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Original

Indicadores de performance que diferenciem equipes de sucesso das equipes de não sucesso na La Liga

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RESUMO

Objetivo: Este estudo buscou identificar se existe influência na classificação nos indicadores de performance técnico das equipes liga espanhola, e identificar indicadores de performance técnico que diferenciem equipes de sucesso das equipes de não sucesso da liga espanhola.
Método: Foram coletados dados de cinco variáveis técnicas, sendo elas: chute de dentro da área e de fora da área, média de passes para setor de defesa, meio-campo e ataque de 1900 partidas da La Liga entre os anos 2014 a 2019, por meio do site "whoscored.com", a análise da confiabilidade utilizou-se o sistema de rastreamento OPTA com valores ponderados de 0,92 e 0,94. As equipes foram divididas em cinco grupos contendo 4 equipes, de acordo com a sua classificação na competição anualmente. Após a coleta, para determinação da distribuição das variáveis foi utilizado o teste de Kolmogorov-Smirnov. Para a identificação do efeito da tabela nas ações técnicas das equipes, foi utilizado o teste de ANOVA One-Way. Para as comparações múltiplas entre os grupos, foi utilizado o teste de Bonferroni.
Resultado: Os indicadores de técnicos de desempenho que permitem diferenciar as quatro melhores equipes da competição das demais equipes são: chute de dentro da área, passe para o setor de meio-campo e para o setor de ataque.
Conclusão: O estudo demostrou eficaz pois alcançou seus objetivos ao identificar as variáveis técnicas que diferenciam equipes de sucesso das equipes de não sucesso, bem como auxilia treinadores, analistas e demais profissionais do futebol a entender o contexto de atuação e se direcionar suas intervenções futuras.
Palavras-chave: Futebol; Indicadores Chaves de Desempenho; Análise de Partida; Análise de Desempenho.

Indicadores de performance que diferencian equipos exitosos, equipos no exitosos en La Liga

RESUMEN

Objetivo: Este estudio buscó identificar si existe influencia en la clasificación en los indicadores de desempeño técnico de los equipos de la liga española, e identificar indicadores de desempeño técnico que diferencian a los equipos exitosos de los no exitosos en la liga española.
Método: Se recogieron datos de cinco variables técnicas, a saber: tiros desde dentro y fuera del área, promedio de pases para el sector defensa, mediocampo y ataque de 1900 partidos de La Liga entre los años 2014 a 2019, a través del sitio web "whoscored.com ", el análisis de confiabilidad utilizó el sistema de rastreo OPTA con valores ponderados de 0.92 y 0.94. Los equipos se dividieron en cinco grupos de 4 equipos, según su clasificación en la competición anualmente. Después de la recolección, se utilizó la prueba de Kolmogorov-Smirnov para determinar la distribución de las variables. Para identificar el efecto de la tabla en las acciones técnicas de los equipos, se utilizó la prueba ANOVA de una vía. Para las comparaciones múltiples entre grupos se utilizó la prueba de Bonferroni.
Resultado: Los indicadores de rendimiento técnico que permiten diferenciar a los cuatro mejores equipos de la competición del resto de equipos son: tiro desde dentro del área, pase al sector medio y al sector de ataque.
Conclusión: El estudio demostró ser efectivo pues logró sus objetivos identificando las variables técnicas que diferencian a los equipos exitosos de los no exitosos, además de ayudar a entrenadores, analistas y otros profesionales del fútbol a comprender el contexto de su desempeño y orientar sus futuras intervenciones.
Palabras clave: Fútbol; Indicadores Clave de Rendimiento; Análisis de Partidos; Análisis de Rendimiento.

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Influence of some types of passes and finishing in the comparison of the performance of successful and unsuccessful teams in La Liga

ABSTRACT

Objective: This study sought to identify if there is an influence on the classification in the technical performance indicators of the Spanish league teams, and to identify technical performance indicators that differentiate successful from non-successful teams in the Spanish league.
Method: Data were collected from five technical variables, namely: kicking from inside the area and outside the area, average passes for the defense sector, midfield and attack of 1900 La Liga matches between the years 2014 to 2019, through from the website "whoscored.com", the reliability analysis used the OPTA tracking system with weighted values of 0.92 and 0.94. Teams are divided into five groups containing 4 teams, according to their ranking in the competition annually. After data collection, the Kolmogorov-Smirnov test was used to determine the distribution of variables. To identify the effect of the table on the technical actions of the teams, the One-Way ANOVA test was used. For multiple comparisons between groups, the Bonferroni test was used.
Results: The technical performance indicators that allow you to differentiate the four best teams in the competition from the other teams are: kick from inside the area, pass to the midfield sector and to the attack sector.
Conclusion: The study proved to be effective because it achieved its objectives by identifying the technical variables that differentiated successful from non-successful teams, and can help coaches, analysts and other football professionals to understand the context of their performance and target their future interventions.
Keywords: Soccer; Key Performance Indicators; Match Analysis; Performance Analysis.

Introdução

A análise de uma partida de futebol tem por meta a identificação de pontos fortes e fracos da própria equipe e de seus adversários[1]. Este processo de análise pode ser realizado através da avaliação e monitoramento de ações coletivas e individuas, apresentando uma descrição da equipe, afim de fornecer informações importantes para a preparação e desenvolvimento da equipe [2-3].

Para Castellano et al.[4], a análise de jogos nos esportes tem sido usada como um processo importante que fornece ao treinador informações determinadas que pode ser usada na potencialização do rendimento da equipe e no planejamento de treinamentos. Lago e Dellal[5], corrobora apontando que os principais benefícios de realizar uma análise de desempenho da sua própria equipe é identificar qualidades que podem ser potencializadas e fraquezas que devem ser melhoradas. Assim sendo, os estudos de análise de desempenho têm direcionado principalmente nos indicadores de sucesso, variáveis de passes, finalização e probabilidade de vencer[6], subentender futuros desempenhos bem sucedidos ou identificando diferenças entre competições e equipes[7]. Esses indicadores servem como parâmetros que ajudam a projetar resultados esportivos em um campeonato.

Dentre os estudos com análise de desempenho no futebol, destacam-se os que buscam identificar indicadores que discriminam equipes vencedoras de equipes perdedoras. O estudo de Zhou et al.[8] apontou que a probabilidade de vencer é 0,79-3,50 vezes maior de vencer partidas, a partir de chutes ao gol, então a sustentação do impacto positivo dos chutes exige que os treinadores estejam atentos a esse indicador. Zhou, Gómez, & Lorenzo[9], na Superliga Chinesa demostraram que as equipes que obtiveram sucesso na competição, tiveram números de chutes ao gol aumentados ao longo das seis temporadas analisadas (2012-17). Sob o mesmo ponto de vista Alves et al.[10], as equipes vencedoras na Copa do Mundo FIFA 2018, demonstraram realizar mais finalização e finalização ao gol. Contudo Liu et al.[2], apresenta uma ressalva importante, em relação aos indicadores de performance de finalização, devido sua instabilidade ao longo de uma sequência de partidas. No estudo de Yi et al.[11], a variável de chutes e chutes ao gol não obteve alteração, entretanto embora os números de chutes variaram pouco, o número de toques e passes realizados para terços de jogo foram aumentados nas temporadas analisadas (2009-2018).

Vale destacar que no estudo foram coletadas as variáveis técnicas ofensivas relacionadas a finalização e passe, buscando entender a partir delas qual sua influência nos resultados finais de uma partida e de um campeonato. Por fim, evidenciar a importância dos estudos acima que comparam os times vencedores dos perdedores, mas que há uma necessidade de uma nova abordagem desta temática, afim de identificar as diferenças entre as equipes de diferentes posições na tabela com base em seu comportamento técnico ofensivo.

Desta forma, este estudo tem como objetivos: (i) identificar se existe influência na classificação nos indicadores de performance técnico das equipes liga espanhola; (ii) identificar indicadores de performance técnico que diferenciem equipes de sucesso das equipes de não sucesso da liga espanhola.

Método.

Amostra

A amostra deste estudo consistiu na coleta de dados referentes ao comportamento técnico ofensivo de 5 temporadas completas, totalizando 1900 partidas da La Liga entre os anos de 2014 a 2019.

