15.9-24 km·h$^{-1}$)<br>- Sprinting (actions above 24 km·h$^{-1}$) |

# CAPÍTULO 4. ESTUDO 3

# VALIDITY AND RELIABILITY OF A 6-A-SIDE SMALL-SIDED GAME AS AN INDICATOR OF MATCH-RELATED PHYSICAL PERFORMANCE IN ELITE YOUTH BRAZILIAN SOCCER PLAYERS

**Shortened title:** Running performance in Brazilian soccer players

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AQUINO, R.; MELLI-NETO, B.; FERRARI, J. V. S,; BEDO, B. L. S.; PALUCCI VIEIRA, L. H.; SANTIAGO, P. R. P; PUGGINA, E. F. Validity and reliability of a 6-a-side small-sided game as an indicator of match-related physical performance in elite youth Brazilian soccer players. **Journal of Sports Sciences**, *under review*, 2019.

**Abstract**

The aims of this study were: (i) to compare the external and internal load during a 6-a-side small-sided game (6v6-SSG) according to age-group (i.e., sensitivity); (ii) to relate these parameters between the 6v6-SSG and official matches (i.e., construct validity); (iii) to test the reliability of the 6v6-SSG. A total of 51 Brazilian youth soccer players participated in this study (U11 [n=16]; U13 [n=10]; U15 [n=9]; U17 [n=8]; U20 [n=8]). Three experiments were conducted. Experiment A: fifty-one U11 to U20 players were submitted to 6v6-SSGs. Experiment B: thirty-two players were randomized to also play official matches. Experiment C: thirty-five youth players played the 6v6-SSG twice for test and retest reliability analysis. External load was obtained using Global Positioning System and internal load parameters were calculated through perceived exertion (RPE) and mean heart rate. Statistical approaches showed progressive increases in all parameters according to categories (U11 < U13 < U15 < U17 < U20; $p<0.05$; ES=0.42-23.68). Even controlled by chronological age, all parameters showed likely to almost certain correlations between 6v6-SSG and official matches (r=0.25-0.92), with exception of RPE (r = 0.002). Collectively, the proposed protocol indicates good reliability (CV%=2.0-12.6; TE%=2.3-2.7%; ICC=0.78-0.90). This research suggests that the 6v6-SSG is an alternative tool to evaluate physical fitness in soccer players.

**Key-words**: association football; time-motion analysis; soccer-specific fitness; GPS; sports sciences.

**Introduction**

A variety of methods exist to assess soccer player physical performance both outside the match context (Stølen, Chamari, Castagna, & Wisløff, 2005), as well as during actual competitions (Carling, Bloomfield, Nelsen, & Reilly, 2008). Traditionally, assessments of the former have mainly been conducted in laboratory settings, e.g., incremental treadmill tests (Cerda-Kohler et al., 2016), Wingate Anaerobic Test (Meckel, Machnai, & Eliakim, 2009), and the maximal anaerobic oxygen deficit test (Andrade et al., 2015). However, to improve ecological estimations of physical performance, there has been an emergent trend of using field tests to assess physical fitness, e.g., Yo-Yo Intermittent Recovery Test (Yo-Yo IR) (Krustrup et al., 2003), repeated sprint ability test (Impellizzeri et al., 2008), Hoff Test (Chamari et al., 2005), and Footeval (Manouvrier, Cassirame, & Ahmaidi, 2016). In general, these physical fitness tests have various purposes, notably to identify player individual strengths and weaknesses, investigate the effects of training interventions, aid in rehabilitation programs following injury, and profile and monitor youth player development (Svensson & Drust, 2005).

In order to ensure that the protocol and subsequent information gathered from a given physical test have practical meaning, large relationships between the player's physical fitness (derived from laboratory and field tests) and match running performance assessments using time-motion analyses are required, to gain insights into construct validity (Aquino, Palucci Vieira, de Paula Oliveira, Cruz Gonçalves, & Pereira Santiago, 2018). In the 1990´s, Bangsbo and Lindquist, (1992) were the first to address this issue in professional soccer players. Subsequently, there was a rapid increase in similar research (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010; Castagna, Manzi, Impellizzeri, Weston, & Barbero Alvarez, 2010), mainly related to the growth and availability of a range of portable match-play tracking equipment, e.g., accelerometers, local position measurement, global positioning systems (GPS) (Carling et al., 2008). However, Drust, Atkinson, and Reilly (2007) reported that the match-play running profile is not-continuous; therefore its patterns defy precise modeling and are difficult to replicate or predict, hindering the creation of specific and valid tests outside the match context for evaluating soccer players.

Small-sided games (SSGs) have been widely used as a training methodology in team sports (e.g. soccer) (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). Therefore, since SSGs are highly specific and frequently used during the season, an additional practical application could be their use as a fitness indicator, mainly since: (i) more players can be evaluated at the same time; (ii) SSGs involve technical and tactical demands; and (iii) players are performing soccer training during the test. Stevens, De Ruiter, Beek, and Savelsbergh (2016) tested this hypothesis and found that SSGs alone cannot be used as a valid and reliable fitness indicator. However, the authors used a field test as the criterion measure (Yo-Yo IR) to relate the external (e.g., GPS measures) and internal (e.g., perceived exertion scores [RPE], heart rate) load obtained during the SSGs. With substantial methodological alterations, the aims of the present study, therefore, were: (i) to test the sensitivity of the 6v6-SSG to discriminate external and internal load according to age (U11 to U20); (ii) to evaluate construct validity by relating these parameters between the 6v6-SSG and official matches and; (iii) to test the reliability of the 6v6-SSG.

## Methods

*Participants*

A total of 51 Brazilian youth soccer players participated in this study (U11 [n=16]; U13 [n=10]; U15 [n=9]; U17 [n=8]; U20 [n=8]). All measurements were performed in-season as a part of the regular testing program of the teams analyzed. The players were members of a professional soccer club that plays in the 1st division of the São Paulo State Championship, Brazil – leading state-level tournament in the country (Aquino et al., 2016). The sample size was calculated according to a previous study (Stevens et al., 2016) (statistical power = 0.85; alpha = 5%; software G*Power, Dusseldorf, Germany). This study was approved by the Research Ethics Committee of the School of Physical Education and Sport of Ribeirão Preto/USP (CAAE: 61884716.9.0000.5659) and was conducted in accordance with the Declaration of Helsinki. All participants and their legal guardians signed an Assent and Consent Term, respectively.

*Experimental Design*

Three experiments were conducted. First, all 51 players were submitted to a 6-a-side small-sided game (6v6-SSG) to investigate the sensitivity of the protocol. In this step, we compared external and internal load parameters between U11 to U20 age-groups (Experiment A). Second, thirty-two players were randomized to play official matches according to the official rules of their category (U11: n=16 players, n=2 matches; U15: n=8 players; n=2 matches; U17: n=8 players; n=2 matches). This experiment was performed to test the construct validity of the 6v6-SSG as an indicator of match-related physical performance (Experiment B). Finally, thirty-five youth players (U11: n=16; U13: n=10; U15: n=9) played the 6v6-SSG twice to test and retest the reliability analysis (Experiment C). During all the study phases, each test (6vs6-SSG or official matches) was followed by at least 48-hours of recovery. In addition, all the tests were performed on artificial grass (~105 x 68 m) between 09:00 AM and 12:00 AM. Prior to the tests, the players performed a habitual warm-up, consisting of 5-minutes of low-intensity running and 10-minutes of coordinative running (i.e., skipping, dribbling, anfersen, hopserlauf, and kick-out).

*Measures*

6v6-SSG: the protocol was played including goalkeepers, in 6 x 6 min with 90 s of active rest between periods (pitch size = 49 x 25 m). Field size and playing time were adapted from previous studies (Rebelo, Silva, Rago, Barreira, & Krustrup, 2016; Stevens et al., 2016). Consistent coach encouragement was given at all times during the 6v6-SSG. We recommended the players use the 1–2–2–1 team formation (i.e., goalkeeper – central + external defender – central + external midfielder – forward). All official match rules were applied with the exception of “offside” and yellow/red cards. Aiming to maintain the competitiveness of the playing teams, the coaches organized the players in evenly balanced teams. The players were familiar with the 6v6-SSG structure from their training routines. Goalkeepers could be involved with the play, but restricted to a maximum of 3 ball possessions (Stevens et al., 2016). For the reliability analysis, the teams were composed with the same players (e.g., test: team A vs. team B; re-test: team A vs. team B).

Official matches: all matches were performed during the in-competitive season. Two matches (one at home and one away) were monitored for each age-group (U11: 20’ x 20’ with 10 minutes of passive rest; U15: 30’ x 30’ with 15 minutes of passive rest; U17: 40’ x 40’ with 15 minutes of passive rest), to prevent the possible confounding factor of a home advantage. External and internal measures were obtained (see below). The team formation in all categories was 1–4–4–2 with occasional minor variations. In the U11 category, the corner kick was performed at the intersection between the lateral line and penalty area (Palucci Vieira et al., 2018). The players were allowed to drink water and isotonic beverage (6% tangerine-flavored carbohydrate-electrolyte) freely before, during, and after the matches.

External and internal load: external load was measured using GPS technology (Sports®, QSTARZ, BT-Q1300ST, 5 Hz, Taipei, Taiwan). Previous studies have reported good coefficients of variation and error rate, i.e., < 5% in all running outputs (Aquino, Carling, et al., 2018; Aquino et al., 2017). In this study, a complementary control-quality assessment was conducted. The players wearing the GPS device covered a known distance (calculated by tape measure) at different intensities (6, 13, and 15 $km \cdot h^{-1}$). The error rate was < 5% for all running categories. The GPS units were attached to players' shorts. All players used the same unit throughout the study. The 2D reconstruction of the geographical coordinates (latitude and longitude) of each player at each time point were exported to a CSV format file using QSports software (Taipei, Taiwan) for later analysis in Matlab environment (The MathWorks Inc., Natick, USA). The geographic coordinates were converted to Cartesian coordinates (*xy*) and smoothed by a third order Butterworth digital filter (cutoff frequency = 0.4 Hz) for further calculation of the total distance covered (m), high-intensity running (> 60% of peak game speed), acceleration ($\geq 2\ m \cdot s^{2}$), and deceleration ($\geq -2\ m \cdot s^{2}$) (Castagna, Varley, Póvoas, & D'Ottavio, 2017). Five minutes after the final bout, the internal loads (RPE; CR100) were obtained from the players by asking "How intense was the 6v6-SSG?" (Borg & Kaijser, 2006; Fanchini et al., 2016). In addition, the mean heart rate ($HR_{MEAN}$) was calculated after beat-to-beat monitoring using the Polar Team System (Polar Electro OY, Kempele, Finland) (Hill-Haas, Rowsell, Coutts, & Dawson, 2008).

*Statistical Analysis*

Data normality and homogeneity of variance were checked using the Shapiro-Wilk and Levene tests, respectively. The p-value threshold was pre-fixed at 5% ($p < 0.05$). Comparisons between internal and external load according to age-groups were performed by ANOVA one-way (Experiment A). When necessary, we used the Bonferroni post-hoc and log-transformed data. Partial correlations (to control for the possible effect of chronological age) of Pearson (parametric) and Spearman (nonparametric) were used to assess the relationships between 6v6-SSG and official matches (Experiment B) according to each age-group. This was performed while controlling for the possible casual relationships between 6v6-SSG and official matches. The test and retest reliability of the internal and external load parameters was tested using the t-test for dependent samples, coefficients of variation (CV%), absolute and typical percentage error (TE), and intraclass correlation coefficient (ICC). The typical percentage error was obtained by dividing the resulting estimate of the typical error by the mean for the participants in all trials, then multiplying by 100 (Hopkins, 2000). In addition, the smallest detectable difference (SDD) was calculated using the following equation: SDD = [1.96 · √2 · (SD of the test and retest differences · √1 – ICC)] (Haley & Fragala-Pinkham, 2006) (Experiment C). The analyses were performed using the software IBM SPSS Statistics for Windows, version 22.0 (Armonk, NY: IBM Corporation®). In addition, a magnitude-based inferential (MBI) statistical approach was used (confidence level = 90%, number of independent inferences = 1; maximum risk of harm = 0.5%; minimum chance of benefit = 25%; benefit/harm odds ratio = 66). Raw data outcomes in standardized Cohen units were used (Effect Size [ES]). Quantitative chances of higher or lower differences were assessed qualitatively as follows: < 1 %, almost certainly not; 1 − 5 %, very unlikely; 5 − 25 %, unlikely; 25 − 75 %, possibly; 75 − 95 %, likely; 95 − 99 %, very likely; > 99 %, almost certain. If the chance of higher or lower differences was > 5%, the true difference was assumed as unclear. Otherwise the effect was deemed clear (Hopkins, Marshall, Batterham, & Hanin, 2009). For greater impact of the results, only likely chances (> 75%) of differences were considered true (Lacome, Simpson, Cholley, Lambert, & Buchheit, 2018).

## Results

*Experiment A*

Table 1 presents the values of the external and internal load obtained during the proposed protocol 6v6-SSG in the analyzed age-groups (U11 to U20). We observed progressive increases in all parameters according to categories (U11 < U13 < U15 < U17 < U20; $p < 0.05$; ES = 0.42-23.68; *likely-almost certain*).

**Table 1.** Mean (standard deviation) of external and internal load obtained during the 6-a-side small-sided game according to age-groups analyzed (U11 [n=16], U13 [n=10], U15 [n=9], U17 [n=8], U20 [n=8].

| **Variables** | **U11** | **U13** | **U15** | **U17** | **U20** |
|---|---|---|---|---|---|
| TD (m) | 2786.3 (304.6) | 3421.6 (382.2) | 5699.1 (770.2) | 6086.0 (214.9) | 6416.3 (149.4) |
| DAcHI (m) | 42.1 (15.1) | 75.9 (14.6) | 191.4 (51.8) | 243.9 (40.9) | 298.8 (12.4) |
| DDecHI (m) | 24.7 (10.6) | 79.3 (17.7) | 160.9 (47.4) | 258.4 (34) | 298.6 (22) |
| HIR (m) | 179 (57.7) | 413.8 (137.7) | 447 (40.5) | 629.3 (68.7) | 757.8 (55.5) |
| $HR_{MEAN}$ (bpm) | 160.8 (5.1) | 174.5 (4.1) | 188.2 (2.4) | 189.4 (2.1) | 188.4 (3.3) |
| RPE (au) | 72.8 (3.4) | 82.1 (2.9) | 91.7 (1.7) | 92.6 (2.9) | 93.3 (2.9) |

Note: TD = Total Distance covered; DAcHI = Distance covered at High-Intensity Accelerations (≥ 2 $m.s^2$); DDecHI = Distance covered at High-Intensity Deceleration (≥ -2 $m.s^2$); HIR = Distance covered at High-Intensity Running (60.1 to 100% of maximum running speed); $HR_{MEAN}$ = Mean Heart Rate; RPE = Rating of Perceived Exertion (CR100).

*Experiment B*

Figure 1 show the correlation coefficients (r) observed in the relationships between 6v6-SSG and official matches controlled by chronological age. All parameters showed *likely* to *almost certain* correlations (r = 0.25-0.92), with exception of RPE scores (r = 0.002; *unclear*). The distance covered in HIR was the best predictor in the relationship between 6v6-SSG and official matches (r = 0.92; *almost certain*). Within age-groups (Table 2), U11 and U17 players demonstrated *likely* to *almost certain* relations in all variables (r = 0.46-0.98), with the exception of $HR_{MEAN}$ (r = 0.29-0.54; *unclear*). The U15 category showed *likely* to *almost certain* relations for TD, DAcHI, HIR (r = 0.62-0.90), and *unclear* for DDecHI, $HR_{MEAN}$, RPE (r = 0.004-0.42).