Variáveis

Os indicadores de desempenho técnico selecionados para o presente estudo foram: chute de dentro da área; chute de fora da área; passes para o setor de defesa; passes para o setor de meio campo; passes para o setor de ataque; total de pontos obtidos pelas equipes na competição ao longo das temporadas analisadas. No total, em todas as temporadas analisadas ocorreram 27.231 chutes de dentro da área, 19.416 chutes de fora da área, 309.008 passes para o setor de defesa, 909.125 passes para o setor de meio campo e 576.450 passes para o setor de ataque, sendo todos os dados apresentados em médias por partida das equipes analisadas.

Coleta de Dados e Análise de Confiabilidade

Os dados utilizados no estudo foram coletados do site "whoscored.com", das quais o fornecedor dos recursos é a empresa de dados esportivos OPTA Sportsdata Company[12].

Em relação a análise da confiabilidade do estudo, utilizou o sistema de rastreamento (*OPTA Client System*) usado pela empresa para gerar estatísticas de partidas ao vivo. De acordo com o estudo Liu et al.[13], percebeu-se que os eventos das equipes codificadas por operadores independentes alcançou uma consonância ótima, como valores de Kappa ponderados de 0.92 e 0.94.

Procedimentos

Para este estudo, foram determinados cinco grupos contendo 4 equipes, de acordo com a sua classificação final por ano na competição. Sendo assim, o Grupo 1 é composto pelo 1º colocado

ao 4º colocado; o Grupo 2 é composto pelo 5º colocado ao 8º colocado; o Grupo 3 é composto pelo 9º colocado ao 12º colocado; o Grupo 4 é composto pelo 13º colocado ao 16º colocado; e o Grupo 5 é composto pelo 17º colocado ao 20º colocado. Desta forma, será analisado se há influência na classificação final a partir da média de realização das variáveis e quais indicadores de performance técnicos determinam sucesso e não sucesso na liga espanhola.

Análise Estatística

Na análise estatística, realizamos a análise por temporada para evidenciar se a influência das variáveis no sucesso das equipes se manteve constante ao longo das temporadas ou se modifica, para determinação da distribuição das variáveis foi utilizado o teste de Kolmogorov-Smirnov. Para a identificação do efeito da tabela nas ações técnicas das equipes, foi utilizado o teste de ANOVA One-Way. Para as comparações múltiplas entre os grupos de equipes analisados, foi utilizado o teste de Bonferroni. Foi considerado para a análise o valor de p<0.05 para nível de significância. O *software* SPSS® 20.0 para Windows, Chicago, IL, USA. foi utilizado em todos os testes neste estudo.

Resultados

A partir da aplicação dos procedimentos anteriormente descritos, nesta seção apresenta-se os resultados obtidos. Na Tabela 1, observa-se os valores médios anuais por partida e totais da realização das ações de chute de dentro da área e fora da área. Nota-se que os valores totais da variável de chute de dentro da área apresenta influência nos grupos, com valores de p<0,05. Nesta variável no valor total o Grupo 1 diferenciou-se significativamente dos demais grupos, enquanto no valor por partida, no campeonato 2016-17 apenas o Grupo 3, 4 e 5 diferenciaram do Grupo 1. Em relação a variável de chute de fora da área, a única influência foi na temporada 2014-15, no qual o Grupo 3, 4 e 5 demostraram diferença significativa em relação ao Grupo 1, bem como o Grupo 02 em relação ao Grupo 5.

Na Tabela 2, verifica-se os valores médios anuais por partida e totais da realização das ações de passe para o terço defensivo, para o terço de meio campo e para o terço de ataque. Percebe-se que os valores totais da variável de passe para o terço defensivo apresentam apenas diferença significativa entre o Grupo 1 em relação ao Grupo 5. Em relação aos valores totais das variáveis de passe para o terço de meio campo e para o terço de ataque apresentam influência nos grupos, com valores de p<0.05. Nessas variáveis o valor total do Grupo 1 se diferenciou significativamente dos demais grupos, com exceção da variável passe para o terço de ataque que o Grupo 2 demostrou diferença significativa para o Grupo 5. Em relação os valores por temporada, as ações de passes para o setor de meio campo, na temporada 2016-17 o Grupo 1 teve diferença significativa para o Grupo 5, por fim na variável de passe para terço de ataque nas temporadas 2014-15 e 2018-19 o Grupo 1 demostrou diferença significativa para o Grupo 5, bem como na temporada 2017-18 o Grupo 1 obteve uma diferença significativa em relação ao Grupo 3, 4 e 5.

Discussão

O presente estudo teve como objetivos identificar se existe influência na classificação nos indicadores de performance técnico das equipes liga espanhola, bem como identificar indicadores de performance técnico que diferenciem equipes de sucesso das equipes de não sucesso da liga espanhola. Os resultados do estudo identificaram que os indicadores que permitiram diferenciar as equipes foram chute de dentro da área, passe para o setor de meio-campo e passe para o setor de ataque. Esses dados confirmam o estudo de Andrzejewski, et al.[14] que destaca a importância das equipes concentra-se no desenvolvimento de estratégias para criar situações mais frequentes de chutes ao gol como fundamentais para o sucesso de uma equipe

Tabela 1. Comparação da frequência de Chutes por partida entre diferentes grupos de classificação.

Ação Técnica Ofensiva		Grupo 1 (M±SD)	Grupo 2 (M±SD)	Grupo 3 (M±SD)	Grupo 4 (M±SD)	Grupo 5 (M±SD)	F	P
Chute de dentro da área	Total	8.61±2.30	7.21±0.95 [a]	6.89±0.98 [a]	6.21±0.89 [a]	6.48±0.77 [a]	8.47	<0.001
	2014-2015	6.40±1,29	6.37±0,68	6.31±1.28	5.87±0.99	6.22±0.55	0.18	0.946
	2015-2016	9.06±2.88	7.58±0.90	6.56±0.67	6.42±0.60	6.76±0.66	2.29	0.107
	2016-2017	9.99±2.06	7.38±0.65	6.70±0.84 [a]	6.66±0.47 [a]	5.80±0.83 [a]	8.08	0.001
	2017-2018	9.11±2.73	7.10±1.28	7.41±0.61	6.90±1.01	6.63±0.89	1.69	0.204
	2018-2019	8.48±1.43	7.60±1.01	7.44±1.23	7.30±0.97	7.01±0.58	1.04	0.418
Chute de fora da área	Total	5.95±2.11	5.17±1.65	4.89±0.92	4.75±0.85	4.77±0.87	2.66	0.037
	2014-2015	9.40±2.18	8.05±1.03	6.37±0.47 [a]	5.80±0.37 [a]	5.27±0.71 [a,b]	8.67	0.001
	2015-2016	4.97±1.55	4.30±0.73	4.38±0.39	4.71±1.21	4.71±0.77	0.29	0.881
	2016-2017	5.13±0.63	4.75±0.43	4.28±0.92	4.82±0.20	4.85±1.59	0.47	0.756
	2017-2018	5.11±0.70	4.61±0.63	4.80±0.50	4.10±0.63	4.35±0.49	1.68	0.207
	2018-2019	5.16±0.52	4.17±1.06	4.59±0.18	4.31±0.50	4.65±0.59	1.41	0.277

M = Média; DP = Desvio Padrão; [a]Diferença significativa para o Grupo 1; [b]Diferença significativa para o Grupo 2. p<0.05.

Tabela 2. Comparação da frequência de Passes por partida entre diferentes grupos de classificação.

Ação Técnica Ofensiva		Grupo 1 (M±SD)	Grupo 2 (M±SD)	Grupo 3 (M±SD)	Grupo 4 (M±SD)	Grupo 5 (M±SD)	F	P
Passe para o terço defensivo	Total	93.99±21.34	81.23±22.05	82.23±22.82	75.04±19.13	74.08±18.87 [a]	2.90	0.026
	2014-2015	73.72±10.26	73.40±8.06	71.67±21.98	66.14±8.44	73.72±10.26	1.07	0.404
	2015-2016	86.49±17.94	79.21±14.42	83.97±15.87	61.01±5.73	74.20±16.62	1.86	0.169
	2016-2017	102.19±20.14	82.49±20.17	82.59±7.66	90.82±23.03	66.92±13.15	2.12	0.129
	2017-2018	105.06±19.33	93.63±33.59	86.20±28.18	82.98±28.53	83.21±22.20	0.48	0.747
	2018-2019	102.51±26.54	77.39±30.93	86.72±38.85	74.27±9.25	88.60±18.09	0.68	0.613
Passe para o terço de meio campo	Total	286.65±50.29	236.37±37.40 [a]	235.14±31.13 [a]	223.09±31.93 [a]	214.95±21.27 [a]	12.26	<0.001
	2014-2015	288.40±76.39	246.06±31.88	220.85±28.83	215.65±14.74	204.90±17.32	2.71	0.070
	2015-2016	288.42±55.30	235.05±37.71	249.50±38.86	215.81±6.93	220.28±16.52	2.71	0.070
	2016-2017	285.17±37.65	242.66±22.33	231.73±11.96	258.02±37.32	206.64±11.46 [a]	4.79	0.011
	2017-2018	282.73±49.05	246.06±61.19	232.11±23.50	219.52±47.36	220.00±31.21	1.38	0.287
	2018-2019	288.53±57.15	212.00±32.82	241.51±49.70	206.45±19.95	222.92±28.37	2.74	0.068
Passe para o terço de ataque	Total	183.82±31.35	154.24±11.70 [a]	147.85±23.41 [a]	139.21±10.83 [a]	133.35±08.45 [a,b]	20.80	<0.001
	2014-2015	188±47.21	160.95±7.47	154.84±10.42	138.20±6.95	128.91±6.37 [a]	4.29	0.016
	2015-2016	183.98±32.93	157.66±2.15	147.16±19.31	142.62±19.55	139.40±8.51	3.37	0.037
	2016-2017	184.86±22.59	157.65±15.03	129.46±17.10 [a]	140.93±3.42 [a]	132.86±10.92 [a]	8.91	0.001
	2017-2018	179.91±37.60	145.06±13.47	151.90±25.36	137.14±15.17	137.07±7.32	2.48	0.088
	2018-2019	181.61±30.44	149.86±13.05	155.91±37.81	137.15±6.20	128.37±5.85 [a]	3.21	0.043

M = Média; DP = Desvio Padrão; [a]Diferença significativa para o Grupo 1; [b]Diferença significativa para o Grupo 2. p<0.05.

A Tabela 1 mostra que a média de chutes de dentro da área e fora da área apresentaram-se como uma variável capaz de influenciar o resultado de uma partida e de um campeonato, indicando que estás variáveis podem determinar sucesso das equipes. Stafylidisi et al.[15] completa, demostrando uma considerável probabilidade de vencer jogos na Liga Grega de 2020-21 a partir de chutes no gol e chutes totais, o estudo de Lepschy, Wäsche, & Woll[16] corrobora destacando a influência significativa nas vitorias das ações de chute ao gol, chutes dentro da área penal e total de chutes, mas chama atenção que não só a frequência dos disparos, mas também a qualidade dos disparos está intimamente relacionada ao sucesso da partida.

Ainda na Tabela 2 a média de passe para o setor de meio-campo e passe para o setor de ataque também se apresentaram como variáveis capazes de influenciar o resultado de uma partida e de um campeonato. Rein, Raabe, & Mennert[17] sugere que o número de jogadores ultrapassados, bem como a eficácia do passe de mudança de terço de ataque do campo, fornece um valor considerável para analisar o desempenho no futebol. Indo de encontro Bradley et al.[18] pontua que as esquipes bem sucedidas tendem a "controlar" e ditar o jogo para se aproximar do setor de ataque do campo, para criar oportunidades de finalização.

No estudo de Tenga et al.[19] foi detectado diferenças significativas nas zonas frequentadas pelos times de sucesso, onde os gols marcados iniciados por passes no terço de ataque mostram-se mais eficaz entre as equipes bem sucedidas, solidificando Casal et al.[20] verificou que equipes de sucesso, tendem a ocupar com maior frequência o terço meio-ofensivo, enquanto os times menor sucesso tentem a ocupar o terço meio-defensivo, no entanto Tenga & Sigmundstad[21] destacou que as equipes bem sucedidas marcaram mais gols em passes que começaram no terço de meio campo em comparação as equipes mal sucedidas, isto ocorre, porque para marcar gols a partir de passes que comecem distantes de gol exige-se jogadores com alto nível de habilidade, muitas vezes encontrados em equipes de sucesso. Para que esses dados sejam respeitáveis, seria necessário realizar novos estudos que identificassem a relação entre posse de bola e zonas de passes entre equipes de nível técnico similares.

Desta forma, os indicadores de desempenho quantificados fornecem informações importantes para os treinadores e analistas de desempenho durante a elaboração de treinamento e preparação para jogos. Por exemplo, uma maior ênfase na precisão de passes e chutes pode ser benéfica, medidas de treinos podem ser adaptadas a jogos médios e grandes, e que as equipes podem competir de acordo com os princípios de superioridade numérica, ex: 8 contra 6, 9 contra 7, 10 contra 8 podem ser ambientes que provoquem mais situações que terminem com um gol ou finalização. Além de servir como *benchmark* para os grupos 2 ao 5, que buscam melhora no desempenho, sendo uma alternativa é preconizar no modelo de jogo do time a manutenção da posse de bola nos setores de meio-campo e ataque, tentando sempre que possível a finalização no gol adversário.

Com base nos resultados obtidos, conclui-se que, na liga espanhola, os indicadores de técnicos de desempenho que permitem diferenciar as quatro melhores equipes da competição das demais equipes são: chute de dentro da área, passe para o setor de meio-campo e passe para o setor de ataque. Assim, estes indicadores permitem uma caracterização do perfil de sucesso de uma equipe na liga espanhola, o que auxilia treinadores, analistas e demais profissionais do futebol a entender o contexto de atuação e se direcionar suas intervenções futuras.

Autoria. Todos os autores contribuíram intelectualmente no desenvolvimento do trabalho, assumiram a responsabilidade do conteúdo e, da mesma forma, concordam com a versão final do artigo. **Financiamento.** Os autores declaram que não receberam financiamento. **Agradecimentos.** Os autores agradecem o apoio do Programa de Pós-Graduação em Educação Física da Universidade Federal de Viçosa, em especial ao Núcleo de Pesquisa e Estudos em Futebol, coordenado pelo Prof. Dr. Israel Teoldo da Costa. **Conflito de interesses.** Os autores declaram não haver conflito de interesses. **Origem e revisão.** Não foi encomendada, a revisão foi externa e por pares. **Responsabilidades Éticas.** *Proteção de pessoas e animais:* Os autores declaram que os procedimentos seguidos estão de acordo com os padrões éticos da Associação Médica Mundial e da Declaração de Helsinque. *Confidencialidade:* Os autores declaram que seguiram os protocolos estabelecidos por seus respectivos centros para acessar os dados das histórias clínicas, a fim de realizar este tipo de publicação e realizar uma investigação / divulgação para a comunidade. *Privacidade:* Os autores declaram que nenhum dado que identifique o paciente aparece neste artigo.