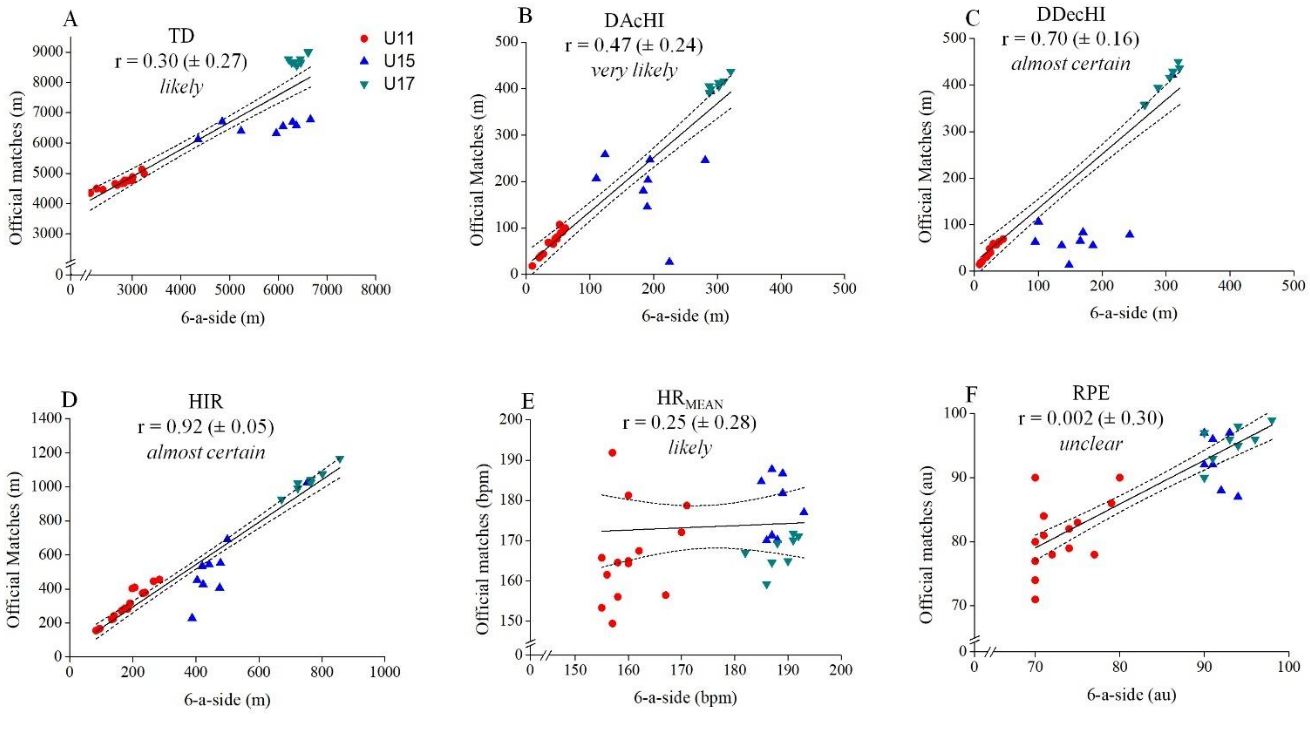


**Figure 1.** Correlation coefficients (± 90% confidence interval and quantitative chances) of external and internal loads between 6-a-side small-sided game and official matches controlled by chronological. Note: TD = Total Distance covered; DAcHI = Distance covered at High-Intensity Accelerations (≥ 2 $m.s^2$); DDecHI = Distance covered at High-Intensity Deceleration (≥ -2 $m.s^2$); HIR = Distance covered at High-Intensity Running (60.1 to 100% of maximum running speed); $HR_{MEAN}$ = Mean Heart Rate; RPE = Rating of Perceived Exertion (CR100).

**Table 2.** Correlation coefficients (± 90% confidence interval and quantitative chances) of external and internal load measures of the 6-a-side small-sided game with official matches per age-group.

| **Variables** | **U11** | | | **U15** | | | **U17** | | |
|---|---|---|---|---|---|---|---|---|---|
| | r | ±90% CI | QC | r | ±90% CI | QC | r | ±90% CI | QC |
| TD (m) | 0.94 | 0.06 | *almost certain* | 0.62 | 0.45 | *likely* | 0.71 | 0.39 | *very likely* |
| DAcHI (m) | 0.97 | 0.03 | *almost certain* | 0.22 | 0.61 | *unclear* | 0.92 | 0.14 | *almost certain* |
| DDecHI (m) | 0.98 | 0.02 | *almost certain* | 0.05 | 0.63 | *unclear* | 0.98 | 0.04 | *almost certain* |
| HIR (m) | 0.96 | 0.04 | *almost certain* | 0.71 | 0.39 | *very likely* | 0.97 | 0.06 | *almost certain* |
| $HR_{MEAN}$ (bpm) | 0.29 | 0.40 | *unclear* | 0.004 | 0.63 | *unclear* | 0.54 | 0.50 | *unclear* |
| RPE (au) | 0.46 | 0.35 | *likely* | 0.52 | 0.51 | *unclear* | 0.66 | 0.43 | *likely* |

Note: TD = Total Distance covered; DAcHI = Distance covered at High-Intensity Accelerations (≥ 2 $m.s^2$); DDecHI = Distance covered at High-Intensity Deceleration (≥ -2 $m.s^2$); HIR = Distance covered at High-Intensity Running (60.1 to 100% of maximum running speed); $HR_{MEAN}$ = Mean Heart Rate; RPE = Rating of Perceived Exertion (CR100); 90% CI = Confidence Interval; QC = Quantitative Chance.

*Experiment C*

In general, Table 3 indicates good reliability of the 6v6-SSG. In relation to CV%, the DAcHI, DDecHI, and HIR demonstrated greater values (CV% = 8.1-12.6); however, TD, $HR_{MEAN}$, and RPE presented good reproducibility (CV < 5%). All parameters of external and internal load demonstrated low values of typical percentage error (TE = 2.3-2.7%) and high ICC (0.78-0.90). The test and retest measures did not differ substantially according to magnitude-based inference ($p > 0.05$; ES = -0.19-0.25; *possibly*).

**Table 3.** Reliability analysis for external and internal load obtained during the 6-a-side small-sided game.

| **Variables** | Test | Retest | CV% | TE | ICC | SDD | ES | QC |
|---|---|---|---|---|---|---|---|---|
| TD (m) | 3716.8 (1300.9) | 3522.6 (1314.4) | 4.4 (2.8) | 86.9 (2.4%) | 0.89 | 339.9 | -.019 | *possibly* |
| DAcHI (m) | 90.2 (68.2) | 98.7 (68.1) | 10.0 (8.0) | 2.2 (2.3%) | 0.79 | 7.7 | 0.19 | *possibly* |
| DDecHI (m) | 75.3 (61.7) | 84.1 (61.8) | 12.6 (13.2) | 1.8 (2.3%) | 0.80 | 6.4 | 0.22 | *possibly* |
| HIR (m) | 315.0 (151.9) | 345.2 (153.2) | 8.1 (4.7) | 8.8 (2.7%) | 0.78 | 33.5 | 0.21 | *possibly* |
| $HR_{MEAN}$ (bpm) | 171.7 (12.2) | 175.0 (14.8) | 2.0 (1.7) | 4.1 (2.4%) | 0.87 | 15.4 | 0.25 | *possibly* |
| RPE (au) | 80.3 (8.4) | 81.4 (9.3) | 2.1 (1.5) | 1.9 (2.4%) | 0.90 | 6.5 | 0.12 | *possibly* |

Note: TD = Total Distance covered; DAcHI = Distance covered at High-Intensity Accelerations (≥ 2 $m.s^2$); DDecHI = Distance covered at High-Intensity Deceleration (≥ -2 $m.s^2$); HIR = Distance covered at High-Intensity Running (60.1 to 100% of maximum running speed); $HR_{MEAN}$ = Mean Heart Rate; RPE = Rating of Perceived Exertion (CR100); CV% = Coefficient of Variation; TE = Typical Error Absolute (relative); ICC = Intraclass Coefficient Correlation (all values were *almost certain*); SDD = Smallest Detectable Difference; ES = Effect Size; QC = Quantitative Chance.

**Discussion**

The present investigation was conducted in youth soccer players with the aim of verifying the sensitivity, validity, and reliability of a 6v6-SSG as an indicator of match-related physical performance. The main findings were: (i) the protocol presented sensitivity in discriminating age-related performance (U11 to U20, see Table 1); (ii) even controlled by chronological age, all external and internal measures showed *likely* to *almost certain* correlations, with exception for RPE scores (see Figure 1 and Table 2); iii) the distance covered in HIR during the 6v6-SSG explained 84% of the variance of the distance covered in HIR during the official matches; and (iii) the proposed protocol demonstrated good reliability (see Table 3).

Sports scientists continuously address physical tests that are closely linked to match physical demands. Krustrup and colleagues (2003) reported that high-intensity running (> 18.0 $km \cdot h^{-1}$) covered by the players during matches was correlated to Yo-Yo test performance (r = 0.71) but not to $\dot{V}O2_{MAX}$ or an incremental treadmill test in professional soccer players. In addition, two previous recent systematic reviews indicated trends of associations between several physical fitness tests (e.g., Yo-Yo IR-1, IR-2; multistage fitness test, Carminatti test, 20-m shuttle run test, Zig-Zag test, Hoff test) and match running performance (e.g., total distance covered, sprinting, high-intensity running) in youth soccer players (Palucci Vieira, Carling, Barbieri, Aquino, & Santiago, 2019; Paul & Nassis, 2015). However, Aquino, Palucci Vieira, et al. (2018) showed low explanation power (17 to 22%) of tests outside the match context and running demands during soccer match-play and suggested that additional assessment of player physical fitness in match conditions can provide more realistic analysis.

One can argue that laboratory and field tests *per se* are not sensitive enough to profile in-match performance (Stølen et al., 2005; Williams & Reilly, 2000), implying the need for additional studies to justify the use of tests outside the match context to predict match physical demands in soccer players (Carling et al., 2008). This statement is supported by the apparent lack of laboratory/field tests which reproduce construct validity with respect to the motion types, directions, and intensities corresponding to match running demands. In addition, the literature does not provide sufficiently adapted protocols for the individual playing positions within soccer (Carling et al., 2008). Therefore, the representativeness of these tests compared to the reality of actual competition demands remains questionable (Drust et al., 2007; Mendez-Villanueva & Buchheit, 2013). Recently, attempts have been made to develop treadmill laboratory-based (Page, Marrin, Brogden, & Greig, 2015) and field tests (Bendiksen et al., 2012) characterized as match-play simulations in order to create similar conditions to those of real on-field running demands during official matches. In 2016, Manouvrier and colleagues proposed a specific-aerobic test ("Footeval") for soccer players using the ball. However, to date, the construct validity of these soccer-specific protocols has not been fully assessed. In addition, these tests are performed in a closed environment without the presence of teammates and/or opponents.

On the other hand, SSGs are widely used for physical conditioning in soccer players. Their integrated approach, including physical and tactical/technical aspects compared to traditional strength and endurance exercises, has been deemed high enough to promote soccer-specific adaptations (Hill-Haas, Coutts, Rowsell, & Dawson, 2009; Hill-Haas et al., 2011), supporting recent criticisms. Recently, Stevens et al. (2016) observed that 6v6-SSG running demands cannot serve as a valid and reliable fitness indicator for professional and amateur soccer players. Nonetheless, one important methodological concern could be highlighted; the validity was tested with the Yo-Yo IR-2 and not with running outputs during official matches. In this study, the 6v6-SSG presented good sensitivity, validity, and reliability to evaluate physical fitness in youth soccer players.

First, as expected, we observed progressive increments in running demands during the 6v6-SSG across the age-groups analyzed (U11 to U20). Second, we verified positive *likely* to *almost certain* correlations between running outputs in the 6v6-SSG and official matches (even controlled by chronological age), specially to distance covered in HIR (explained 84% of the common variance between 6v6-SSG and official matches). Previous study demonstrated that HIR is one of the best variables to discriminate won vs. lost matches (Aquino, Carling, et al., 2018); therefore, the current results showed a construct validity of the 6v6-SSG. Third, collectively the protocol demonstrated good reliability. Only the external load related to high-intensity efforts (i.e., DAcHI, DDecHI, and HIR) presented greater values of CV% (CV% = 8.1-12.6), in agreement with previous studies (Hill-Haas et al., 2008; Stevens et al., 2016). These results promote novel insights for coaches and practitioners, primarily by providing scientific evidence that the 6v6-SSG can be useful for physical evaluation in youth soccer players.

We consider two main limitations of this study. First, we used a cross-sectional design. Further studies should adopt repeated assessment during the season and analyze the consistency of the relationships reported in this study. Second, in this study it was not possible to separate the players according to their positional role (reduced sample size of forwards and central defenders). On the other hand, this study also has some novel aspects: (i) to the best of our knowledge, this is the first study to demonstrate the possible use of SSGs to evaluate physical fitness of youth soccer players; (ii) external and internal parameters were considered to define physical fitness; (iii) the results proved to be efficient in supporting conditioning coaches during the evaluation periods. In addition, we highlighted five crucial points for when clubs opt to use SSGs as a match-fitness indicator: (i) consistent coach encouragement should be given at all times during the 6v6-SSG, as this can improve the reliability analysis; (ii) although the SSGs are better standardized than official matches (e.g., less position-dependent; Stevens et al., 2016), we recommend the players use the 1-2-2-1 team formation, and the same teams in the comparisons between two or more moments (e.g., test: team A vs. team B; re-test: team A vs. team B); (iii) all official rules should be applied with the exception of “offside” and yellow/red cards – increasing the representativeness of SSGs with official matches; (iv) in practice, the players often like competitive playing teams, therefore, the coaches and sports scientists should use evenly balanced teams (Hill-Haas et al., 2011); (v) youth players should be familiar with the 6v6-SSG structure.

**Practical Application**

Physical fitness evaluated outside the match context may well guide training and research, but does not seem to have the best potential to predict match running demands in youth soccer players (Aquino, Palucci Vieira, et al., 2018). Our research suggests that the 6v6-SSG can be an alternative tool to evaluate physical performance in soccer players, with greater specificity and representativeness than traditional approaches; therefore, coaches and practitioners should include these SSGs in the evaluation periods.

**Conclusion**

The overall aim of our study was to determine whether the use of the 6v6-SSG internal and external load can serve as an indicator of match-related physical performance for youth soccer players. We performed three experiments to test this hypothesis: (i) we compared $HR_{MEAN}$, RPE scores, and running demands according to age-groups (U11 to U20); (ii) we checked the relationships between the 6v6-SSG and official matches; (iii) we verified the reliability analysis of the protocol used. Collectively, we demonstrated that the 6v6-SSG presented sensitivity, validity, and reliability to evaluate physical fitness in youth Brazilian soccer players.

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# CAPÍTULO 5. ESTUDO 4

# EFFECTS OF COMPETITIVE STANDARD, TEAM FORMATION AND PLAYING POSITION ON MATCH RUNNING PERFORMANCE OF BRAZILIAN PROFESSIONAL SOCCER PLAYERS

**Shortened title:** Match Analysis in Soccer

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AQUINO, R.; VIEIRA, L. H. P.; CARLING, C.; MARTINS, G. H. M.; ALVES, I. S.; PUGGINA, E. F. Effects of competitive standard, team formation and playing position on match running performance of Brazilian professional soccer players. **International Journal of Performance Analysis in Sport**, v. 17, n. 5, p. 1-11, 2017. doi: 10.1080/24748668.2017.1384976

**Abstract**

This study examined the effects of competitive standard, team formation and playing position on match running performance in a Brazilian professional soccer team. Performance was investigated in 36 players in 48 matches at three competitive standards: 1st São Paulo State Championship; 3rd and 4th Brazilian leagues. Global Positioning System technology was used to determine total distance covered (TD), maximal running speed (MRS), mean speed ($S_{MEAN}$) and frequency of high-intensity activities (HIA). Data were compared across competitive standards, team formations and playing positions. Magnitude-based inferences showed greater values for TD, $S_{MEAN}$ and HIA (*likely* to *almost certain*) in the lower national (3rd, 4th Brazilian) versus the top state division (1st São Paulo). Higher values for all variables were reported for the 1–4–3–3 versus the 1–4–4–2 formation (*likely* to *almost certain*). External defenders/midfielders and forwards reported greater values (*likely* to *almost certain*) versus central defenders/midfielders, especially in HIA. Linear regression analyses showed that playing position demonstrated a higher relative contribution to the variance in MRS (24%) and HIA (29%) compared to team formation (16% and 25%, respectively). In a Brazilian professional soccer team, match running performance was dependent upon competitive standard, playing formation and playing position.