Referências

1. Carling C, Bloomfield J, Nelsen L, Reilly T. The role of motion analysis in elite soccer: contemporary performance measurement techniques and work rate data. Sports Med. 2008;38(10):839-62.
2. Liu H, Gómez MA, Gonçalves B, Sampaio J. Technical performance and match-to-match variation in elite football teams. J Sports Sci. 2016;34(6):509-18.
3. Liu H, Hopkins WG, Gómez MA. Modelling relationships between match events and match outcome in elite football. Eur J Sport Sci. 2016 Aug;16(5):516-25.
4. Castellano J, Casamichana D, Lago C. The Use of Match Statistics that Discriminate Between Successful and Unsuccessful Soccer Teams. J Hum Kinet. 2012 Mar;31:139-47.
5. Lago-Peñas C, Dellal A. Ball Possession Strategies in Elite Soccer According to the Evolution of the Match-Score: the Influence of Situational Variables. J Hum Kinet. 2010;25(2010): 93-100.
6. Carling C, Wright C, Nelson LJ, Bradley PS. Comment on 'Performance analysis in football: a critical review and implications for future research'. J Sports Sci. 2014;32(1):2-7.
7. Lago-Ballesteros J, Lago-Peñas C. Performance in Team Sports: Identifying the Keys to Success in Soccer. J Hum Kinet. 2010;25(2010): 85-91.
8. Zhou C, Calvo AL, Robertson S, Gómez MÁ. Long-term influence of technical, physical performance indicators and situational variables on match outcome in male professional Chinese soccer. J Sports Sci. 2021 Mar;39(6):598-608.
9. Zhou C, Gómez MÁ, Lorenzo A. The evolution of physical and technical performance parameters in the Chinese Soccer Super League. Biol Sport. 2020 Jun;37(2):139-145.
10. Alves DL, Osiecki R, Palumbo DP, Moiano-Junior JVM, Oneda G, Cruz R. What variables can differentiate winning and losing teams in the group and final stages of the 2018 FIFA World Cup?. Int. J. Perform. Anal. Sport. 2019;19(2), 248–257.
11. Yi Q, Liu H, Nassis GP, Gómez MÁ. Evolutionary Trends of Players' Technical Characteristics in the UEFA Champions League. Front Psychol. 2020 Jun 16;11:1032.
12. Liu H, Yi Q, Giménez JV, Gómez MA, Lago-Peñas C. Performance profiles of football teams in the UEFA champions league considering situational efficiency. Int J. Perform. Anal. Sport. 2015;*15*(1), 371–390.
13. Liu H, Hopkins W, Gómez MÁ, Molinuevo SJ. Inter-operator reliability of live football match statistics from OPTA Sportsdata. Int. J. Perform. Anal. Sport. 2013;13(3), 803–821.
14. Andrzejewski M, Oliva-Lozano JM, Chmura P, Chmura J, Czarniecki S, Kowalczuk E, Rokita A, Muyor JM, Konefał M. Analysis of team success based on match technical and running performance in a professional soccer league. BMC Sports Sci Med Rehabil. 2022 May 5;14(1):82.
15. Stafylidis A, Michailidis Y, Mandroukas A, Gissis I, Metaxas T. Analysis of goal scoring and performance indicators in the

2020-2021 Greek soccer league. J. Phys. Educ. Sport. 2022;22(1),91-9.
16. Lepschy H, Wäsche H, Woll A. Success factors in football: an analysis of the German Bundesliga. Int. J. Perform. Anal. Sport. 2020;20(2), 150-164.
17. Rein R, Raabe D, Memmert D. "Which pass is better?" Novel approaches to assess passing effectiveness in elite soccer. Hum Mov Sci. 2017 Oct;55:172-181.
18. Bradley PS, Lago-Peñas C, Rey E, Sampaio J. The influence of situational variables on ball possession in the English Premier League. J Sports Sci. 2014 Dec;32(20):1867-73.
19. Tenga A, Holme I, Ronglan LT, Bahr R. Effect of playing tactics on achieving score-box possessions in a random series of team possessions from Norwegian professional soccer matches. J Sports Sci. 2010 Feb;28(3):245-55.
20. Casal CA, Maneiro R, Ardá T, Marí FJ, Losada JL. Possession Zone as a Performance Indicator in Football. The Game of the Best Teams. Front Psychol. 2017 Jul 14;8:1176.
21. Tenga A, Sigmundstad E. Characteristics of goal-scoring possessions in open play: Comparing the top, in-between and bottom teams from professional soccer league. Int. J. Perform. Anal. Sport. 2011; *11*(3), 545–552.

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Original

Comparative effectiveness of Yoga and Pilates intervention on respiratory function of patients with breast cancer

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ABSTRACT

Objective: Most modern breast cancer treatments are shown to be effective in terms of survival but lead to side effects such as dysfunction of the upper limb, lymphedema, pain syndrome, plexitis, cardiotoxicity, fatigue, and pulmonary complications. Applied radiotherapy enhances the number of side effects that patients with breast cancer experience over a long period. The aim of this study was to compare effectiveness of Hatha Yoga and Pilates interventions on respiratory function in patients with breast cancer.
Methods: 95 women completed the interventions and were included in the final analysis. The participants, staged I-II, were randomly assigned to 2 groups. Group A (n = 48, 57.53 ± 1.92 years) received Hatha Yoga intervention and group B (n = 47, 58.00 ± 1.27 years) received Pilates intervention. Both programs were conducted for 12 weeks, with three 60-min sessions per week. Spirometry was used to measure pre- and post-intervention functional capacity of the respiratory system.
Results: Significant differences ($p<0.05$) were found in Vital Capacity, Forced Vital Capacity, Peak Expiratory Flow, Maximum Expiratory Flow25, Expiratory Reserve Volume and Maximal Voluntary Ventilation in Hatha Yoga group compared with Pilates group. There was no significant difference between both groups in Force Expiratory Volume and Maximum Expiratory Flow50 ($p>0,05$)
Conclusions: Hatha Yoga and Pilates interventions are both effective in respiratory function, but Hatha Yoga turns out more beneficial.
Keywords: Breast cancer; Respiratory system; Yoga; Pilates

Efectividad de la intervención de Yoga vs Pilates en la función respiratoria de pacientes con cáncer de mama

RESUMEN

Objetivo: La mayoría de los tratamientos modernos contra el cáncer de mama han demostrado ser efectivos en términos de supervivencia, pero provocan efectos secundarios como disfunción del miembro superior, linfedema, síndrome de dolor, plexitis, cardiotoxicidad, fatiga y complicaciones pulmonares. La radioterapia aplicada aumenta la cantidad de efectos secundarios que experimentan los pacientes con cáncer de mama durante un período prolongado. El objetivo de este estudio fue comparar la efectividad de las intervenciones de Hatha Yoga y Pilates sobre la función respiratoria en pacientes con cáncer de mama.
Métodos: 95 mujeres completaron las intervenciones y fueron incluidas en el análisis final. Los participantes, estadios I-II, fueron asignados aleatoriamente a 2 grupos. El grupo A (n = 48, 57.53 ± 1.92 años) recibió intervención de Hatha Yoga y el grupo B (n = 47, 58.00 ± 1.27 años) recibió intervención de Pilates. Ambos programas se realizaron durante 12 semanas, con tres sesiones de 60 min por semana. La espirometría se utilizó para medir la capacidad funcional del sistema respiratorio antes y después de la intervención.
Resultados: Se encontraron diferencias significativas ($p<0.05$) en Capacidad Vital, Capacidad Vital Forzada, Flujo Espiratorio Pico, Flujo Espiratorio Máximo25, Volumen de Reserva Espiratorio y Ventilación Voluntaria Máxima en el grupo de Hatha Yoga comparado con el grupo de Pilates. No hubo diferencia significativa entre ambos grupos en Volumen Espiratorio Forzado y Flujo Espiratorio Máximo50 ($p>0.05$).
Conclusiones: Las intervenciones de Hatha Yoga y Pilates son efectivas en la función respiratoria, pero Hatha Yoga resulta más beneficiosa.
Palabras clave: Cáncer de mama; Sistema respiratorio; Yoga; Pilates

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Eficácia comparativa da intervenção de Yoga e Pilates na função respiratória de pacientes com câncer de mama

RESUMO

Objetivo: A maioria dos tratamentos modernos de câncer de mama se mostram eficazes em termos de sobrevida, mas levam a efeitos colaterais como disfunção do membro superior, linfedema, síndrome da dor, plexite, cardiotoxicidade, fadiga e complicações pulmonares. A radioterapia aplicada aumenta o número de efeitos colaterais que as pacientes com câncer de mama experimentam por um longo período. O objetivo deste estudo foi comparar a eficácia das intervenções Hatha Yoga e Pilates na função respiratória em pacientes com câncer de mama.
Métodos: 95 mulheres completaram as intervenções e foram incluídas na análise final. Os participantes, estágio I-II, foram distribuídos aleatoriamente em 2 grupos. O grupo A (n = 48, 57.53 ± 1.92 anos) recebeu intervenção de Hatha Yoga e o grupo B (n = 47, 58.00 ± 1.27 anos) recebeu intervenção de Pilates. Ambos os programas foram realizados durante 12 semanas, com três sessões de 60 minutos por semana. A espirometria foi utilizada para medir a capacidade funcional pré e pós-intervenção do sistema respiratório.
Resultados: Foram encontradas diferenças significativas (p<0.05) na Capacidade Vital, Capacidade Vital Forçada, Pico de Fluxo Expiratório, Fluxo Expiratório Máximo25, Volume Expiratório de Reserva e Ventilação Voluntária Máxima no grupo Hatha Yoga comparado ao grupo Pilates. Não houve diferença significativa entre os dois grupos no Volume Expiratório de Força e Fluxo Expiratório Máximo50 (p>0.05).
Conclusões: As intervenções de Hatha Yoga e Pilates são eficazes na função respiratória, mas Hatha Yoga se mostra mais benéfica.
Palavras-chave: Câncer de mama; Sistema respiratório; Yoga; Pilates