**Kew-words:** association football; time-motion analysis; match demands; match preparation.

**Introduction**

Knowledge of the physical demands of professional soccer match-play is required to construct optimal training programs to respond to these needs (Carling, 2011). Time-motion analyses of running performance is employed to evaluate external load in soccer match-play (Castagna, Varley, Povoas, & D'Ottavio, 2017) and provide information for coaches and conditioning practitioners in the decision-making process for player fitness and match preparation (Bradley et al., 2009; Carling, 2010). The current literature is vast and has helped characterize the general demands of match-play and determine a myriad of variables that potentially affect match running performance (Carling, 2013). The latter notably include competitive level, frequently characterized by analysis of the various divisions in national championships, final ranking of teams or level of play (i.e., professional, semi-professional and amateur), team formation and playing position (Barros et al., 2007; Bradley et al., 2011, 2013; Carling, 2011; Di Salvo et al., 2007; Di Salvo, Pigozzi, Gonzalez-Haro, Laughlin, & De Witt, 2013).

In Brazilian professional soccer players however, the literature regarding match running demands is scarce (Aquino, Munhoz, Vieira, & Menezes, 2017). According to Dellal et al. (2011), cultural differences in playing style in various countries affect the match running output of players at professional standards. Therefore, the running demands in competition in professional Brazilian soccer may not be similar to another countries and information is needed to characterize the demands specific to the country. In addition, only one study has investigated the influence of playing position on running output in matches in Brazilian professional soccer (Barros, et al., 2007). The results in a 1$^{st}$ Brazilian Division team showed that the distances covered by external defenders, central midfielders and external midfielders were greater than forwards while the latter covered greater distances than central defenders. However, data was limited to distances covered and no information was provided on performance at other competitive standards across elite Brazilian soccer or on the effects of commonly used team formations (e.g., 1–4–4–2 and 1–4–3–3). Indeed, no studies in the elite Brazilian game or other national leagues generally have examined the relative contribution of these variables to match running performance. This information would help coaches and practitioners identify the main variable that explains the variance in the running demands in soccer competition and, therefore, which should be focused upon in physical conditioning regimens.

Therefore, the aims of this study in a reference Brazilian professional soccer team were: i) to examine the effects of independent variables including standard of play determined by the division the team participated in, and team formation and playing position on match running performance; and ii) to verify the relative contribution of the independent variables to the variance in match running performance, in particular maximal running speed and the frequency of high-intensity activities.

## Methods

### *Experimental Design*

We used an observational design to verify the effects of competitive standard, team formation and playing position on match running performance in one reference team during 48 matches in three consecutive seasons: 1$^{st}$ São Paulo State season 2016 [January to April], 3$^{rd}$ Brazilian season 2016 [May to September] and 4$^{th}$ Brazilian season 2015 [June to November]. The 1$^{st}$ São Paulo State division is the top state-level tournament in the country (Aquino et al., 2016). The 3$^{rd}$ and 4$^{th}$ Brazilian divisions are the lower national leagues. The matches (2 x 45') were performed in official stadiums (FIFA standard; natural grass;~100 x 70 m), between 11:00 AM to 08:00 PM and the mean temperature was 25.2 (5.3) $^{o}$C (77.4 (9.5) $^{o}$F).

*Participants and match analysis data*

Match running performance data (318 observations) was collected from 36 male outfield players (mean (SD): 27.72 (3.94) yrs; 180.59 (6.25) cm; 76.79 (7.35) kg) from the same reference team when it participated in three professional divisions in Brazil: 1st São Paulo State season 2016 (n = 90 observations), 3rd Brazilian season 2016 (n = 129 observations) and 4th Brazilian season 2015 (n = 99 observations). The reference team was champion in 4th Brazilian season 2015 and reached the quarter-finals phase in the 3rd Brazilian and 1st São Paulo State seasons in 2016. Global Positioning System (GPS) Sports® devices (QSTARZ – 1 Hz, Taipei, Taiwan) were employed (Aquino, et al., 2017). GPS technology has been extensively used for the measurement of match running performance in team sports and its accuracy and reliability have been determined (Barbero-Alvarez, Coutts, Granda, Barbero-Alvarez, & Castagna, 2010; Buchheit et al., 2011; Coutts and Duffield, 2010). While the low frequency of the present devices used in our study (1 Hz) can potentially underestimate the total distance covered in high-intensity running compared to optical computerized tracking (Randers et al., 2010), quality-control analyses we performed demonstrated good reliability (coefficient of variation < 5%). All players wore the same unit during the entire competition season (Jennings, Cormack, Coutts, Boyd, & Aughey, 2010). The GPS unit was attached in each players' shorts before matches commenced. Players that completed the entire match (i.e., ≥ 90 minutes) were considered.

This study was approved by the local University ethical guidelines (School of Physical Education and Sport, Ribeirão Preto, Brazil; protocol number: 61884716.9.0000.5659) and was conducted in accordance with the Declaration of Helsinki. All players signed a consent form to participate in the investigation.

*Measures*

Dependent variables included: total distance covered in meters (TD), maximum running speed in km·h$^{-1}$ (MRS), mean speed in km·h$^{-1}$ ($S_{MEAN}$) and frequency of high-intensity activities (HIA: ≥ 15.0 km·h$^{-1}$: Bradley, Di Mascio, Peart, Olsen, & Sheldon, 2010; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007). Measures were analysed using QSports software (Taipei, Taiwan).

Independent variables: match running performance data was analysed as independent variables according to competitive standard, team formation and playing position. Team formations (1–4–4–2 [n=68 observations]; 1–4–3–3 [n=250 observations]) and playing positions (central defenders [n=88 observations]; external defenders [n=65 observations]; central midfielders [n=81 observations]; external midfielders [n=17 observations]; forwards [n=67 observations]) were determined by one CBF-qualified coach who was a member of the reference club's coaching staff. The coach visualized recordings of each match to verify that team formation remained consistent through the entire match. Matches in which a dismissal occurred were not included for analysis as this can substantially influence running output (Carling, 2011).

*Statistical Analysis*

A magnitude-based inferential (MBI) statistical approach adopted analysis based on previous recommendations for studies with athletic performance (Buchheit, Simpson, & Mendez-Villanueva, 2013; Hopkins, Marshall, Batterham, & Hanin, 2009; Winter, Abt, & Nevill, 2014) (confidence level = 90%; number of independent inferences = 1; maximum risk of harm = 0.5%; minimum chance of benefit = 25%; benefit/harm odds ratio = 66). Raw data outcomes in standardized Cohen units were used. Quantitative chances of higher or lower differences were assessment qualitatively as follows: < 1 %, almost certainly not; 1 − 5 %, very unlikely; 5 − 25 %, unlikely; 25 − 75 %, possibly; 75 − 95 %, likely; 95 − 99 %, very likely; > 99 %, almost certain. If the chance of higher or lower differences was > 5 %, the true difference was assumed as unclear. Otherwise the effect was deemed clear (Hopkins, et al., 2009). For simplicity and greater impact of the present results in the field only likely chances (> 75%) that the differences were true (Lacome, Simpson, Cholley, Lambert, & Buchheit, 2017). Multiple linear regression (stepwise method – excluded standards divisions) was used to estimate the relative contribution of the dummy variables regarding team formations (1–4–4–2 = 1; 1–4–3–3 = 2) and playing positions (central defenders = 1, external defenders = 2; central midfielders = 3, external midfielders = 4; forwards = 5) to the variance in MRS and HIA (dependent variables). The data for regression analysis assumed homoscedasticity, independence, normal distribution of residuals and no multicollinearity between the independent variables (Hair Junior, Anderson, Tatham, & Black, 1998). Significance level was preset at 5% ($p < 0.05$). The second analyses were performed in IBM SPSS Statistics software for Windows, version 22.0 (IBM Corporation©).

**Results**

Data regarding match running performance according to competitive standard, team formation and playing position respectively are presented in Table 1-2 (descriptive statistics) and Figure 1-2 (MBI). In lower national divisions (3$^{rd}$ and 4$^{th}$ Brazilian), the players covered more TD compared to the top state division (1$^{st}$ São Paulo) (*almost certain*) and also reported greater values for $S_{MEAN}$ (*likely* to *almost certain*) and HIA frequency (*very likely*) (Figure 1A). Analysis of matches played in the 1–4–3–3 formation demonstrated higher values for all match running performance variables (i.e., TD, MRS, SMEAN and HIA) compared to the 1–4–4–2 formation (*likely* to *almost certain*) (Figure 1B).

**Table 1.** Mean (standard deviation) of match running performance according to standards divisions (1st São Paulo State Division season 2016 [n = 14 matches]; 3rd Brazilian Division season 2016 [n = 19 matches]; 4th Brazilian Division season 2015 [n = 15 matches]) and team formations (1–4–4–2 [n = 68 observations]; 1–4–3–3 [n = 250 observations]).*

| Variables | Competitive Standard Divisions | | | Team Formation | |
|---|---|---|---|---|---|
| | 1st São Paulo State | 3rd Brazilian | 4th Brazilian | 1–4–4–2 | 1–4–3–3 |
| TD (m) | 8518.3 (1090.2) | 9108.2 (809.6) | 9375.4 (1219.5) | 8537.4 (1251.6) | 9518.0 (1197.1) |
| MRS ($km \cdot h^{-1}$) | 28.1 (3.4) | 28.7 (3.2) | 28.3 (4.4) | 27.3 (4.5) | 29.2 (3.7) |
| $S_{MEAN}$ ($km \cdot h^{-1}$) | 4.6 (0.6) | 5.0 (0.6) | 4.9 (0.7) | 4.6 (0.6) | 4.9 (0.7) |
| HIA (a.u.) | 45.9 (23.3) | 57.2 (24.1) | 53.3 (32.2) | 39.8 (22.0) | 55.6 (32.0) |

*TD = total distance covered. $S_{MEAN}$ = mean speed. MRS = maximal running speed. HIA = frequency of high-intensity activities. a.u. = arbitrary units.

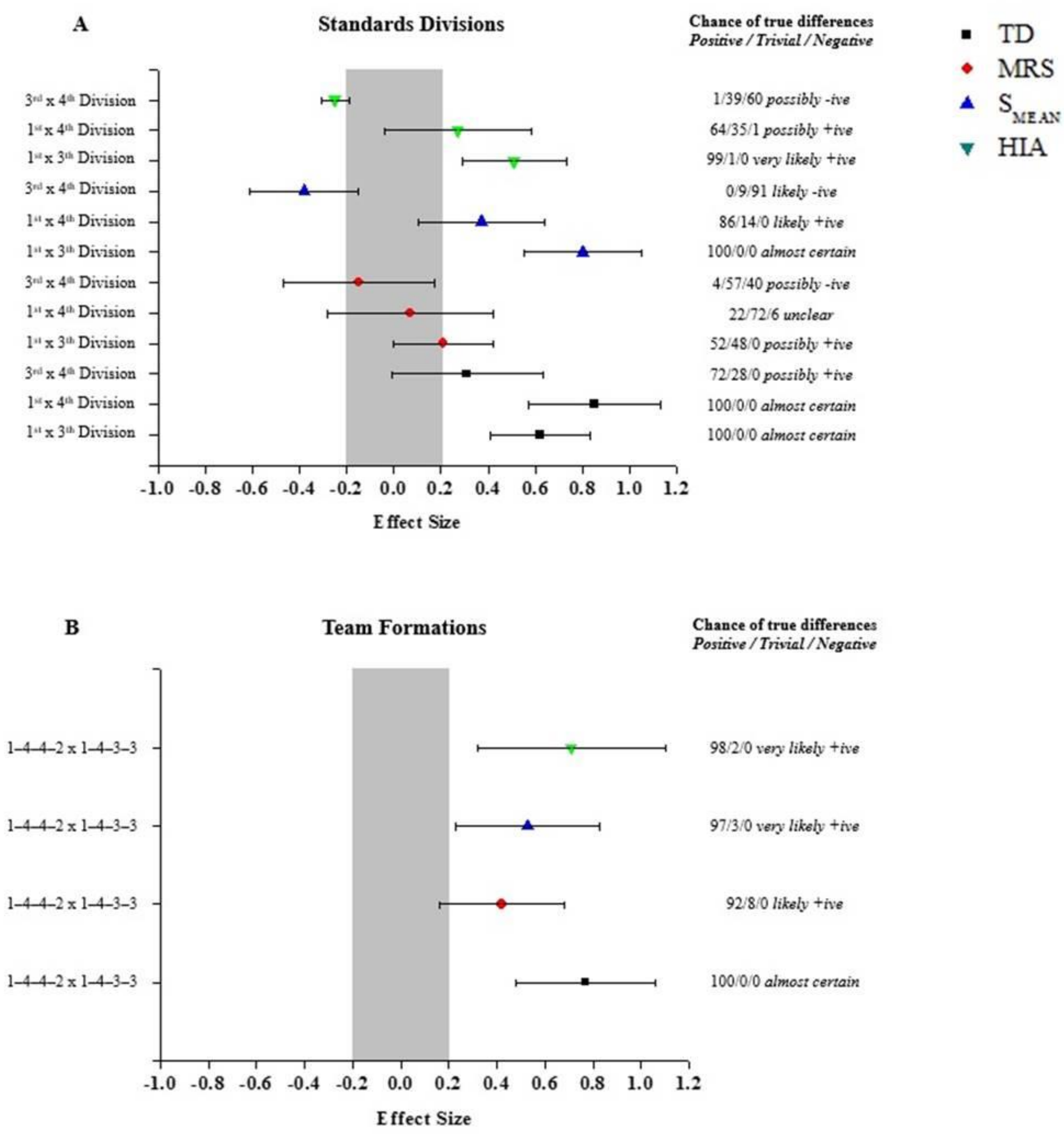


**Figure 1.** Magnitude-based inference of standards divisions and team formations on match running performance in Brazilian male soccer players.* TD = total distance covered. $S_{MEAN}$ = mean speed. MRS = maximal running speed. HIA = frequency of high-intensity activities.

In relation to playing position, results highlight that: i) external defenders, central/external midfielders and forwards covered more TD compared to central defenders (*likely* to *almost certain*) and external defenders covered more TD than central midfielders and forwards (*likely* to *almost certain*) (Figure 2A); ii) external defenders, external midfielders and forwards achieved higher MRS compared to central defenders (*very likely* to *almost certain*). External defenders reached greater MRS than central midfielders (*almost certain*) but lower than external midfielders (*likely*). External midfielders and forwards showed greater values of MRS compared to central midfielders (*likely* to *almost certain*) (Figure 2B); iii) external defenders, central/external midfielders and forwards reported greater values for $S_{MEAN}$ than central defenders (*likely* to *almost certain*). External defenders showed higher $S_{MEAN}$ compared to central/external midfielders and forwards (*likely* to *almost certain*) (Figure 2C); iv) external defenders, central/external midfielders and forwards achieved higher HIA than central defenders (*almost certain*). External defenders also reported greater HIA compared to central midfielders (*likely*) while external midfielders showed higher HIA than central midfielders (*very likely*) but less than forwards (*likely*) (Figure 2D).

**Table 2.** Mean (standard deviation) of match running performance according to playing positions (central defenders [n=88 observations]; external defenders [n=65 observations]; central midfielders [n=81 observations]; external midfielders [n=17 observations]; forwards [n=67 observations]).*

| **Variables** | **Playing Positions** | | | | |
|---|---|---|---|---|---|
| | Central Defenders | External Defenders | Central Midfielders | External Midfielders | Forwards |
| TD (m) | 8256.4 (698.8) | 9670.0 (739.5) | 9201.6 (1141.5) | 9583.8 (1432.8) | 9050.7 (1030.5) |
| MRS (km·h$^{-1}$) | 27.1 (3.2) | 29.9 (2.2) | 26.8 (4.0) | 30.4 (2.3) | 30.2 (3.7) |
| $S_{MEAN}$ (km·h$^{-1}$) | 4.4 (0.6) | 5.2 (0.5) | 5.0 (0.7) | 5.0 (0.8) | 4.9 (0.5) |
| HIA (a.u.) | 34.6 (14.5) | 66.0 (25.0) | 52.4 (31.3) | 66.1 (25.9) | 61.0 (23.3) |

*TD = total distance covered. $S_{MEAN}$ = mean speed. MRS = maximal running speed. HIA = frequency of high-intensity activities. a.u. = arbitrary units.

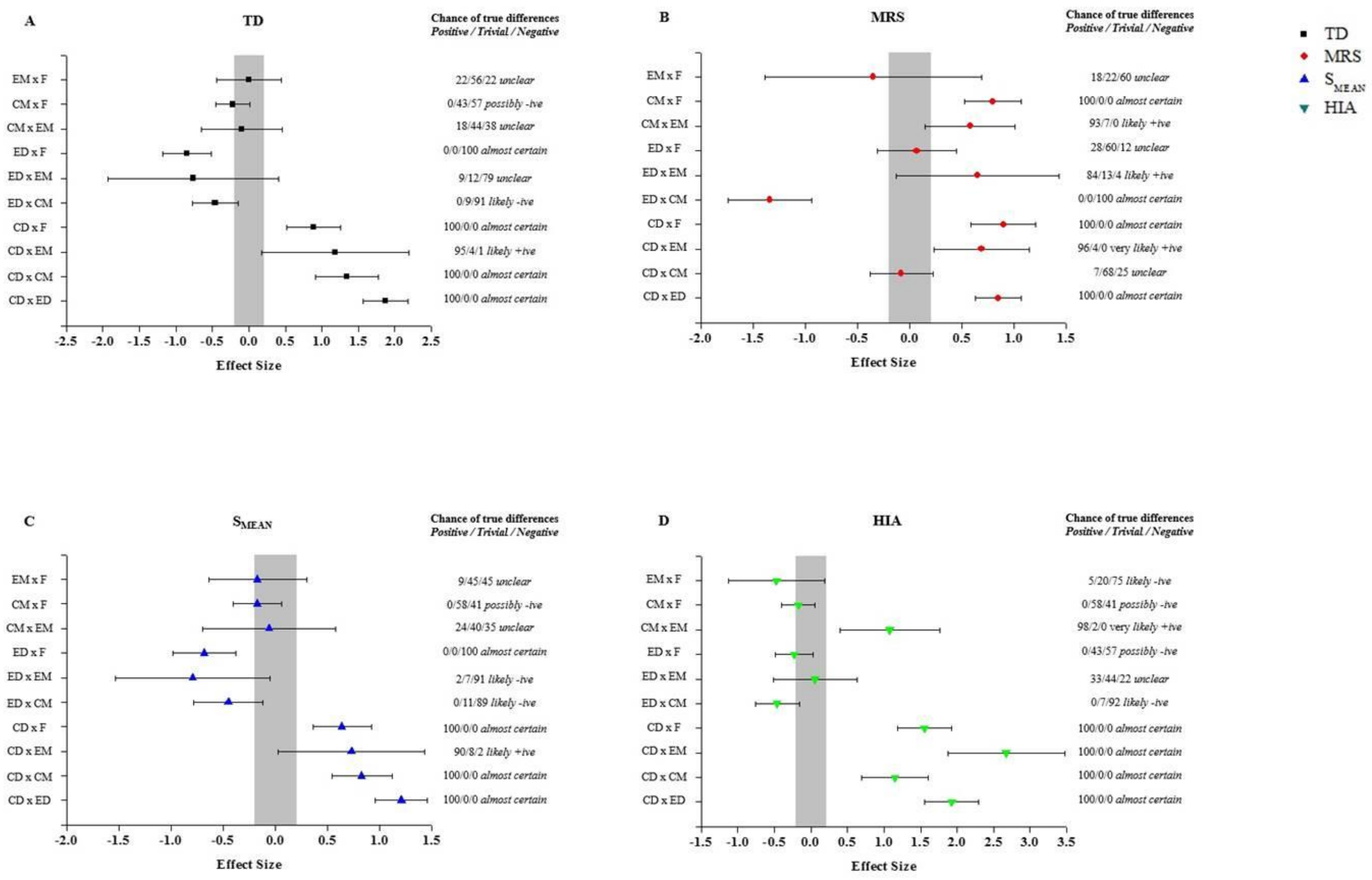


**Figure 2.** Magnitude-based inference of playing positions on match running performance in Brazilian male soccer players.* CD = central defenders. ED = external defenders. CM = central midfielders. EM = external midfielders. F = forwards. TD = total distance covered. $S_{MEAN}$ = mean speed. MRS = maximal running speed. HIA = frequency of high-intensity activities.

Table 3 reports the results of the multiple linear regression analyses. All regression coefficients were significant ($p < 0.05$). According to the relative contribution of independent variables, playing position explained 24% of the variance of MRS and 29% of HIA, while team formation explained 16% and 25% respectively. In addition, different possibilities for each independent variable were included. For instance, the minimum values of MRS and HIA can be observed if the central defender played in 1–4–4–2 formation (26.3 $km \cdot h^{-1}$ and 30.5 arbitrary units, respectively). On the other hand, maximum values were observed if the forwards played in 1–4–3–3 formation (MRS: 30.1 $km \cdot h^{-1}$; and HIA: 68.7 arbitrary units).

**Table 3.** Simulated maximum running speed (MRS: $km \cdot h^{-1}$) and frequency of high-intensity activities (HIA: arbitrary units) for the player depending of team formations and playing positions.*

| | MRS | | HIA | |
|---|---|---|---|---|
| | Team Formations | | | |
| **Playing Positions** | 1–4–4–2 | 1–4–3–3 | 1–4–4–2 | 1–4–3–3 |
| Central Defenders | 26.3 | 27.7 | 30.5 | 47.0 |
| External Defenders | 26.9 | 28.3 | 35.9 | 52.4 |
| Central Midfielders | 27.5 | 28.9 | 41.4 | 57.9 |
| External Midfielders | 28.1 | 29.5 | 46.8 | 63.3 |
| Forwards | 28.7 | 30.1 | 52.2 | 68.7 |

* Team formations: 1 = 1–4–4–2, 2 = 1–4–3–3; Playing Positions: 1 = Central Defenders, 2 = External Defenders; 3 = Central Midfielders, 4 = External Midfielders; 5 = Forwards. Model: MRS = 24.196 + 0.601*(playing positions) + 1.448*(team formations). Model: HIA = 8.538 + 5.434*(playing positions) + 16.505*(team formations).

**Discussion**

To the best knowledge of the authors, this was the first study to simultaneously examine match running performance in a reference professional soccer team taking into account competitive standard, team formation and playing position. The main findings were: i) match running performance was dependent upon all three factors. Greater running demands were observed when the team participated in lower national ($3^{rd}$, $4^{th}$ Brazilian) compared to top state divisions ($1^{st}$ São Paulo). Running output was higher for all performance variables in the 1–4–3–3 compared to the 1–4–4–2 formation. External defenders/midfielders and forwards positions reported greater running outputs than central defenders/midfielders, especially in the frequency of HIA; ii) according to the predictors of match running performance, playing position had a higher relative contribution to the variance in MRS and HIA compared to team formation.

Match running performance has previously been compared across different competitive standards. Researchers have used a range of methods to determine competitive levels (Sarmento et al., 2014): final ranking, playing standard (i.e., professional, semi-professional and amateur), quality of teams, and upper and lower placed teams. This might explain contrasting findings in the literature. Research has shown for example that lower distances were covered in total and high-intensity running ($\geq$ 19.8 $km \cdot h^{-1}$) in higher (e.g., English Premier League) compared to lower-standard divisions (e.g., English Championship, League 1) (Bradley, et al., 2013; Di Salvo, et al., 2013). In contrast, other studies demonstrated greater physical running demands at higher standards of play (Bangsbo, Norregaard, & Thorso, 1991; Mohr, Krustrup, Andersson, Kirkendal, & Bangsbo, 2008; Mohr, Krustrup, & Bangsbo, 2003; Rampinini, Impellizzeri, Castagna, Coutts, & Wisloff, 2009). Bradley et al. (2010) described no significant differences between elite domestic vs. international players for high-intensity running distance (≥ 14.4 km·h$^{-1}$) and maximal running speed (MRS). Further possible explications for these divergent results can be attributed to methodological issues and particularly speed zone delimitations to classify high-intensity running activities (Mackenzie and Cushion, 2013). Additional factors influencing running demands also include physical fitness (Krustrup et al., 2003), skill-related performance (Bradley, et al., 2013; Rampinini, et al., 2009), situational variables (Aquino, et al., 2017), team formations (Bradley, et al., 2011; Carling, 2011) and playing position (Barros, et al., 2007; Di Salvo, et al., 2007). Ideally in future studies, the relative impact of these variables on running output should be simultaneously investigated.

In Brazilian professional male soccer, this is the first study to directly compare match running performance in a reference team performing in top state league (1st São Paulo State) and lower level national divisions (3rd and 4th Brazilian). Previous studies have analysed only one division; Barros et al. (2007): 1st Brazilian Division and Aquino et al. (2017): 4th Brazilian Division. Our findings demonstrate greater physical demands (i.e., higher values of TD, MRS, $S_{MEAN}$, HIA) in the reference team in lower compared to upper divisions. This finding is in accordance with results reported by Bradley et al. (2013). In addition, Rampinini et al. (2009) reported lower total and high-intensity running distances in successful compared to unsuccessful teams in the same division. With these findings we can speculate that in upper divisions, players do not utilize their entire physical fitness potential as often as peers participating in lower divisions (Bradley, et al., 2013).

The findings presented here confirm previous evidence that team formations partly govern match running performance (Bradley, et al., 2011; Carling, 2011). In our study, teams playing in a 1–4–3–3 formation reported greater values for TD, MRS, $S_{MEAN}$ and HIA compared to teams employing a 1–4–4–2 formation. In the English Premier

League, Bradley et al. (2011) reported no significant differences between these team formations. However, magnitude-based inferences (MBI) were used here for statistical analysis. These are typically more sensitive and relevant to comparisons of athletic performance than any statistically significant effect (Buchheit, et al., 2013; Hopkins, et al., 2009). Tactical explanations can be forwarded to explain these differences. In a 1–4–3–3 formation the three midfielders support both the defenders and forwards, potentially resulting in increased physical running demands. In addition, forwards in the 1–4–3–3 formation often assume defensive functions without ball possession, contributing to the midfield sector, also possibly resulting in greater physical output. However, the present study did not differentiate between defensive and offensive running efforts made by players according to whether their team was in or out of possession and further research is necessary.

Variations in running performance are also related to the demands specific to playing position (Barros, et al., 2007; Dellal, Wong, Moalla, & Chamari, 2010; Di Salvo, et al., 2007; Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009; Vigne, Gaudino, Rogowski, Alloatti, & Hautier, 2010). However, only one study in Brazilian soccer (1$^{st}$ Brazilian Division) has reported data in relation to playing position (Barros, et al., 2007). Here, external defenders/midfielder and forward positions reported greater match-play running demands compared to central defenders/midfielders. These results are, in part, similar to those reported in other studies (e.g., Italian Serie A League: Rampinini, et al., (2007); England Premier League: Di Salvo, et al., (2009); Spanish Premier League: Di Salvo, et al., (2007)). Despite a plethora of research on performance characteristics according to playing position, to the best of our knowledge, no studies have examined the relative contribution of playing position on match running performance. Here, results demonstrate that playing position is the most important factor to explain differences in high-intensity activity i (i.e., MRS and HIA). Therefore, Brazilian coaches and practitioners would potentially need to adopt a position-specific approach to player conditioning in their teams.

Our study has some limitations; therefore the results should be interpreted with caution. First, other common team formations used in professional soccer could not be evaluated (e.g., 1–3–5–2, 1–4–1–4–1, 1–4–2–3–1). We also did not consider the influence of opposition team formation on the reference team's performance. Carling (2011) demonstrated that players (generally organized in the 1–4–3–3/1–4–5–1 formats) covered a greater distance running ≥ 14.4 $km \cdot h^{-1}$ in matches against 1–4–4–2 compared to 1–4–2–3–1 formation. Second, analysis of tactical and skill-related performance was not included. Third, all the analysis were performed in the same reference team and results are a reflection of this team. Thus, additional studies are warranted to examine the effects of competitive standard, team formations and playing positions on running, technical and tactical performance in a larger sample of Brazilian teams.

**Practical Applications**

This is the first study to simultaneously verify the effects of competitive standard, team formations and playing positions in Brazilian soccer players. Sports scientists and performance analysts use data on match running performance to mainly aid coaches and practitioners in decision-making processes for structuring the elements of training and subsequent match preparation (Bradley, et al., 2009; Carling, 2010). Our research suggests two main practical applications for Brazilian soccer players:

1) The running demands are highest in lower national divisions, compared to higher standard counterparts. Therefore, physical conditioning programs need to be adapted accordingly.

2) A combination of playing position and team formation could be used to develop a model to predict future MRS and HIA in soccer. Playing position is the variable with the greatest relative contribution to the variance in high-intensity efforts (i.e. MRS and HIA). Therefore, a position-specific approach to player conditioning should be adopted.

**Conclusions**

This study provides a comprehensive evaluation of match running performance in a professional team when competing in three standards of soccer and differences according to team formation and playing position. The findings showed greater physical running demands in the team when playing in lower divisions and when it employed a 1–4–3–3 formation. Highest running outputs were observed in external defenders/midfielders and forwards positions and playing position had the largest relative contribution to variance in high-intensity efforts (specifically MRS and HIA) during match-play.

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# CAPÍTULO 6. ESTUDO 5

# INFLUENCE OF SITUATIONAL VARIABLES, TEAM FORMATION AND PLAYING POSITION ON MATCH RUNNING PERFORMANCE AND SOCIAL NETWORK ANALYSIS OF BRAZILIAN PROFESSIONAL SOCCER PLAYERS

**Shortened title:** Performance analysis in soccer players

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**ABSTRACT**

The purpose of this study was to investigate the independent and interactive effects of situational variables, opposition team formation, and playing position on running performance and network analysis in Brazilian professional soccer players (n=22). Global Positioning System technology was used to determine total distance covered, mean speed, maximum running speed, and distance covered in six speed ranges. Social network analysis was used to assess interpersonal coordination (team interactions characterized as successful passes (n=3033) between teammates). Observations of match running performance (n=129), and network analysis (n=108) were obtained. The main results were: (i) no interactive effects between team formation and playing position were observed for running and network variables (*unclear* to *possibly*); (ii) matches played at home or against 'weaker' opponents presented greater running demands and individual/global metrics of network analysis (*likely* to *almost certain*); (iii) match outcome demonstrated influence only for running performance; matches in which the reference team won resulted in higher values than in lost matches; (iv) when the reference team competed in 1-4-4-2 formation, this resulted in greater running demands than 1-4-2-3-1 formation (*likely* to *almost certain*); (v) reduced values of running performance variables were reported in central defenders compared to other positions. Central/external midfielders reported greater closeness/betweenness centrality, out-degree and eigenvector compared to central/external defenders and forwards (*likely* to *almost certain*). The results from this study provide practical information to potentially impact on physical, tactical and technical training.


**KEY WORDS:** association football; time-motion analysis; interpersonal coordination; sports sciences.

## INTRODUCTION

Team sports performance is dependent upon the cooperative and competitive interactions between performers, and there is a need to determine the individual and collective contributions to achieve high standard performance (38). The complexity of these interactions emerging between players has been analyzed using novel investigative methods such as dynamical systems (14, 41). Indeed, contemporary empirical research recommends social network analyses to verify interpersonal coordination/interactions between soccer players; notably using completed passes between teammates (12, 20). While this approach provides novel insights into the complexity of cooperative relationships, previous research has not analyzed the influence of different contextual variables that can affect playing performance on individual and global metrics emerging from network analysis (33).

In contrast, an extensive body of literature investigating a myriad of contextual variables that affect match running performance is currently available (11). It is suggested that these contextual factors might play a substantial role in the data collection, analysis, and interpretation of performance variables (43), e.g. metrics of network analysis and running outputs. The situational variables (e.g. competition stage, match location, quality of opposition, and match status (score-line during the match) or match outcome (final result of a match)) have been identified as impacting on team sports performance (18). Soccer is dominated by strategic/tactical factors; therefore, it is reasonable to suggest that situational variables influence team and player performance (1, 26, 27, 29). For example, when a team is winning, it possible that its players adopt a ball retention strategy, slowing down the match resulting in lower physical demands (6, 30). Additional key contextual factors identified include team formation (8, 10), and playing position (3, 5, 9). However, these factors have not been simultaneously analyzed in the same study. In one of the aforementioned studies, Carling (10) examined the effects of opposition team formation and playing position on running and skill-related performance in a French League 1 club. The author did not observe interaction effects between these variables and recommended additional research. Indeed, a combined analysis of contextual effects on running performance and network analysis can provide more rounded information to improve understanding of the demands of match-play.