Introduction

Modern data underline the rise in the number of women with breast cancer.[1] Most modern oncological treatment methods are shown to be effective in terms of survival but lead to side effects such as dysfunction of the upper limb, lymphedema, pain syndrome, plexitis, cardiotoxicity, fatigue, and pulmonary complications, fatigue, and pulmonary complications induced by adjuvant cancer therapies.[2-4] Furthermore, applied radiotherapy enhances the number of side effects that patients experience over a long period,[5] which necessitates the development of differentiated physical rehabilitation aimed at preventing post-treatment complications and improving the functional state of the cardiovascular system.

Numerous studies have shown that thoracic radiotherapy in patients with breast cancer might lead to significant impairment in functional capacity of respiratory system (chest mobility restriction , muscle weakness, dyspnea, impaired lung diffusion) and exercise performance,[6-8] which is imperative to consider when developing a rehabilitation program.

Previous studies have emphasized the significant role of different interventions in improving functional capacity in breast cancer patients. These interventions include aerobic exercises,[9] Pilates exercises,[10] yoga exercises,[11-15] and combined aerobic and resistance exercise programs.[16,17] Nevertheless, previous studies have principally focused on the efficacy of yoga therapy in reducing fatigue, depression, and cancer-related lymphoedema in women suffering from breast cancer.[18-21]

To date, there are publications that show the positive role of Pilates in improving the respiratory function in patients with multiple sclerosis[22] and cardiorespiratory parameters in healthy sedentary women with low respiratory capacities.[23] Contemporary publications also show that regular Yoga practice increases the vital capacity, timed vital capacity, maximum voluntary ventilation, breath holding time and maximal inspiratory and expiratory pressures in yoga practitioners[24] and lung cancer patients.[25] The aim of this study was to compare effectiveness of Hatha Yoga and Pilates interventions separately on respiratory function in patients with breast cancer.

Methods

Participants

A total of 110 women consented to take part in the study but only 102 met the inclusion criteria and were involved (8 patients did not meet the research criteria and were excluded). The inclusion criteria were as follows: Ukrainian individuals aged between 55 and 60 years, I–II stages of the tumour; the average time after breast cancer surgery (Madden mastectomy) ranged between 3 and 4 weeks. The exclusion criteria involved cognitive deficiency or psychiatric disease, bilateral mastectomy, heart failure, stage III tumour, refusal to participate. Overall, 95 women completed the interventions and were included in the final analysis (Figure 1).

Subject characteristics and breast cancer stage are shown in Table 1. The women were randomized by using sequentially numbered, opaque sealed envelopes. The randomization was performed by an independent person via random numbers generated in Microsoft Excel. An independent person who was separate from the assessment and recruitment of the patients opened the envelopes. The participants' mean age was 57.53 ± 1.92 years for group A (Hatha Yoga) and 58.00 ± 1.27 years for group B (Pilates).

Table 1. Demographic and clinical characteristics of the participants

Characteristics		Groups		*p*
		A (*n* = 48)	B (*n* = 47)	
Age, years (*M* ± *SD*)		57.53±1.92	58.00±1.27	> 0.05
Race	White, *n* (%)	46 (96)	45 (96)	> 0.05
	Black, *n* (%)	2 (4)	2 (4)	> 0.05
Body mass index, kg/m2 (*M* ± *SD*)		24.23±0.38	24.25±0.38	> 0.05
Weeks since surgery treatment completion (*M*± *SD*)		3.23 ± 1.17	3.25 ± 1.19	> 0.05
Cancer stage	1, *n* (%)	8 (17)	9 (19)	> 0.05
	2, n (%)	40 (83)	38 (81)	>0.05

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the ethical committee of Khortytsia National Academy. Written informed consent has been obtained from all individuals included in this study.

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the ethical committee of Khortytsia National Academy. Written informed consent has been obtained from all individuals included in this study.

Procedure

The independent researcher who administered the spirometry was blinded to the group assignment of the participants. Spirometry was used to measure pre- and post-intervention

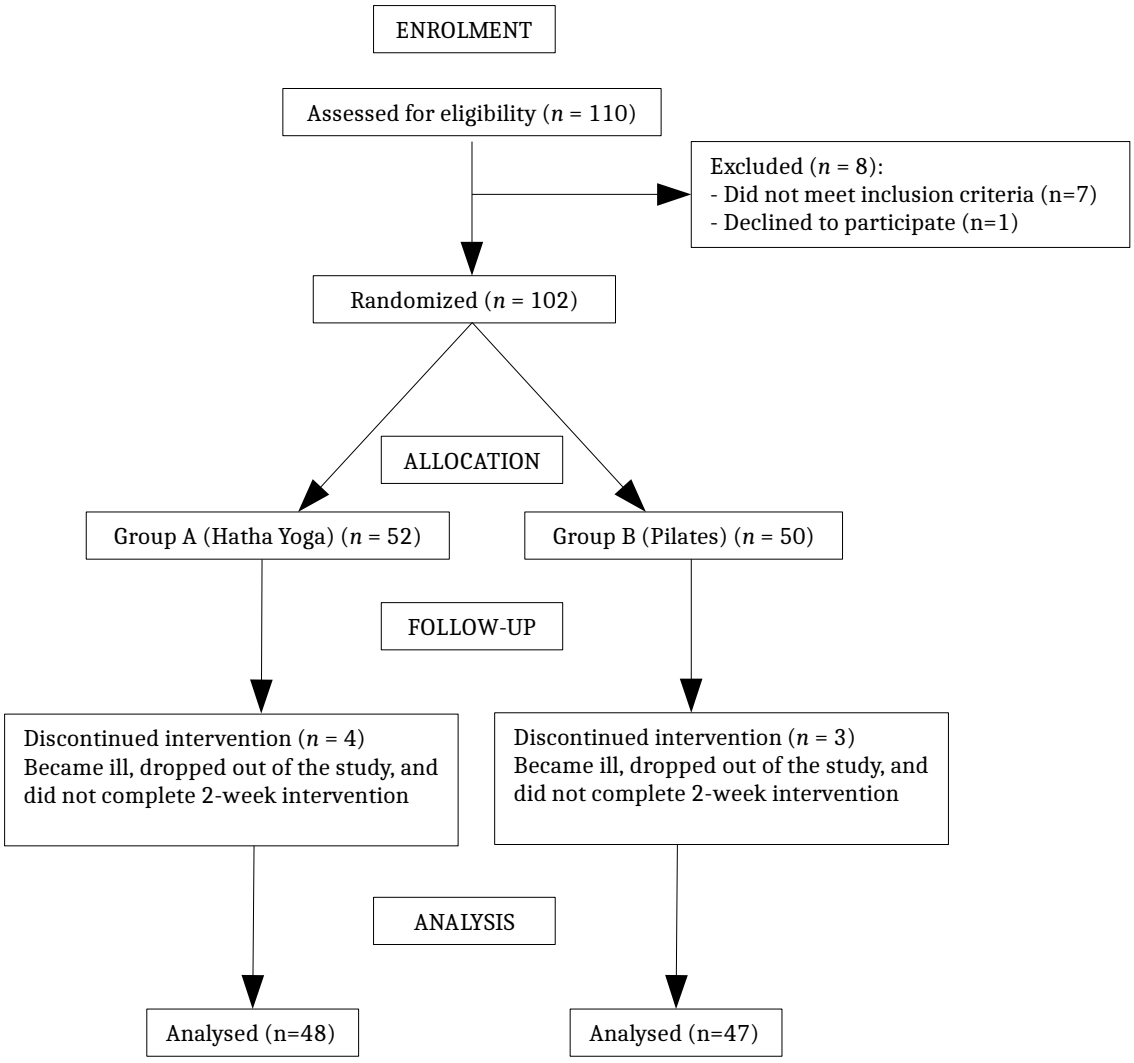

Figure 1. CONSORT flow diagram of the study

respiratory function. Spirometry was performed with the help of SMP-21/01 RD Spirometer SMP-21/01 RD (Monitor Ltd. Co., Rostov-on-Don, Russia). The following variables were assessed:

• Vital Capacity (VC): the largest volume measured on complete exhalation after full inspiration, expressed in liters and was performed unforced. For VC, the largest value from at least three acceptable maneuvers was recorded.