Therefore, the aim of this study was to examine the independent and interactive effects of situational variables (i.e. competition stage, match location, quality of opposition, match outcome), opposition team formation, and playing position on running performance and network analysis in Brazilian professional soccer players during official match-play.

## METHODS

### Experimental Approach to the Problem

An observational design was considered to examine the influence of independent variables on running performance and network analysis in a single reference Brazilian professional soccer team. A total of 18 matches played in the 3$^{rd}$ Brazilian Division in 2017 were included (May 13 to September 09; 6$^{th}$ place in the end-league ranking). The matches were performed in official stadiums (FIFA recommendations: natural grass, ~105 m x 68m), between 3:00 to 9:00 pm. A range of independent variables were analyzed jointly: situational (i.e. competition stage, match location, quality of opposition, match outcome), opposition team formation, and playing position. Match running performance was assessed using Global Positioning System (GPS) units, and network analysis by a performance analyst.

## Participants and match analysis data

Match running performance (129 observations) and network analysis data (108 observations) were obtained from 22 players [mean (standard deviation)]: age 27.9 (3.9) yrs; height 180.1 (5.2) cm; body mass 79.3 (8.6) kg). Inclusion required participation in ≥ 90 min play. GPS Sports® devices (QSTARZ; 1 Hz; Taipei, Taiwan) and a digital video camera (CASIO EX-FH25; 30 Hz; 720 x 480 pixel) were used for data collection. While a previous study reported good reliability for similar GPS technology (3), a complementary control-quality assessment was conducted. The players wearing the GPS device covered a known distance (calculated by tape measure) at different intensities (Low-intensity Running [LIR]: 11.01-14 $km \cdot h^{-1}$; Moderate-intensity Running [MIR]: 14.01-19 $km \cdot h^{-1}$; High-intensity Running [HIR]: 19.01-23 $km \cdot h^{-1}$; Sprinting [SPR]: ≥ 23.01 $km \cdot h^{-1}$). The error rate was $< 5\%$ for all running categories. The players used the same unit throughout the season (24). Local University ethical approval was obtained and the participants signed a consent form (School of Physical Education and Sport, Ribeirão Preto, Brazil; protocol number: 61884716.9.0000.5659).

## Dependent Variables

*Match Running Performance*: After the matches, the 2D reconstruction of the geographic coordinates (latitude and longitude) of each player at each time point were exported to a CSV format file through QSports software (Taipei, Taiwan) for analysis in Matlab environment (The MathWorks Inc Natick, USA). Using specific routines, the geographic coordinates were converted to cartesian coordinates (xy) and were smoothed by a Butterworth digital filter (third order; cutoff frequency = 0.4 Hz) to calculate total distance covered (TD), mean speed, maximum running speed (MRS), and distances travelled in six speed ranges (4): jogging = 4.91-11 $km \cdot h^{-1}$; LIR = 11.01-14 $km \cdot h^{-1}$; MIR

= 14.01-19 km·h$^{-1}$; HIR = 19.01-23 km·h$^{-1}$; SPR ≥ 23.01 km·h$^{-1}$; High-intensity Activities (HIA) = HIR + SPR; Number of sprints = efforts ≥ 23.01 km·h$^{-1}$.

*Network Analysis*: Interpersonal coordination was assessed through network analysis (38). Completed passes between teammates can be considered the most consequential form of interaction in soccer matches, and can be used to verify the ‘orchestration’ of group production (20). Here, a total of 3033 passes were subsequently analyzed. Individual metrics evaluated included (7, 17, 21, 38): in-degree, i.e. the number of passes that the player receives effectively; out-degree, i.e. the number of passes that the player performs effectively; closeness centrality represents how close the player is to other teammates players, where players with low closeness score have little proximity to others; betweenness centrality indicates the amount of network that a particular player “controls”, and; eigenvector identifies potential key-players who play a crucial role in organizing the offensive phases. Density and clustering coefficients were assessed as global (i.e. collective) metrics. Density describes the overall level of cooperation/coordination shown by teammates (15), i.e., higher values identify a better homogeneity of interactions between players of the same team; this may be related to team success (20). Clustering coefficients provide coaches with knowledge about subgroups of players who coordinate their actions through passes more frequently (i.e. high values of this metric represent team capacity to form functional clusters (32). Both individual and global metrics were calculated using the software Gephi (version 0.9.1). Figure 1 describes a representation of cooperative and competitive interaction between performers.

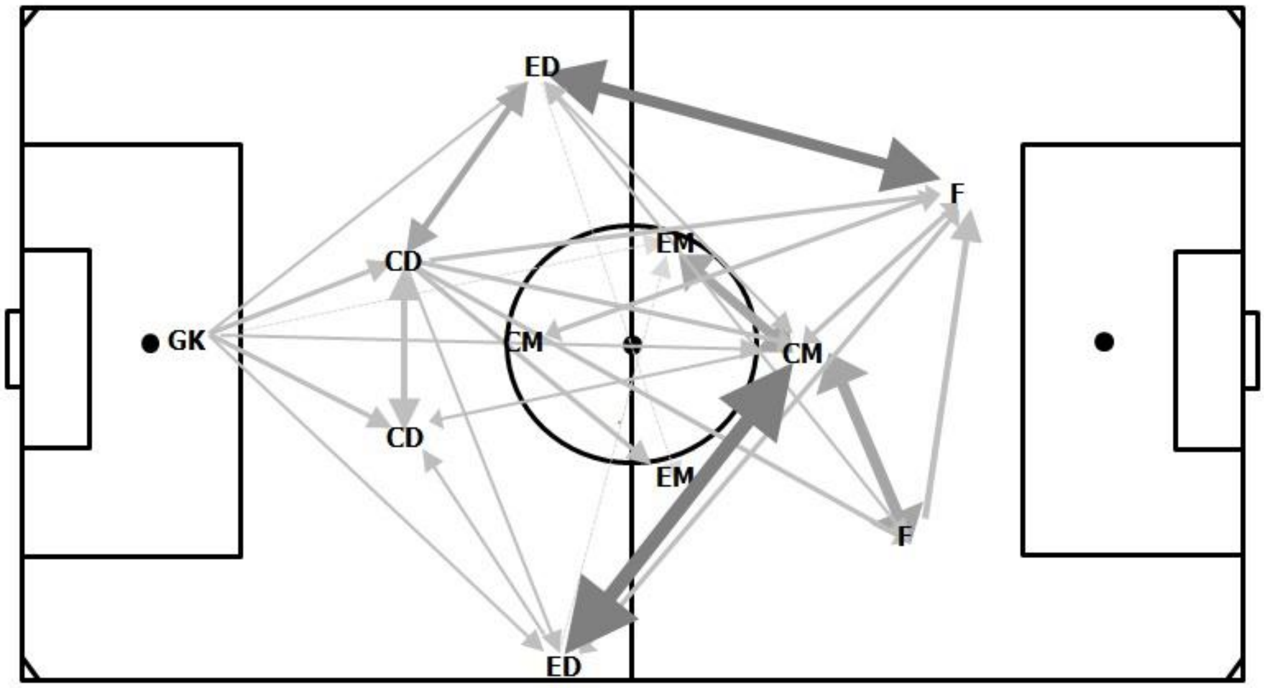


**Figure 1.** Graphical representation of cooperative and competitive interactions between soccer players. The team is displayed in 1-4-4-2 team formation. Grey arrows indicate the pass direction. The origin of the arrow indicates the player who passed the ball and the arrowhead indicates the player who received the ball. The width and color of each arrow represents the quantity of passes completed between players during the matches (thicker arrows represent a greater quantity of passes between players (38)). Gk = Goalkeeper; CD = Central Defenders; ED = External Defenders; CM = Central Midfielders; EM = External Midfielders; F = Forwards.

**Independent Variables**

For data analysis, four independent variables were considered: (i) Situational variables were identified as competition stage (matches 1-9 [1$^{st}$ stage: n=61] vs. matches 10-18 [2$^{nd}$ stage: n=68]), match location (home [n=65] vs. away [n=64]), quality of opposition (strong [n=91] vs. weak [n=38]) and match outcome (final result of the matches; lost [n=35] vs. draw [n=54] vs. won [n=40]). The quality of opposition was calculated according to k-means cluster analysis based on end-league ranking (2, 30); reference team: 6$^{th}$ place. Two clusters were identified, "higher-ranking" (strong opposition [1-7 teams ranking]) and "lower-ranking" (weak opposition [8-10 teams ranking]). (ii) Opposition team formation (1-4-4-2 vs. 1-4-4-2/1-4-2-3-1 [n=66], 1-4-1-4-1 vs. 1-4-4-2/1-4-2-3-1 [n=63]) was determined by a Brazilian Soccer Confederation qualified coach for each match (3). (iii) Playing position for each player was also defined by the same coach (central defenders [n=26] vs. external defenders [n=31] vs. central midfielders [n=26] vs. external midfielders [n=22] vs. forwards [n=24]).

**Statistical Analysis**

Data are presented as mean values (standard deviation). The normality and homogeneity of variance were checked by Shapiro-Wilk and Levene tests, respectively. Comparisons between competition stages, match location, quality of opposition, and opposition team formation were performed using t-test for independent samples. Match outcome and playing position were compared by a univariate general linear model for independent samples. Threshold values of partial eta-squared ($\eta^2$) were > 0.01 (small), > 0.06 (moderate), > 0.15 (large) (13). Interactions effects were also verified. When necessary, non-parametric counterpart tests and Bonferroni post-hoc tests were employed. Forward stepwise discriminant function analysis was employed to identify the smallest set of variables that maximized differences between the groups, using only variables that were statistically significant, and calculating the unique contribution of each variable to the discriminant function (40). The p-value threshold was pre-fixed at 5% ($p < 0.05$). Analyses were performed using the software IBM SPSS Statistics for Windows, version 22.0 (Armonk, NY: IBM Corporation®). In addition, a magnitude-based inferential (MBI) statistical approach was used (22, 42) (confidence level = 90%). Raw data outcomes in standardized Cohen units were used (Effect Size [ES]). Quantitative chances of higher or lower differences were assessed qualitatively as follows (22): <1%, almost certainly not; 1 − 5%, very unlikely; 5 − 25%, unlikely; 25 − 75%, possibly; 75 − 95%, likely; 95 − 99%, very likely; >99%, almost certain. If the chance of higher or lower differences was >5%, the true difference was assumed as unclear. Otherwise, the effect was deemed clear (22). Regarding the greater impact of the present results in the field, only likely chances that the differences were true (>75%) were considered (25).

## RESULTS

### Match Running Performance

Table 1 shows the independent effects of match situational variables on running performance. The 1st and 2nd competition stage did not differ for all variables ($t_{127}$ = -1.393 to 1.735; p = 0.08 to 0.91; ES = 0.01 to 0.28 [*unclear* to *possibly*]). Home matches presented higher values for TD, mean speed, jogging, LIR, and HIR compared to away matches ($t_{127}$ = -2.329 to 2.934; p = 0.004 to 0.04; ES = 0.35 to 0.51 [*likely* to *very likely*]), with exception for MRS. In matches against weak opponents, the reference team showed greater running demands (TD, mean speed, LIR, MIR, and HIR) than against strong opposition ($t_{127}$ = -1.993 to -2.464; p = 0.01 to 0.04; ES = 0.57 to 0.72 [*likely* to *very likely*]). In summary, when the reference team won, greater values were reported for TD, mean speed, jogging, LIR, MIR, and HIR in comparisons to matches it lost ($F_{2,126}$ = 3.245 to 6.992; p = 0.001 to 0.04; $\eta^2$ = 0.04 to 0.10; ES = 0.52 to 0.82 [*likely* to *very likely*]). Interaction effects of match location*quality of opposition*match outcome on match running performance were not significant ($F_{1,121}$ = 0.033 to 2.751; p = 0.10 to 0.67; $\eta^2$ = 0.001 to 0.02 [small]).

**Table 1.** Effects of match situational variables on match running performance in Brazilian professional soccer players [mean (standard deviation)].

| **Variables** | **Competition Stage** | | **Match Location** | | **Quality of Opposition** | | **Match Outcome** | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1st Stage | 2nd Stage | Away | Home | Strong | Weak | Lost | Draw | Won |
| TD (m) | 8739.4 (1466.4) | 9105.5 (1511.7) | 8632.3 (1483.0) | 9227.8 (1460.1)$^{*,a}$ | 8762.1 (1437.9) | 9340.1 (1571.8)$^{*,c}$ | 8384.3 (1682.5) | 9019.0 (1310.7)$^{*,d}$ | 9295.0 (1458.5)$^{**,e}$ |
| Mean Speed ($km \cdot h^{-1}$) | 5.6 (0.9) | 5.7 (0.9) | 5.4 (0.9) | 5.9 (0.9)$^{**,a}$ | 5.6 (0.8) | 5.9 (1.0)$^{*,c}$ | 5.28 (0.92) | 5.64 (0.81) $^{*,d}$ | 6.01 (0.82)$^{**,e,f}$ |
| MRS ($km \cdot h^{-1}$) | 31.3 (3.1) | 30.4 (2.9) | 31.5 (3.0) | 30.2 (3.0)$^{*,b}$ | 31.1 (3.1) | 30.3 (3.0) | 31.4 (2.7) | 31.2 (3.3) | 29.9 (2.9) |
| Jogging (m) | 3463.9 (692.5) | 3498.0 (696.7) | 3343.1 (564.9) | 3618.4 (705.6)$^{*,a}$ | 3446.5 (712.8) | 3566.6 (641.3) | 3156.2 (684.1) | 3561.5 (670.6) | 3659.2 (645.9)$^{**,e}$ |
| LIR (m) | 1253.2 (428.5) | 1343.0 (471.9) | 1217.4 (427.6) | 1382.4 (464.4)$^{*,a}$ | 1238.3 (423.2) | 1449.5 (490.0)$^{**,c}$ | 1156.5 (468.4) | 1306.5 (410.4) | 1418.4 (467.8)$^{**,e}$ |
| MIR (m) | 1120.3 (429.9) | 1213.3 (535.3) | 1090.1 (481.5) | 1247.4 (486.8) | 1102.3 (435.5) | 1329.8 (572.2)$^{**,c}$ | 1049.5 (535.4) | 1151.8 (436.3) | 1297.8 (495.0)$^{*,e}$ |
| HIR (m) | 341.6 (193.0) | 369.4 (214.2) | 316.3 (180.4) | 395.6 (219.4)$^{*,a}$ | 332.5 (191.5) | 413.1 (224.1)$^{*,c}$ | 301.8 (185.5) | 350.7 (189.0) | 411.4 (228.9)$^{*,e}$ |
| SPR (m) | 232.3 (151.0) | 225.4 (164.4) | 222.1 (148.8) | 235.1 (166.8) | 219.7 (154.9) | 250.1 (164.0) | 211.0 (129.6) | 231.1 (161.5) | 240.8 (176.1) |
| HIA (m) | 573.9 (320.0) | 594.8 (353.4) | 538.4 (301.0) | 630.6 (365.4) | 552.2 (323.9) | 663.3 (358.4) | 512.8 (281.8) | 581.8 (239.1) | 652.1 (382.9) |
| NS (a.u.) | 28.0 (21.6) | 28.8 (22.9) | 26.7 (20.7) | 30.2 (23.6) | 26.4 (22.0) | 33.4 (22.2) | 25.9 (17.9) | 27.1 (23.0) | 32.5 (24.3) |

Note: TD = Total Distance covered. MRS = Maximal Running Speed. LIR = Low-intensity Running (11.01-14 $km \cdot h^{-1}$). MIR = Moderate-intensity Running (14.01-19 $km \cdot h^{-1}$). HIR = High-intensity Running (19.01-23 $km \cdot h^{-1}$). SPR = Sprinting ($\geq$ 23.01 $km \cdot h^{-1}$). HIA = High-intensity Activities (HIR + SPR). NS = Number of Sprints [a.u. (arbitrary unites)], characterized by frequencies of efforts $\geq$ 23.01 $km \cdot h^{-1}$. * p-value < 0.05. ** p-value < 0.01. $^{a}$ Home > Away. $^{b}$ Home < Away. $^{c}$ Weak > Strong. $^{d}$ Draw > Lost. $^{e}$ Won > Lost. $^{f}$ Won > Draw.