• Forced vital capacity (FVC): the maximal volume of air exhaled with maximally forced effort from a maximal inspiration, expressed in liters. The subject inhaled rapidly and completely from functional residual capacity while the breathing tube was inserted into the subject's mouth with lips sealed around the mouthpiece and tongue not occluding the mouthpiece.

• Forced expiratory volume in 1 s (FEV_1): the maximal volume of air exhaled in the first second of a forced expiration from a position of full inspiration, expressed in liters. FVC and FEV_1 were measured from three forced expiratory curves that had an acceptable start of test and were free from artifact. The largest FVC and the largest FEV_1 were recorded after examining the data from all of the usable curves.

• Peak expiratory flow (PEF): the highest flow achieved from a maximum forced expiratory maneuver started without hesitation from a position of maximal lung inflation, expressed in l/s. PEF is dependent on effort and lung volume, with subject cooperation being essential. PEF must be achieved as rapidly as possible and at as high a lung volume as possible, in order to obtain the maximum value.

• Maximum Expiratory Flow at 25% of FVC (MEF25): the maximum expiratory flow, when 25% of the FVC has been exhaled.

• Maximal Expiratory Flow at 50% FVC (MEF50): the maximum expiratory flow, when 50% of the FVC has been exhaled.

• Maximum Volume of Ventilation (MVV): the maximum volume of air a subject can breathe over a specified period.

• Inspiratory Reserve Volume (IRV): the maximal volume of air inhaled from end-inspiration.

• Expiratory Reserve Volume (ERV): the maximal volume of air exhaled from end-expiration, expressed.

Heart rate control mode during hatha yoga and Pilates sessions were monitored using a tracker Polar.

Interventions

The participants of group A and group B performed both programs for 12 weeks, with three 60-min sessions per week. Exercise intensity was individualized for the patients and varied from 50% to 60%. Heart rate control mode during hatha yoga and Pilates sessions. Both interventions took place at the Zaporizhzhya Regional Cancer Centre and were performed by the same certified yoga and Pilates therapist. Each session of yoga intervention consisted of several continuous poses (static, dynamic, stato-dynamic, relaxing, and respiratory) that were based on the participants' individual baseline functional capacity of the cardiovascular system. The yoga intervention consisted of breathing exercises (10 min), asanas in standing, sitting, lying

Table 2. Dynamics of respiratory function in the studied groups

Indicator		Group A (n = 48)		Group B (n = 47)	
		Beginning	3-month intervention	Beginning	3-month intervention
Vital capacity, l	Actual	2.58±0.04	2.83±0.07**	2.51±0.08	2.60±0.07
	% of predicted	79.72±1.98	85.92±2.09*	78.00±2.73	79.82±2.20
Forced vital capacity, l	Actual	2.50±0.02	2.65±0.04**	2.47±0.04	2.48±0.03
	% of predicted	79.12±1.41	83.36±1.51*	79.68±1.70	79.96±1.68
Forced expiratory volume in 1 second, l	Actual	1.97±0.07	2.36±0.06***	1.96±0.05	2.23±0.04***
	% of predicted	79.90±3.28	89.16±2.74**	79.35±2.07	89.91±2.24**
Peak expiratory flow, l/sec	Actual	3.86±0.13	4.66±0.16**	3.74±0.17	3.75±0.15
	% of predicted	63.88±2.13	72.84±2.70*	61.96±2.96	62.16±2.64
Maximum expiratory flow $_{25}$, l/sec	Actual	3.52±0.14	3.99±0.13*	3.48±0.16	3.57±0.14
	% of predicted	65.72±2.46	76.68±2.50**	65.04±3.16	66.84±2.82
Maximum expiratory flow $_{50}$, l/sec	Actual	3.42±0.12	3.75±0.15	3.39±0.14	3.40±0.15
	% of predicted	90.00±3.24	98.76±3.62	89.72±3.93	89.82±4.23
Inspiratory reserve volume, l		1.11±0.03	1.19±0.07	0.99±0.06	1.11±0.07
Expiratory reserve volume, l		0.70±0.03	0.96±0.08**	0.88±0.12	0.70±0.08
Maximal voluntary ventilation, l/min		58.86±1.52	67.77±2.40*	64.61±3.15	61.04±2.18

* p < 0.05, ** p < 0.01, *** p < 0.001 for the data in groups A and B after intervention; VC – Vital capacity, FVC – Forced vital capacity, FEV1 – Forced expiratory volume in 1 second, PEF – Peak expiratory flow, MEF25 – Maximum expiratory flow 25, l/sec, MEF50 – Maximum expiratory flow 50, IRV – Inspiratory reserve volume, ERV – Expiratory reserve volume, MVV – Maximal voluntary ventilation.

Table 3. A comparison of post-intervention score averages of the spirometry indicators between the groups

Indicator		Group A (n = 48)	Group B (n = 47)	p
		3-month intervention	3-month intervention	
Vital capacity, l	Actual	2.83±0.07	2.60±0.07	<0.05
	% of predicted	85.92±2.09	79.82±2.20	<0.05
Forced vital capacity, l	Actual	2.65±0.04	2.48±0.03	<0.05
	% of predicted	83.36±1.51	79.96±1.68	<0.05
Forced expiratory volume in 1 second, l	Actual	2.36±0.06	2.23±0.04	>0.05
	% of predicted	89.16±2.74	89.91±2.24	>0.05
Peak expiratory flow, l/sec	Actual	4.66±0.16	3.75±0.15	<0.05
	% of predicted	72.84±2.70	62.16±2.64	<0.05
Maximum expiratory flow $_{25}$, l/sec	Actual	3.99±0.13	3.57±0.14	<0.05
	% of predicted	76.68±2.50	66.84±2.82	<0.05
Maximum expiratory flow $_{50}$, l/sec	Actual	3.75±0.15	3.40±0.15	>0.05
	% of predicted	98.76±3.62	89.82±4.23	>0.05
Inspiratory reserve volume, l		1.19±0.07	1.11±0.07	
Expiratory reserve volume, l		0.96±0.08	0.70±0.08	<0.05
Maximal voluntary ventilation, l/min		67.77±2.40	61.04±2.18	<0.05

VC – Vital capacity, FVC – Forced vital capacity, FEV1 – Forced expiratory volume in 1 second, PEF – Peak expiratory flow, MEF25 – Maximum expiratory flow 25, l/sec, MEF50 – Maximum expiratory flow 50, IRV – Inspiratory reserve volume, ERV – Expiratory reserve volume, MVV – Maximal voluntary ventilation.

positions (40 min), and relaxation exercises in lying position (10 min).

To improve the functional state of the respiratory system, static pranayama was used to change the phases of the respiratory cycle (time of inhalation and exhalation); with alternate change of the type of breathing (elements of full breathing); with forced exhalations due to abdominal and diaphragm muscles (Kapalabhati, Bhastrika breathing); with delayed breathing after prolonged exhalation (Rechaka, Shunyaka, rhythmic breathing); with increasing strength and endurance of expiratory respiratory muscles (Uddiyana Bandha, Uddiyana Bandha Kriya, etc.).