Interaction effects of both opposition team formation and playing position were not significant ($F_{12,109}$ = 0.646 to 1.350; p = 0.20 to 0.80; $\eta^2$ = 0.06 to 0.12 [moderate]). However, when the reference team competed in a 1-4-4-2 formation, greater running demands (i.e. TD, mean speed, jogging, LIR, MIR, HIR) were observed against a 1-4-4-2 compared to 1-4-2-3-1 formation (p < 0.01; ES = 0.61 to 1.00 [*very likely* to *almost certain*]) (Table 2). In contrast, no difference was reported for the reference team competing in 1-4-1-4-1 against 1-4-4-2 and 1-4-2-3-1 formation (p ≥ 0.05; ES = 0.01 to 0.13 [*unclear*]) (Supplemental file 1).

Independent analysis of playing position showed reduced values for central defenders compared to other positions in all running performance variables (p < 0.05; ES = 0.74 to 5.18 [*likely* to *almost certain*]), with the exception being MRS. External defenders and midfielders run more in HIR, sprinting, and HIA than central midfielders (p < 0.01; ES = 0.82 to 1.25 [*very likely* to *almost certain*]). Central midfielders covered greater distances jogging than external defenders (p = 0.03; ES = 0.67 [*very likely*]), and forwards (p = 0.02; ES = 0.83 [*very likely*]). External midfielders showed higher values of LIR and MIR compared to central midfielders (p = 0.01; ES = 0.84 [*almost certain*]), and forwards (p = 0.007, ES = 0.74 [*very likely*]; and p = 0.005, ES = 0.80 [*very likely*] – respectively). Forwards covered greater distances in HIA than central midfielders (p = 0.02; ES = 1.18 [*almost certain*]). Finally, external defenders performed a greater number of sprints than other positions (p < 0.01; ES = 0.66 to 1.50 [*very likely* to *almost certain*]) (Table 3).

**Table 2.** Effects of opposition team formation (1-4-4-2 vs. 1-4-2-3-1 or 1-4-4-2) according to playing position on match running performance in Brazilian professional soccer players [mean (standard deviation)].

| Position | Opposition Team Formation | TD (m) | Mean Speed ($km \cdot h^{-1}$) | MRS ($km \cdot h^{-1}$) | Jogging (m) | LIR (m) | MIR (m) | HIR (m) | SPR (m) | HIA (m) | NS (a.u.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1-4-4-2 vs. | | | | | | | | | | |
| CD | 1-4-2-3-1 | 7517.7 (817.8) | 4.6 (0.5) | 29.9 (3.1) | 2871.8 (572.8) | 805.9 (275.1) | 609.1 (164.8) | 154.9 (51.4) | 163.3 (173.7) | 318.2 (207.2) | 13.6 (12.3) |
| CD | 1-4-4-2 | 8017.8 (515.2) | 4.8 (0.5) | 28.4 (1.7) | 3075.2 (619) | 843.7 (264.8) | 722.2 (214.2) | 149.0 (72.0) | 80.4 (39.7) | 229.4 (103.1) | 8.2 (4.1) |
| ED | 1-4-2-3-1 | 9020.4 (1442.3) | 5.5 (0.9) | 32.2 (2.3) | 3136.3 (445.1) | 1217.3 (429.3) | 1279.2 (565.3) | 460.3 (228) | 310.9 (167.7) | 771.2 (374.6) | 46.0 (22.9) |
| ED | 1-4-4-2 | 10442.3 (1056.3) | 6.4 (0.6) | 30.8 (2.5) | 3717.5 (759) | 1641.5 (244.8) | 1530.2 (457.2) | 569.3 (185.8) | 359.9 (241.6) | 929.2 (393.3) | 53.1 (34.6) |
| CM | 1-4-2-3-1 | 8873.3 (884.6) | 5.5 (0.5) | 32.1 (2.7) | 3762.4 (531) | 1361.0 (450.2) | 1001.5 (252.8) | 214.7 (55.6) | 174.8 (64.2) | 389.6 (91.1) | 16.4 (7.0) |
| CM | 1-4-4-2 | 10144.6 (971.9) | 6.4 (0.5) | 27.8 (3.6) | 4444.7 (415.7) | 1837.4 (314.6) | 1529.4 (416.6) | 304.0 (106.0) | 113.5 (71) | 417.5 (152.1) | 14.4 (9.0) |
| EM | 1-4-2-3-1 | 7607.3 (3468.4) | 5.0 (1.5) | 30.8 (1.9) | 2880.5 (1348.5) | 1080.7 (596.7) | 1075.8 (608.7) | 329.4 (231.4) | 181.8 (68.2) | 511.2 (288.3) | 20.0 (10.0) |
| EM | 1-4-4-2 | 10025.8 (1404.3) | 6.4 (0.7) | 30.4 (2.2) | 3748.8 (535.1) | 1668.1 (504) | 1629.9 (538.2) | 548.7 (192.2) | 272.4 (98.3) | 821.1 (247.5) | 29.3 (13.2) |
| F | 1-4-2-3-1 | 8135 (1108.1) | 5.4 (0.2) | 31.6 (3.7) | 3153.5 (497.7) | 1080.6 (277.6) | 995.8 (259.3) | 288.2 (72.4) | 231.3 (56.9) | 519.5 (57.8) | 26.0 (8.9) |
| F | 1-4-4-2 | 9227.8 (1132.9) | 6.0 (0.3) | 31.0 (3.4) | 3746.6 (604.3) | 1291.2 (305.3) | 1232.5 (226) | 436.7 (135.8) | 291.6 (148.9) | 728.3 (265.6) | 35.0 (17.8) |
| Mean All Positions | 1-4-2-3-1 | 8316.8 (1589.4) | 5.2 (0.8) | 31.4 (2.8) | 3186.6 (699.2) | 1116.0 (425.1) | 993.3 (437.9) | 291.2 (178.8) | 217.8 (132.2) | 508.9 (281.8) | 25.4 (18.5) |
| Mean All Positions | 1-4-4-2 | 9575.7 (1320.4)**,a | 6.0 (0.8)**,a | 29.9 (2.9) | 3724.3 (699)**,a | 1441.5 (458.6)**,a | 1326.3 (480.1)**,a | 417.4 (208.4)**,a | 240.8 (177.6) | 658.2 (360.3) | 30.5 (25.1) |

Note: CD = Central Defenders. ED = External Defenders. CM = Central Midfielders. EM = External Midfielders. F = Forwards. TD = Total Distance covered. MRS = Maximal Running Speed. LIR = Low-intensity Running (11.01-14 $km \cdot h^{-1}$). MIR = Moderate-intensity Running (14.01-19 $km \cdot h^{-1}$). HIR = High-intensity Running (19.01-23 $km \cdot h^{-1}$). SPR = Sprinting ($\geq$ 23.01 $km \cdot h^{-1}$). HIA = High-intensity Activities (HIR + SPR). NS = Number of Sprints [a.u. (arbitrary unites)], characterized by frequencies of efforts $\geq$ 23.01 $km \cdot h^{-1}$. ** p-value < 0.01. [a] 1-4-4-2 vs. 1-4-4-2 > 1-4-4-2 vs. 1-4-2-3-1.

**Table 3.** Effects of playing position on match running performance in Brazilian professional soccer players [mean (standard deviation)].

| Variables | Playing Position | | | | |
|---|---|---|---|---|---|
| | CD | ED | CM | EM | F |
| TD (m) | 7525.2 (922.2) | 9602.5 (1188.6)$^{**,a}$ | 9216.1 (1244.6)$^{**,b}$ | 9576.1 (1981.2)$^{**,c}$ | 8693.7 (1013.9)$^{**,d}$ |
| Mean Speed ($km \cdot h^{-1}$) | 4.6 (0.6) | 5.9 (0.7)$^{**,a}$ | 5.8 (0.8)$^{**,b}$ | 6.2 (1)$^{**,c}$ | 5.7 (0.4)$^{**,d}$ |
| MRS ($km \cdot h^{-1}$) | 29.9 (3) | 32.1 (2.5) | 30.2 (3.2) | 30.6 (3.1) | 31.3 (3.3) |
| Jogging (m) | 2968.1 (629.4) | 3451.1 (536.4)$^{*,a}$ | 3946.4 (613.6)$^{**,b,e,f}$ | 3659.8 (809.1)$^{**,c}$ | 3411.8 (524.1)$^{*,d}$ |
| LIR (m) | 845 (267.1) | 1404.4 (353.6)$^{**,a}$ | 1477.1 (444.8)$^{**,b}$ | 1590.5 (518.6)$^{**,c,g}$ | 1202.8 (251)$^{**,d}$ |
| MIR (m) | 627 (205.5) | 1398.5 (457.5)$^{**,a}$ | 1163.8 (424.8)$^{**,b}$ | 1537.3 (504.5)$^{**,c,g,h}$ | 1129.6 (217.7)$^{**,d}$ |
| HIR (m) | 143.1 (69.7) | 504.4 (194.2)$^{**,a,i}$ | 267.5 (158.5)$^{*,b}$ | 467.4 (196.2)$^{**,c,h}$ | 390.1 (110.2)$^{**,d}$ |
| SPR (m) | 126.6 (138.5) | 338.7 (183.3)$^{**,a,i}$ | 147.4 (99.4)$^{*,b}$ | 259.7 (128.7)$^{**,c,h}$ | 256.5 (102.2)$^{**,d}$ |
| HIA (m) | 269.8 (182.4) | 843.1 (354)$^{**,a,i}$ | 414.9 (234.5)$^{*,b}$ | 727.1 (294.2)$^{**,c,h}$ | 646.6 (187)$^{**,d,j}$ |
| NS (a.u.) | 10.9 (8.6) | 49.1 (25.6)$^{**,a,i,k,l}$ | 17.5 (14.1)$^{*,b}$ | 30.1 (19.4)$^{**,c}$ | 31.2 (13.4)$^{**,d}$ |

Note: CD = Central Defenders. ED = External Defenders. CM = Central Midfielders. EM = External Midfielders. F = Forwards. TD = Total Distance covered. MRS = Maximal Running Speed. LIR = Low-intensity Running (11.01-14 $km \cdot h^{-1}$). MIR = Moderate-intensity Running (14.01-19 $km \cdot h^{-1}$). HIR = High-intensity Running (19.01-23 $km \cdot h^{-1}$). SPR = Sprinting ($\geq$ 23.01 $km \cdot h^{-1}$). HIA = High-intensity Activities (HIR + SPR). NS = Number of Sprints [a.u. (arbitrary unites)], characterized by frequencies of efforts $\geq$ 23.01 $km \cdot h^{-1}$. * p-value < 0.05. ** p-value < 0.01. [a] ED > CD. [b] CM > CD. [c] EM > CD. [d] F > CD. [e] CM > ED. [f] CM > F. [g] EM > F. [h] EM > CM. [i] ED > CM. [j] F > CM. [k] ED > EM. [l] ED > F.

The stepwise discriminant function showed the results for the smallest set of variables that best discriminated between each playing position. In the first discriminant function (eigenvalue = 0.94; Wilks' lambda = 0.32; canonical correlation = 0.67; chi-squared = 142.267; $p < 0.001$), the order of variables was: HIR, LIR, jogging, and number of sprints. The other independent variables that showed a significant difference for match running performance (i.e., match location, quality of oppositions, match outcome, and opposition team formation) demonstrated greater values of Wilks' Lambda (0.89 to 0.95), and reduced values for canonical correlation (0.21 to 0.33) meaning low importance to predict the separation between the aforementioned independent variables, and reduced effect size, respectively.

**Network Analysis**

Individual and global metrics were not significant in the comparisons between 1$^{st}$ vs. 2$^{nd}$ competition stage (U = 1,113.500 to 1,633.000 to p = 0.06 to 0.98; ES = 0.07 to 0.22 [*unclear* to *possibly*]). In home matches, the reference team reported greater in-degree, out-degree, and clustering compared to away games (U = 1,058.500 to 1,125.500; p = 0.02 to 0.04; ES = 0.32 to 0.42 [*likely*]). Matches played against weak opposition demonstrated higher values of individual (in-degree, out-degree, closeness centrality, clustering) and global metrics (density, clustering coefficients) than against strong opposition (U = 1,528.000 to 1,821.000; $p < 0.001$ to p = 0.04; ES 0.49 to 1.18 [*likely* to *almost certain*]). According to match outcome, no significant differences were reported for individual and global metrics ($H_2$ = 0.151 to 3.056; p = 0.22 to 0.92; ES = 0.02 to 0.30 [*unclear* to *possibly*]) (Table 4). Comparisons of individual and global metrics between matches played in 1-4-4-2 vs. 1-4-2-3-1/1-4-4-2 and 1-4-1-4-1 vs. 1-4-2-3-1/1-4-4-2 team formation showed none were significantly different ($H_3$ = 0.443 to 3.739; p = 0.30 to 0.93; ES = 0.01 to 0.52 [*unclear* to *possibly*]) (Supplemental file 2 and 3, respectively).

Playing position confirmed significant differences for individual metrics. External defenders showed higher in-degree and eigenvector than central defenders (p = 0.01, ES = 0.43 [*likely*], p = 0.001, ES = 0.56 [*likely*]; respectively), but reduced out-degree and eigenvector compared to external midfielders (p = 0.03, ES = 0.76 [*almost certain*]; p = 0.001, ES = 1.04 [*almost certain*]; respectively). Central defenders and central midfielders reported greater values of out-degree, closeness, and betweenness centrality compared to forwards ($p < 0.001$ to p = 0.03; ES = 0.64 to 1.83 [*likely* to *almost certain*]). External midfielders showed greater values for all individual metrics compared to forwards ($p < 0.001$ to p = 0.02, ES = 0.46 to 1.61 [*likely* to *almost certain*]), with exception for clustering. In addition, central midfielders reported greater closeness centrality compared to external defenders (p = 0.003; ES = 0.57 [*likely*]) (Table 5). No interactive effects were observed for all independent variables in the network analysis.

**Table 4.** Effects of match situational variables on individual and global metrics of network analysis in Brazilian professional soccer players [mean (standard deviation)].

| **Variables** | **Competition Stage** | | **Match Location** | | **Quality of Opposition** | | **Match Outcome** | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1st Stage | 2nd Stage | Away | Home | Strong | Weak | Lost | Draw | Won |
| *Individual Metrics* | | | | | | | | | |
| In Degree | 25.6 (9.9) | 25.8 (10.7) | 23.3 (7.4) | 27.7 (11.6)[*,a] | 23.5 (9.6) | 30.7 (9.7)[**,b] | 26.6 (11.8) | 24.0 (7.8) | 27.3 (11.5) |
| Out Degree | 24.3 (12.1) | 25.0 (11.6) | 22.5 (10.4) | 26.3 (12.8)[*,a] | 22.5 (11.7) | 29.2 (11.1)[**,b] | 26.2 (13.7) | 22.4 (9.6) | 26.2 (12.9) |
| Closeness Centrality | 0.8 (0.2) | 0.8 (0.2) | 0.8 (0.2) | 0.8 (0.1) | 0.8 (0.2) | 0.8 (0.1)[*,b] | 0.8 (0.2) | 0.8 (0.2) | 0.8 (0.2) |
| Betweenness Centrality | 3.0 (2.3) | 2.7 (1.5) | 3.0 (2.1) | 2.8 (2.0) | 3.0 (2.2) | 2.6 (1.5) | 2.8 (2.1) | 3.0 (2.2) | 2.8 (1.7) |
| Clustering | 0.7 (0.1) | 0.8 (0.1) | 0.7 (0.1) | 0.7 (0.1)[*,a] | 0.7 (0.1) | 0.8 (0.1)[**,b] | 0.7 (0.1) | 0.7 (0.1) | 0.7 (0.1) |
| Eigenvector | 0.8 (0.1) | 0.9 (0.1) | 0.8 (0.1) | 0.9 (0.1) | 0.8 (0.1) | 0.9 (0.1) | 0.8 (0.1) | 0.9 (0.1) | 0.8 (0.1) |
| *Global Metrics* | | | | | | | | | |
| Density | 0.7 (0.1) | 0.7 (0.05) | 0.7 (0.1) | 0.7 (0.1) | 0.7 (0.1) | 0.8 (0.02)[*,b] | 0.7 (0.1) | 0.7 (0.1) | 0.7 (0.1) |
| Clustering Coefficients | 0.7 (0.1) | 0.8 (0.1) | 0.7 (0.05) | 0.7 (0.1) | 0.7 (0.1) | 0.8 (0.02)[*,b] | 0.8 (0.1) | 0.7 (0.05) | 0.7 (0.1) |

Note: * p-value < 0.05. ** p-value < 0.01. [a] = Home > Away. [b] = Weak > Strong.