Group B participants performed a Pilates program that included Pilates matwork exercises (30 min), Power Pilates (10 min), Pilates ball (10 min), and Pilates stretch (10 min). The main purpose of Pilates matwork exercises was to teach the women safe and rational techniques of performing basic exercises, breathing properly, and focusing on the movements performed. Exercise intensity was related to the functional capacity of the cardiovascular system in the women after breast cancer surgery.

Statistical Analysis

The obtained data were analysed with the Statistical Package for the Social Sciences (SPSS) computer program. The Shapiro-Wilk test was preliminarily completed to spot the normal distribution of data. Dependent t-test was used to compare pre- and post-treatment respiratory changes for each group. Independent t-tests served to compare post-intervention respiratory parameters between group A and group B.

Results

All indicators of respiratory function were equivalent in the study groups at the beginning of the rehabilitation. Thus, the groups were homogeneous at the start of the study. Dynamics of respiratory function in the studied groups is presented in Table 2.

As presented in Table 2, the dependent and independent t-test analysis revealed that in group A there was a significant increase in the functional state of the respiratory system.

Post-intervention impact (p < 0.05) in patients of group B was noted only by the forced expiratory volume in 1 second that significantly increased by 0.27 1. Applying the 3-month hatha yoga intervention, a significant increase was observed in group A: in vital capacity by 0,25 l (p < 0.01), in forced vital capacity by 0.15 l (p < 0.01), in forced expiratory volume in 1 second by 0.39 l (p < 0.001), in peak expiratory flow by 0.80 l/sec (p < 0.01), in maximum expiratory flow 25 by 0.47 l/sec (p < 0.05), in expiratory reserve volume by 0.26 l (p < 0.01) and in maximal voluntary ventilation by 8.91 l (p < 0.05). The predicted values of vital capacity improved significantly in patients of group A by 6.20% (p < 0.05), forced vital capacity by 4.24% (p < 0.01), forced expiratory volume in 1 second by 9.26% (p < 0.01), peak expiratory flow by 8.96 % (p < 0.05), maximum expiratory flow 25 by 10.96 % (p < 0.01) respectively. A comparison of post-intervention score averages of the spirometry indicators between the groups is presented in Table 3.

The actual values of vital capacity, forced vital capacity, peak expiratory flow, maximum expiratory flow 25, expiratory reserve volume and maximal voluntary ventilation were significantly higher in group A compared with group B participants: by 0,23 l (p < 0.05), by 0,17 l (p < 0.05), 0,91 l/sec (p < 0.05), 0,42 l/sec (p < 0.05), 0,26 l (p < 0.05) and 6.73 l/min respectively. The predicted values of vital capacity was significantly higher in group A compared with group B patients by 6.10% (p < 0.05), forced vital capacity by 3.4% (p < 0.01), peak expiratory flow by 10.68% (p < 0.05), maximum expiratory flow 25 by 9.84 % (p < 0.01) respectively. No differences were found in FEV and MEF50 between groups after intervention.

Discussion

The study was conducted to assess the impact of Hatha Yoga intervention on the functional state of the respiratory system in patients after breast cancer surgery. It was found a positive effect of Hatha Yoga on respiratory function in patients with breast cancer. Most antecedent yoga intervention for patients with breast cancer have been organized to reduce cancer treatment-related symptoms such as fatigue,[21] functional state of the upper limb,[11,26] peripheral muscle strength,[27] lymphedema,[28] depression, anxiety,[18] and health-related quality of life.[29] Some previous studies have identified that yoga considerably impacts on cardiorespiratory fitness and strength in healthy adults,[14,24] but Hatha Yoga effect on functional capacity of the respiratory system in breast cancer Ukrainian patients has not been reported.

The current results demonstrated significant positive effects of the Hatha Yoga intervention on increasing vital capacity, in forced vital capacity, forced expiratory volume in 1 second, peak expiratory flow, maximum expiratory flow$_{25}$, expiratory reserve volume and in maximal voluntary ventilation. These findings might be particularly important for women with low capacity to participate in traditional aerobic or resistance programs. The results of this research agree with those of other studies which suggest that yoga exercises are a safe and effective intervention for patients with breast cancer.

The current study has several notable strengths, which include a complex application of asanas and breathing exercises in accordance with the type of respiratory and autonomic dysfunction. To regulate the activity of the autonomic nervous system, emphasis was placed on the duration of the respiratory cycle phases, respiratory retardation, and stimulation of breathing through the corresponding nostrils. To increase the activity of the parasympathetic department, we focused on prolonged non-forced exhalation through the left nostril and delay after exhalation; to increase the activity of the sympathetic one – on forced inhalation and exhalation through the right nostril, delay after inhalation. Different asanas were performed in standing, sitting, and lying positions. Despite the positive results, our study has some limitations. The results obtained cannot fully explain the changes in pulmonary function, because our study lacked a control group that received no intervention. In addition, minor differences in the lifestyle and genetic factors of the women studied could have influenced the results obtained.

As conclusion, in the face of these results, we consider that the Hatha Yoga intervention was more effective than Pilates, with a favourable impact on functional capacity of the respiratory system in women after breast cancer surgery. Yoga exercises are a safe and effective intervention for patients with breast cancer.

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References

1. Ahmad A. Breast Cancer Statistics: Recent Trends. Adv Exp Med Biol. 2019;1152:1-7.
2. Spyropoulou D, Leotsinidis M, Tsiamita M, Spiropoulos K, Kardamakis D. Pulmonary function testing in women with breast cancer treated with radiotherapy and chemotherapy. In Vivo. 2009 Sep-Oct;23(5):867-71.
3. Kenyon M, Mayer DK, Owens AK. Late and long-term effects of breast cancer treatment and surveillance management for the general practitioner. J Obstet Gynecol Neonatal Nurs. 2014;43(3):382-98.
4. Dunne M, Keenan K. CE: Late and Long-Term Sequelae of Breast Cancer Treatment. Am J Nurs. 2016;116(6):36-45.
5. Pillai US, Kayal S, Cyriac S, Nisha Y, Dharanipragada K, Kamalanathan SK, Halanaik D, Kumar N, Madasamy P, Muniswamy DK, Dubashi B. Late Effects of Breast Cancer Treatment and Outcome after Corrective Interventions. Asian Pac J Cancer Prev. 2019 1;20(9):20(9): 2673–2679.
6. Verbanck S, Hanon S, Schuermans D, Van Parijs H, Vinh-Hung V, Miedema G, et al. Small airways function in breast cancer patients before and after radiotherapy. Breast Cancer Res Treat. 2012 Oct;135(3):857-65.
7. O'Donnell DE, Webb KA, Langer D, Elbehairy AF, Neder JA, Dudgeon DJ. Respiratory Factors Contributing to Exercise Intolerance in Breast Cancer Survivors: A Case-Control Study. J Pain Symptom Manage. 2016 Jul;52(1):54-63.
8. Suesada MM, Carvalho HA, Albuquerque ALP, Salge JM, Stuart SR, Takagaki TY. Impact of thoracic radiotherapy on respiratory function and exercise capacity in patients with breast cancer. J Bras Pneumol. 2018 Nov-Dec;44(6):469-76.
9. Dolan LB, Gelmon K, Courneya KS, Mackey JR, Segal RJ, Lane K, et al. Hemoglobin and aerobic fitness changes with supervised exercise training in breast cancer patients receiving chemotherapy. Cancer Epidemiol Biomarkers Prev. 2010;19(11):2826–32.
10. Şener H, Malkoç M, Ergin G, Karadibak D, Yavuzşen T. Effects of Clinical Pilates Exercises on Patients Developing Lymphedema after Breast Cancer Treatment: A Randomized Clinical Trial. J Breast Health. 2017 Jan; 13(1): 16–22.
11. Loudon A, Barnett T, Piller N, Immink MA, Visentin D, Williams AD. The effects of yoga on shoulder and spinal actions for women with breast cancer-related lymphoedema of the arm: A randomised controlled pilot study. BMC Complement Altern Med. 2016;16:343.
12. Narahari SR, Aggithaya MG, Thernoe L, Bose KS, Ryan TJ. Yoga protocol for treatment of breast cancer-related lymphedema. Int J Yoga. 2016;9(2):145-55.
13. Beutler E, Beltrami FG, Boutellier Urs, Spengler CM. Effect of Regular Yoga Practice on Respiratory Regulation and Exercise Performance. PLoS One. 2016; 11(4): e0153159.
14. Kongkaew C, Lertsinthai P, Jampachaisri K, Mongkhon P, Meesomperm P, Kornkaew K, Malaiwong P. The Effects of Thai Yoga on Physical Fitness: A Meta-Analysis of Randomized Control Trials. J Altern Complement Med. 2018;24(6):541-51.
15. Odynets T, Briskin Y, Dolinsky B, Todorova V, Vindiuk P, Yefremova A et al. The effect of hatha yoga on range of motion and strength in patients with breast cancer. Physiotherapy Quarterly. 2021;29(1):56-60.
16. Anulika Aweto H, Akinbo SR, Olawale OA. Effects of Combined Aerobic and Stretching Exercises on the Cardiopulmonary Parameters of Premenopausal and Postmenopausal Breast Cancer Survivors. Nig Q J Hosp Med. 2015;25(3):177-83.
17. Odynets T, Briskin Y. Effect of individualised physical rehabilitation programs on the functional state of the cardiovascular system in women with post-mastectomy syndrome. International Journal of Therapy and Rehabilitation. 2019;26(2):1-10.