**Table 5.** Effects of playing position on individual and global metrics of network analysis in Brazilian professional soccer players [mean (standard deviation)].

| **Variables** | **Playing Position** | | | | |
|---|---|---|---|---|---|
| | CD | ED | CM | EM | F |
| *Individual Metrics* | | | | | |
| In Degree | 21.7 (6.9) | 25.4 (10.4) | 28.2 (11.3) | 32.2 (9.5)$^{**,d,e}$ | 20 (7.5) |
| Out Degree | 24.5 (9.6)$^{*,a}$ | 20.9 (11.0) | 29.8 (11.4)$^{**,b}$ | 31.1 (12.6)$^{*,e,f}$ | 15.0 (7.1) |
| Closeness Centrality | 0.8 (0.2)$^{*,a}$ | 0.7 (0.2) | 0.9 (0.1)$^{**,b,c}$ | 0.8 (0.2)$^{**,e}$ | 0.7 (0.1) |
| Betweenness Centrality | 3.7 (2.9)$^{*,a}$ | 2.4 (1.8) | 3.5 (1.7)$^{**,b}$ | 3.1 (1.1)$^{**,e}$ | 1.4 (0.9) |
| Clustering | 0.7 (0.1) | 0.7 (0.1) | 0.7 (0.1) | 0.7 (0.1) | 0.8 (0.1) |
| Eigenvector | 0.8 (0.1) | 0.8 (0.1) | 0.9 (0.1) | 0.9 (0.1)$^{**,e,f}$ | 0.8 (0.1) |

Note: CD = Central Defenders. ED = External Defenders. CM = Central Midfielders. EM = External Midfielders. F = Forwards. * p-value < 0.05. ** p-value < 0.01. $^{a}$ = CD > F. $^{b}$ = CM > F. $^{c}$ = EM > ED. $^{d}$ = EM > F. $^{e}$ = EM > CD. $^{f}$ = CM > ED.D

## DISCUSSION

This study investigated the influence of independent variables on running performance and network analysis in a reference Brazilian professional soccer team during official match-play. The results highlighted that: (i) interactive effects were not significant for either of the indicators of performance (running output and network analysis), and no differences were observed for comparisons between $1^{st}$ vs. $2^{nd}$ competition stage; (ii) matches played at home or against weak opposition presented greater running demands and individual/global metrics of network analysis compared to their counterparts; (iii) match outcome demonstrated influence only for running performance with the team reporting higher values in matches won versus lost; (iv) when the team competed in a 1-4-4-2 formation, greater running demands were observed against a 1-4-4-2 compared to 1-4-2-3-1 formation; (v) reduced values for running performance variables were reported in central defenders compared to peers in the other positions. Central/external midfielders reported greater closeness/betweenness centrality, out-degree, and eigenvector compared to central/external defenders and forwards.

In this study, greater running outputs (e.g. TD, mean speed, HIR) were reported in home compared to away matches. In addition, the number of passes that players received and successfully completed was higher (i.e. in- and out-degree metrics) in home matches. The reference team obtained 80% of the points disputed in home matches (i.e. noticeable home advantage). This finding confirms the results of a meta-analysis showing that home advantage in soccer (23). Several factors associated with home advantage have been discussed (34-36): local crowd support, travel fatigue for opposition, familiarity with local conditions, referee bias to home team, territoriality, and psychological factors.

In relation to the quality of opposition, greater intensity running and interpersonal coordination were observed in matches against weak opposition. These findings suggest that against weaker opposition the reference team presented a better homogeneity of interactions between players and team capacity to play more collectively. These results concur with the findings reported by Lago (29) and Lago-Peñas and Dellal (27) which reported that top-ranked teams tend to control matches, since greater in- and out-degree were observed against weak opposition. Furthermore, the higher values of closeness centrality (i.e. how close the player is to others) observed in the present study explain the greater intensity running (large correlations between closeness centrality and HIR [results not shown]). These findings contrast with those reported in previous research which has shown greater running demands against strong opposition (1, 37). In other countries the team quality also influences match performance variables. For example, in the Chinese super league (44) the top-ranked group of teams presented greater physical (sprinting distance, total distance covered without ball possession) and technical performance (possession in opponents' half, number of entry passes in the final 1/3 of the field and the penalty area) compared to middle/lower-ranked groups.

In this study, the match outcome only seemed to influence running performance. Greater intensity running distances were observed in matches that the team won as opposed to losing. This result can be related to different styles of play during the matches. Previous research demonstrated four styles (see more details in (28)): possession, set pieces attack, counterattacking, and transitional. The coaching staff of the reference team provided information on the strategies adopted according to score-line. When winning matches for example, the team adopted a counterattacking style, i.e. a direct style of play (long and fast passes; see Lago (29)), and this can induce higher match intensity running (1). On the other hand, when losing the matches, used possession style of play with the purpose to "control" the match. Therefore, in this study, winning teams' exhibit different and consistent profiles compared to losing teams (19). In particular, these findings indicate that physical demands vary according to the style of play adopted in different moments of the match. In addition, the present study verified the influence of opposition team formation on match running performance. When the reference team competed in a 1–4–4–2, greater running performance (i.e. mean speed, HIR) was observed against a 1-4-4-2 compared to a 1-4-2-3-1 formation. Carling (10) also demonstrated that players in possession competing in a 1–4–3–3/1–4–5–1 covered greater distances in matches in 1–4–4–2 compared to a 1–4–2–3–1 formation in French League 1. The same study (10) also identified variations on skill-related performance according to opposition formation whereas here, network analysis did not show a significant difference. These results may be useful to aid coaches and practitioners in their tactical preparation (10).

The analysis of playing position on running and skill-related performance has received extensive coverage (9, 16, 39). In Brazilian soccer however, a few studies have addressed this topic but only for match running performance (3, 5, 31). To the best knowledge of the present authors, the current study is the first to provide a detailed investigation of running and network analysis of professional soccer players in all playing positions. This study identified that distance covered in HIR is the best variable for discriminating running outputs across playing positions. According to the network analysis, in general, central/external midfielders reported greater closeness/betweenness centrality, out-degree, and eigenvector compared to central/external defenders and forwards, i.e. midfielders are more effective in performing passes, they are closer to the other players in the field, “control” as many networks, and are key players for the organization of offensive phases. Therefore, it seems relevant that coaching staff adopt a position-specific approach during training.

This study presented some limitations; therefore, the results should be interpreted with caution. First, a relatively small number of matches were analyzed, with a limited sample for analysis of interactive effects between independent vs. dependent variables. However, this low number was due to the combined analysis of running performance and interpersonal coordination in the same matches. Here, we reported the main team formation used by the reference/opposition teams. Future research should analyze the effects of team formation according to different phases of play (in possession, out of possession), and transitions. Finally, the unbalanced number of home and away matches is a further limitation. On the other hand, this study has strengths, namely: (i) the use of a more holistic analysis, i.e. running performance and interpersonal coordination (network analysis); and (ii) inclusion of the main recognized independent variables that affect the performance of soccer players.

## PRACTICAL APPLICATION

The current findings are novel and provide pertinent information on physical and technical-tactical requirements which can inform training. The results show mainly the independent influence of situational variables, opposition team formation, and playing position on running performance and network analysis in Brazilian soccer players during official matches. Home matches or against weak opposition place greater physical, technical, and tactical demands on players. Therefore, coaches and practitioners account for this when prescribing training intensity in close proximity to home matches. In matches won by the reference team, the players presented greater values for TD, mean speed, LIR, MIR, and HIR than matches that were lost. This information can aid coaches to adapt post-match recovery strategies and the intensity of subsequent training sessions. Players should be physically prepared for competing in the 1-4-4-2 versus the opposition in the 1-4-4-2 formation. Finally, specific running and technical-tactical demands were observed for the five playing positions studied; thus, position-specific approach should be adopted in training.

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**Supplemental file 1.** Effects of opposition team formation (1-4-1-4-1 vs. 1-4-2-3-1 or 1-4-4-2) according to playing position on match running performance in Brazilian professional soccer players [mean (standard deviation)].

| Position | Opposition Team Formation | TD (m) | Mean Speed ($km \cdot h^{-1}$) | MRS ($km \cdot h^{-1}$) | Jogging (m) | LIR (m) | MIR (m) | HIR (m) | SPR (m) | HIA (m) | NS (a.u.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1-4-1-4-1 vs. | | | | | | | | | | |
| CD | 1-4-2-3-1 | 6993.8 (1133.5) | 4.6 (0.8) | 29.5 (2.8) | 2933.1 (719.8) | 940.3 (354.9) | 534.3 (207.9) | 118.8 (62.8) | 105.8 (66.7) | 224.6 (66.6) | 11.0 (5.3) |
| CD | 1-4-4-2 | 7565.7 (1027.7) | 4.7 (0.6) | 31.4 (3.8) | 3002.5 (739.2) | 803.4 (213.0) | 642.9 (237.2) | 147.1 (95.9) | 147.5 (200.1) | 294.6 (275.7) | 10.6 (10.2) |
| ED | 1-4-2-3-1 | 9397.4 (1074.5) | 5.8 (0.7) | 32.0 (1.9) | 3459.1 (213.8) | 1346.5 (376.7) | 1345.6 (483.6) | 539.4 (223.5) | 375.7 (179.3) | 915 (392.4) | 49.1 (27.6) |
| ED | 1-4-4-2 | 9524.5 (791.9) | 5.9 (0.4) | 33.3 (2.8) | 3492.4 (472.8) | 1404.8 (250) | 1432.5 (357.1) | 452.9 (145.4) | 312.9 (162.4) | 765.8 (289.3) | 48.0 (20.1) |
| CM | 1-4-2-3-1 | 8789.8 (1020.8) | 5.7 (0.8) | 29.2 (3.7) | 3841.4 (281.8) | 1359.4 (393.3) | 1097.3 (369.9) | 212.5 (183.7) | 84.1 (39.5) | 296.6 (206.5) | 9.5 (6.0) |
| CM | 1-4-4-2 | 9255.4 (1639.0) | 5.8 (1.0) | 30.7 (1.9) | 3874.6 (849.2) | 1441.8 (496.3) | 1127.2 (515.4) | 332.2 (213.2) | 192.0 (143.1) | 524.2 (345.3) | 26.4 (21.0) |
| EM | 1-4-2-3-1 | 9692.3 (1425.6) | 6.2 (0.6) | 31.5 (4.2) | 3718.0 (621.3) | 1557.8 (507.2) | 1440.4 (377.1) | 496.3 (172.6) | 278.3 (141.2) | 774.5 (294.3) | 33.9 (25.6) |
| EM | 1-4-4-2 | 10449 (957.0) | 7.0 (0.4) | 29.5 (3.5) | 4095.1 (523.6) | 1951.1 (91.6) | 1931.1 (216.2) | 439.9 (199.3) | 281.0 (184.5) | 720.9 (349.0) | 33.8 (23.6) |
| F | 1-4-2-3-1 | 8636.5 (642.2) | 5.7 (0.7) | 33.8 (3.3) | 3252.6 (189.3) | 1217.2 (162.1) | 1176.4 (64.8) | 415.6 (54.4) | 267.2 (30.7) | 682.8 (48.3) | 33.3 (11.0) |
| F | 1-4-4-2 | 8448.4 (558.1) | 5.6 (0.4) | 29.4 (1.8) | 3246.3 (317.3) | 1178.8 (137.3) | 1067.5 (159.3) | 408.4 (50.7) | 214.9 (70.9) | 623.3 (113.3) | 28.8 (11.1) |
| Mean All Positions | 1-4-2-3-1 | 8762.5 (1434.8) | 5.6 (0.9) | 31.1 (3.4) | 3463.2 (552.8) | 1299.9 (422.7) | 1326.3 (480.1) | 363.3 (229.1) | 226.2 (159.3) | 589.5 (372.1) | 27.9 (23.8) |
| Mean All Positions | 1-4-4-2 | 9020.8 (1409.4) | 5.8 (0.9) | 31.1 (3.0) | 3535.2 (713.6) | 1334.7 (456.6) | 1211.2 (523.9) | 350.1 (187.4) | 228.8 (163.2) | 578.9 (325.7) | 29.8 (21.4) |

Note: CD = Central Defenders. ED = External Defenders. CM = Central Midfielders. EM = External Midfielders. F = Forwards. TD = Total Distance covered. MRS = Maximal Running Speed. LIR = Low-intensity Running (11.01-14 $km \cdot h^{-1}$). MIR = Moderate-intensity Running (14.01-19 $km \cdot h^{-1}$). HIR = High-intensity Running (19.01-23 $km \cdot h^{-1}$). SPR = Sprinting ($\geq$ 23.01 $km \cdot h^{-1}$). HIA = High-intensity Activities (HIR + SPR). NS = Number of Sprints [a.u. (arbitrary unites)], characterized by frequencies of efforts $\geq$ 23.01 $km \cdot h^{-1}$.

**Supplemental file 2.** Effects of opposition team formation (1-4-4-2 vs. 1-4-2-3-1 or 1-4-4-2) according to playing position on individual and global metrics of network analysis in Brazilian professional soccer players [mean (standard deviation)].

| **Position** | **Opposition Team Formation** | **Individual Metrics** | | | | | | **Global Metrics** | |
|---|---|---|---|---|---|---|---|---|---|
| | 1-4-4-2 vs. | In Degree | Out Degree | Closeness Centrality | Betweenness Centrality | Clustering | Eigenvector | Density | Clustering Coefficients |
| CD | 1-4-2-3-1 | 24.7 (9.0) | 24.6 (15.5) | 0.8 (0.3) | 4.4 (3.7) | 0.7 (0.1) | 0.8 (0.2) | - | - |
| CD | 1-4-4-2 | 23.7 (3.5) | 27.7 (3.2) | 0.8 (0.1) | 4.2 (2.5) | 0.7 (0.1) | 0.8 (0.1) | - | - |
| ED | 1-4-2-3-1 | 25.1 (11.8) | 21.9 (14.6) | 0.7 (0.3) | 1.5 (1.2) | 0.8 (0.1) | 0.8 (0.1) | - | - |
| ED | 1-4-4-2 | 25.3 (6.7) | 19.3 (3.2) | 0.8 (0.1) | 2.9 (2.3) | 0.8 (0.1) | 0.8 (0.1) | - | - |
| CM | 1-4-2-3-1 | 27.9 (14.1) | 31.6 (12.1) | 0.9 (0.1) | 4.0 (1.2) | 0.7 (0.1) | 0.8 (0.1) | - | - |
| CM | 1-4-4-2 | 20.0 (4.2) | 22.5 (7.8) | 0.8 (0.1) | 3.1 (1.1) | 0.8 (0.1) | 0.9 (0.1) | - | - |
| EM | 1-4-2-3-1 | 31.7 (11.7) | 32.7 (10.1) | 0.8 (0.1) | 3.6 (1.0) | 0.7 (0.1) | 0.9 (0.1) | - | - |
| EM | 1-4-4-2 | 28.8 (5.6) | 27.8 (11.7) | 0.9 (0.1) | 3.7 (0.5) | 0.7 (0.1) | 1.0 (0.1) | - | - |
| F | 1-4-2-3-1 | 19.0 (3.7) | 11.8 (1.7) | 0.7 (0.1) | 2.0 (1.1) | 0.8 (0.1) | 0.9 (0.1) | - | - |
| F | 1-4-4-2 | 19.8 (7.9) | 18.8 (10.6) | 0.7 (0.1) | 1.7 (0.8) | 0.8 (0.1) | 0.8 (0.1) | - | - |
| Mean All Positions | 1-4-2-3-1 | 26.2 (11.2) | 25.5 (13.7) | 0.8 (0.2) | 3.1 (2.2) | 0.7 (0.1) | 0.8 (0.1) | 0.7 (0.1) | 0.7 (0.1) |
| Mean All Positions | 1-4-4-2 | 23.7 (6.6) | 22.8 (8.7) | 0.8 (0.1) | 3.0 (1.7) | 0.7 (0.1) | 0.9 (0.1) | 0.7 (0.01) | 0.7 (0.02) |

Note: CD = Central Defenders. ED = External Defenders. CM = Central Midfielders. EM = External Midfielders. F = Forwards.

**Supplemental file 3.** Effects of opposition team formation (1-4-1-4-1 vs. 1-4-2-3-1 or 1-4-4-2) according to playing position on individual and global metrics of network analysis and in Brazilian professional soccer players [mean (standard deviation)].

| **Position** | **Opposition Team Formation** | **Individual Metrics** | | | | | | **Global Metrics** | |
|---|---|---|---|---|---|---|---|---|---|
| | 1-4-1-4-1 vs. | In Degree | Out Degree | Closeness Centrality | Betweenness Centrality | Clustering | Eigenvector | Density | Clustering Coefficients |
| CD | 1-4-2-3-1 | 17.2 (7.7) | 22.6 (9.0) | 0.8 (0.1) | 3.7 (3.8) | 0.7 (0.2) | 0.8 (0.1) | - | - |
| CD | 1-4-4-2 | 21.1 (3.5) | 24.6 (4.0) | 0.8 (0.1) | 2.9 (1.7) | 0.7 (0.1) | 0.8 (0.1) | - | - |
| ED | 1-4-2-3-1 | 24.6 (14.7) | 21.8 (13.4) | 0.8 (0.1) | 2.8 (1.7) | 0.7 (0.1) | 0.8 (0.2) | - | - |
| ED | 1-4-4-2 | 26.4 (9.5) | 20.1 (9.7) | 0.7 (0.3) | 2.9 (2.2) | 0.7 (0.1) | 0.8 (0.1) | - | - |
| CM | 1-4-2-3-1 | 28.4 (12.9) | 28.0 (8.9) | 0.8 (0.1) | 3.0 (1.4) | 0.7 (0.1) | 0.8 (0.1) | - | - |
| CM | 1-4-4-2 | 30.1 (9.1) | 30.8 (13.3) | 0.9 (0.1) | 3.4 (2.5) | 0.7 (0.1) | 0.9 (0.1) | - | - |
| EM | 1-4-2-3-1 | 35.8 (11.6) | 28.8 (16.6) | 0.7 (0.4) | 2.0 (1.4) | 0.8 (0.1) | 0.9 (0.1) | - | - |
| EM | 1-4-4-2 | 32.0 (8.5) | 34.0 (14.6) | 0.8 (0.1) | 2.9 (0.5) | 0.8 (0.1) | 1.0 (0.1) | - | - |
| F | 1-4-2-3-1 | 19.0 (12.2) | 15.7 (8.1) | 0.7 (0.1) | 0.9 (0.8) | 0.7 (0.1) | 0.6 (0.3) | - | - |
| F | 1-4-4-2 | 21.6 (8.5) | 13.4 (4.9) | 0.7 (0.1) | 1.0 (0.6) | 0.8 (0.1) | 0.9 (0.1) | - | - |
| Mean All Positions | 1-4-2-3-1 | 25.5 (12.9) | 24.0 (11.7) | 0.8 (0.2) | 2.6 (2.2) | 0.7 (0.1) | 0.8 (0.2) | 0.7 (0.1) | 0.7 (0.1) |
| Mean All Positions | 1-4-4-2 | 26.4 (8.8) | 24.9 (11.9) | 0.8 (0.2) | 2.8 (1.9) | 0.7 (0.1) | 0.9 (0.1) | 0.7 (0.05) | 0.7 (0.05) |

Note: CD = Central Defenders. ED = External Defenders. CM = Central Midfielders. EM = External Midfielders. F = Forwards.

# CAPÍTULO 7. CONSIDERAÇÕES FINAIS

O conjunto de artigos apresentados examinaram questões contemporâneas sobre as exigências específicas do jogo e os fatores contextuais e posicionais que afetam o desempenho de corrida e a interação interpessoal entre jogadores de futebol de um clube ao longo de três anos. Também foram expostas possíveis direções para futuras pesquisas. Em cada estudo buscamos delinear um procedimento metodológico apropriado para responder aos problemas emergentes da integração entre os aspectos científicos e as demandas do alto desempenho no ambiente esportivo. Em última análise, espera-se que esta tese seja um veículo para direcionar um campo de estudo sobre o desempenho de corrida e a interação interpessoal mais baseado em evidências, tornando o treinamento e a preparação mais fundamentados em evidências. Em geral, as descobertas discutidas permitiram uma maior compreensão e avaliação das práticas atuais. Além disso, importa realçar as importantes contribuições dos estudos para um contexto de alto desempenho esportivo no futebol, um ambiente no Brasil por vezes restrito para o matrimônio entre a “ciência” e a “prática”.

Além das limitações apresentadas em cada um dos estudos, uma crítica que pode ser dirigida ao conjunto de trabalhos expostos é a falta de um estudo de intervenção controlado para fornecer informações sobre o impacto dos regimes de treinamento sobre as variáveis dependentes analisadas (i.e., desempenho de corrida e interação interpessoal). Entretanto, esse é um desafio para os próximos passos da minha trajetória acadêmica como pesquisador. Tenho como propósito no futuro breve verificar os efeitos do treinamento (conteúdos, carga interna/externa, monotonia, *strain*) sobre as variáveis dependentes supracitadas. Problemas de ordem prática impossibilitaram que essas problemáticas longitudinais fossem respondidas nesta tese. A recusa dos treinadores e a relutância de alguns jogadores dificultam a realização de intervenções no ambiente futebolístico, assim como em outras modalidades esportivas com busca ao alto desempenho.

Podemos enfatizar que os resultados apresentados nesta tese tiveram um impacto substancial em diferentes níveis operacionais do clube onde foram coletados os dados. De fato, muitas das descobertas foram aceitas e, podemos nos felicitar por realmente esta pesquisa aplicada no campo das ciências do esporte ter contribuído para o aumento do desempenho esportivo em alguns eixos. Por exemplo: (i) reflexão sobre a real necessidade dos treinadores utilizarem testes fora de contexto de jogo para avaliação dos aspectos tático-técnicos e físicos no futebol, fazendo inferências preditivas ao desempenho competitivo em jogo (Estudos teóricos 1 e 2); (ii) utilização dos jogos reduzidos como alternativa para descrição dos indicadores físicos (Estudo 3); (iii) comportamento do desempenho de corrida e interação interpessoal de acordo com o local do jogo, qualidade dos adversários, resultado da partida (Estudos 4 e 6); (iii) demandas específicas do jogo nas diferentes divisões dos Campeonatos Brasileiros e Estadual (Estudo 5); (iv) fornecimento de *feedbacks* sobre o desempenho de corrida da equipe ao utilizar o sistema 1-4-4-2 ou 1-4-3-3 (Estudo 5), e enfrentar oponentes no 1-4-4-2 ou 1-4-1-4-1 (Estudo 6); (v) enquadramento das sessões de treino com base nas exigências específicas de cada posição (Estudos 5 e 6) e; (vi) exigências específicas de cada posição de jogo no que se refere, por exemplo, as interações com os outros jogadores durante as partidas (Estudo 6).

Fizemos um esforço para “traduzir” o conhecimento produzido nesta tese para uma linguagem acessível aos diferentes níveis de formação humana (e.g., alunos em formação e formados na graduação e pós-graduação; cientistas do esporte; profissionais que estão atuando no campo prático). O fruto deste trabalho está em forma de um e-book e pode ser acessada na íntegra pelo link abaixo[2]:

https://docs.google.com/uc?export=download&id=1oiTzMg6snhbv4Wxka2atGSXnwJDrgHXv

Finalmente, esperamos que o conjunto de ideias apresentadas e discutidas tenha encorajado futuros cientistas do esporte, analistas de desempenho e/ou treinadores a estruturarem experimentos e observações acerca da análise de jogo em outros clubes de futebol e outras instituições. Pensamos que o grande propósito é que a comunidade do futebol, por mais diversa e global que seja, se una em prol do avanço no conhecimento científico/prático para a construção de um “fenômeno” ainda mais “esportivo”.

[2] Caso esteja com problemas para baixar o arquivo, segure a tecla “ctrl” e clique em cima do link. Se o problema persistir, por favor envie um e-mail para: rodrigo.aquino@usp.br

# ANEXOS

# ANEXO 1

HUMAN MOVEMENT
2017;18(5):special/issue: 34–55
SCIENCE IN SOCCER

## SKILL-RELATED PERFORMANCE IN SOCCER: A SYSTEMATIC REVIEW

review paper
doi: 10.1515/humo-2017-0042

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ABSTRACT
The aim of the study was to evaluate and organize systematically the available literature on skill-related performance in young and adult male soccer players in an attempt to identify the most common topics, ascertain the weaknesses, and elucidate the main contributions of the scientific papers on this issue. A systematic review of the Institute for Scientific Information (ISI) Web of Knowledge database was performed in accordance with the Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA) guidelines. The keywords 'football' and 'soccer' were used, each associated with the following terms: 'technical analysis,' 'technical performance,' 'technical activity,' 'technical skill,' 'technical demands,' 'technical profiles,' 'technical characteristics,' 'technical actions,' 'technical scores,' 'technical ability,' 'motor skills,' and 'skill acquisition'. From the 2830 papers, only 60 were reviewed, of which 75% had been published in years 2011–2015 and 53.3% concerned professional or seniors players (above the U-20 category). Out of the 41 papers that analysed the skill-related performance in the match, 48.8% evaluated the performance in small-sided and conditioned games. Among the 27 papers that used validated instruments, 88.9% assessed technical actions outside the match context (e.g. dribbling, shooting tests). Future research should pay attention to the definition and classification of the skill-related variables under investigation in match context and propose tests for measured skill-related performance in soccer, considering that the representativeness task design allies the players' possibilities of action to the situation of the match.
**Key words:** ecological approach, technical performance, representative design, team sports

### INTRODUCTION

The pursuit of sporting success constantly leads the coaches, performance analysts, and sports researchers to explore methods to evaluate and promote performance. In this sense, match analysis investigates the performance of teams with regard to the different scales of analysis, from the individual level (micro) towards the collective level (macro). Moreover, it provides informational knowledge regarding the development of the training process, as well as the competitive outcomes, considering various features displayed by teams in competitive matches [1]. It is a foundation for decision-making processes referring to the performance of players and sequentially enables the provision of feedbacks as part of the coaching process. However, accurate feedback on the actual players' performance requires testing with the representative task design of the specific match demands (i.e. generalization of task constraints in experimental designs to the constraints in sports; for more details, see [2]).

The theoretical principles of ecological dynamics revealed that the most relevant information for decision-making and the regulation of action in dynamic environments is emergent during continuous performer-environment interactions [3]. In this approach, the environment provides information that directly influences the behaviour of the agent (i.e. player) [4]. This information, perceived by the players, enhances the possibilities of action (i.e. affordances). Therefore, the responses to the constraints imposed by the match context materialize through the execution of technical actions in order to achieve a certain objective [5]. These actions endue an adaptive character as a func-

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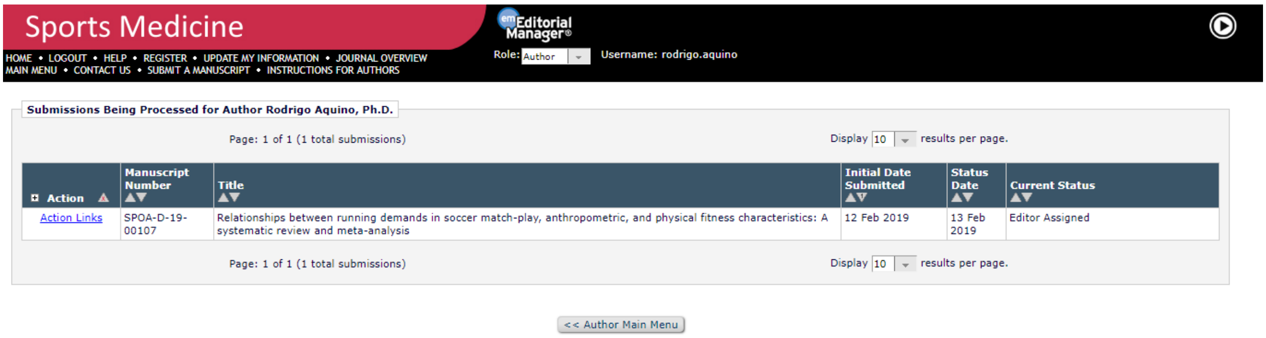
# ANEXO 2



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# Effects of competitive standard, team formation and playing position on match running performance of Brazilian professional soccer players

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**ABSTRACT**

This study examined the effects of competitive standard, team formation and playing position on match running performance in a Brazilian professional soccer team. Performance was investigated in 36 players in 48 matches at 3 competitive standards: 1st São Paulo State Championship; 3rd and 4th Brazilian leagues. Global Positioning System technology was used to determine total distance covered (TD), maximal running speed (MRS), mean speed ($S_{MEAN}$) and frequency of high-intensity activities (HIA). Data were compared across competitive standards, team formations and playing positions. Magnitude-based inferences showed greater values for TD, $S_{MEAN}$ and HIA (*likely* to *almost certain*) in the lower national (3rd, 4th Brazilian) vs. the top state division (1st São Paulo). Higher values for all variables were reported for the 1–4–3–3 vs. the 1–4–4–2 formation (*likely* to *almost certain*). External defenders/midfielders and forwards reported greater values (*likely* to *almost certain*) vs. central defenders/midfielders, especially in HIA. Linear regression analyses showed that playing position demonstrated a higher relative contribution to the variance in MRS (24%) and HIA (29%) compared to team formation (16 and 25%, respectively). In a Brazilian professional soccer team, match running performance was dependent upon competitive standard, playing formation and playing position.

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**KEYWORDS**
Association football; time–motion analysis; match demands; match preparation

## 1. Introduction

Knowledge of the physical demands of professional soccer match-play is required to construct optimal training programmes to respond to these needs (Carling, 2011). Time–motion analyses of running performance are employed to evaluate external load in soccer match-play (Castagna, Varley, Povoas, & D'Ottavio, 2017) and provide information for coaches and conditioning practitioners in the decision-making process for player fitness

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ANEXO 5

# Influence of Situational Variables, Team Formation, and Playing Position on Match Running Performance and Social Network Analysis of Brazilian Professional Soccer Players

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## Abstract

Aquino, R, Carling, C, Vieira, L, Martins, G, Jabor, G, Machado, J, Santiago, P, Garganta, J, and Puggina, E. Influence of situational variables, team formation, and playing position on match running performance and social network analysis of brazilian professional soccer players. *J Strength Cond Res* XX (X): 000–000, 2018–The purpose of this study was to investigate the independent and interactive effects of situational variables, opposition team formation, and playing position on running performance and network analysis in Brazilian professional soccer players ($n = 22$). Global positioning system technology was used to determine total distance covered, mean speed, maximum running speed, and distance covered in 6 speed ranges. Social network analysis was used to assess interpersonal coordination (team interactions characterized as successful passes [$n = 3{,}033$] between teammates). Observations of match running performance ($n = 129$) and network analysis ($n = 108$) were obtained. The main results were: (a) no interactive effects between team formation and playing position were observed for running and network variables (unclear to possibly); (b) matches played at home or against "weaker" opponents presented greater running demands and individual/global metrics of network analysis (likely to almost certain); (c) match outcome demonstrated influence only for running performance; matches in which the reference team won resulted in higher values than in matches lost; (d) when the reference team competed in 1-4-4-2 formation, this resulted in greater running demands than 1-4-2-3-1 formation (likely to almost certain); (e) reduced values of running performance variables were reported in central defenders compared with other positions. Central/external midfielders reported greater closeness/betweenness centrality, outdegree, and eigenvector compared with central/external defenders and forwards (likely to almost certain). The results from this study provide practical information to potentially impact on physical, tactical, and technical training.

**Key Words** association football, time-motion analysis, interpersonal coordination, sports sciences AU2

## Introduction

Team sports performance is dependent on the cooperative and competitive interactions between performers, and there is a need to determine the individual and collective contributions to achieve high standard performance (38). The complexity of these interactions emerging between players has been analyzed using novel investigative methods such as dynamical systems (14,41). Indeed, contemporary empirical research recommends social network analyses to verify interpersonal coordination/interactions between soccer players, notably using completed passes between teammates (12,20). Although this approach provides novel insights into the complexity of

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