18. Taso CJ, Lin HS, Lin WL, Chen SM, Huang WT, Chen SW. The effect of yoga exercise on improving depression, anxiety, and fatigue in women with breast cancer: a randomized controlled trial. J Nurs Res. 2014;22(3):155-64.
19. Cramer H, Lauche R, Klose P, Lange S, Langhorst J, Dobos GJ. Yoga for improving health- related quality of life, mental health and cancer-related symptoms in women diagnosed with breast cancer. Cochrane Database Syst Rev. 2017 Jan 3;1(1):CD010802.
20. Mazor M, Lee JQ, Peled A, Zerzan S, Irwin C, Chesney MA, et al. The Effect of Yoga on Arm Volume, Strength, and Range of Motion in Women at Risk for Breast Cancer-Related Lymphedema. J Altern Complement Med. 2018;24(2):154-60.
21. Jong MC, Boers I, Schouten van der Velden AP, Meij SV, Göker E, Timmer-Bonte ANJH, et al. A Randomized Study of Yoga for Fatigue and Quality of Life in Women with Breast Cancer Undergoing (Neo) Adjuvant Chemotherapy. J Altern Complement Med. 2018;24(9-10):942-53.
22. Abasıyanık Z, Ertekin Ö, Kahraman T, Yigit P, Özakbaş S. The effects of Clinical Pilates training on walking, balance, fall risk, respiratory, and cognitive functions in persons with multiple sclerosis: A randomized controlled trial. Explore (NY). 2020 Jan-Feb;16(1):12-20.
23. Souza C, Krüger RL, Schmit EFD, Wagner Neto ES, Reischak-Oliveira Á, de Sá CKC, et al. Cardiorespiratory Adaptation to Pilates Training. Res Q Exerc Sport. 2021 Sep;92(3):453-459.
24. Shobha Rani Vedala, Abhay B Mane, C Nliranjan Paul. Pulmonary functions in yogic and sedentary population. Int J Yoga. 2014 Jul;7(2):155-9.
25. Fouladbakhsh JM, Davis JE, Yarandi HN. Using a standardized Viniyoga protocol for lung cancer survivors: a pilot study examining effects on breathing ease. J Complement Integr Med. 2013 Jun 26;10.
26. Pasyar N, Barshan Tashnizi N, Mansouri P, Tahmasebi S. Effect of yoga exercise on the quality of life and upper extremity volume among women with breast cancer related lymphedema: A pilot study. Eur J Oncol Nurs. 2019 Oct;42:103-109.
27. Vardar Yağlı N, Şener G, Arıkan H, Sağlam M, İnal İnce D, Savcı S, et al. Do yoga and aerobic exercise training have impact on functional capacity, fatigue, peripheral muscle strength, and quality of life in breast cancer survivors? Integr Cancer Ther. 2015 Mar;14(2):125-32.
28. Loudon A, Barnett T, Williams A. Yoga, breast cancer-related lymphoedema and well- being: A descriptive report of women's participation in a clinical trial. J Clin Nurs. 2017;26(23-24):4685-95.
29. McCall M. Yoga intervention may improve health-related quality of life (HRQL), fatigue, depression, anxiety and sleep in patients with breast cancer. Evid Based Nurs. 2018 Jan;21(1):9.

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Original

Re-warm-up practices in elite and sub-elite Spanish men's and women's basketball team: practitioners' perspectives

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ABSTRACT

Objective: Research suggests that an active re-warm-up (RW-U) during half-time improves performance capacity in team sports, despite limited evidence in basketball. This study aimed to identify the practice of RW-U activities during the half-time period in elite and sub-elite Spanish men's and women's basketball teams.
Methods: We asked strength and conditioning coaches from all teams competing at ACB, LF, LF2, LEB Oro, LEB Plata and EBA leagues during the 2020/21 season to fill in a web survey.
Results: All respondents reported familiarization with the RW-U concept, although 45% only reproduced traditional strategies. Half of the coaches indicated that they always performed some activity, while the other half pointed out lack of time (45.7%) and player demands (62.9%) as the main constraints impeding its regular use.
Conclusion: Spanish basketball teams continue to reproduce traditional practices of active re-warm-up during half-time, regardless of their competitive level.
Keywords: Coaches; Half-time; Performance; Survey; Team sport.

Prácticas de re-calentamiento en equipos de baloncesto masculino y femenino de élite y sub-élite españoles: perspectivas de los profesionales

RESUMEN

Objetivo: La investigación sugiere que un recalentamiento activo (RW-U) durante el descanso mejora la capacidad de rendimiento en los deportes de equipo, a pesar de que la evidencia en el baloncesto es limitada. Este estudio tiene como objetivo identificar la práctica de actividades de RW-U durante el periodo de descanso en equipos de baloncesto españoles de élite y sub-élite.
Métodos: Se pidió a los preparadores físicos de todos los equipos que compiten en las ligas ACB, LF, LF2, LEB Oro, LEB Plata y EBA durante la temporada 2020/21 que rellenaran una encuesta web.
Resultados: Todos los encuestados declararon estar familiarizados con el concepto RW-U, aunque el 45% sólo reprodujo las estrategias tradicionales. La mitad de los entrenadores indicó que siempre realizaba alguna actividad, mientras que la otra mitad señaló la falta de tiempo (45,7%) y la exigencia de los jugadores (62,9%) como las principales razones que limitan su uso regular.
Conclusión: Los equipos de baloncesto español siguen reproduciendo prácticas tradicionales de re-calentamiento activo durante el medio tiempo, independientemente de su nivel competitivo.
Palabras clave: Entrenadores; Medio tiempo; Rendimiento; Encuesta; Deportes de equipo.

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Práticas de reaquecimento nas equipas de elite e subelite espanholas de basquetebol masculino e feminino: perspectivas dos praticantes

RESUMO

Objectivos: A investigação sugere que um reaquecimento activo (RW-U) durante o intervalo melhora a capacidade de desempenho nos desportos de equipa, apesar das provas limitadas no basquetebol. Este estudo visava identificar a prática de actividades de RW-U durante o intervalo nas equipas de elite e subelite espanholas de basquetebol masculino e feminino.
Métodos: Pedimos força e condicionamento aos treinadores de toda as equipas que competiram nas ligas ACB, LF, LF2, LEB Oro, LEB Plata e EBA durante a época de 2020/21 para preencher um inquérito na web.
Resultados: Todos os inquiridos relataram familiarização com o conceito de RW-U, embora 45% reproduzissem apenas estratégias tradicionais. Metade dos treinadores indicaram que sempre realizaram alguma actividade, enquanto a outra metade apontou a falta de tempo (45,7%) e as exigências dos jogadores (62,9%) como os principais constrangimentos que impedem a sua utilização regular.
Conclusão: As equipas espanholas de basquetebol continuam a reproduzir práticas tradicionais de reaquecimento activo durante o intervalo, independentemente do seu nível competitivo.
Palavras-chave: Treinadores; Intervalo; Desempenho; Inquérito; Esportes de equipa.

Introduction

Basketball is a court-based team sport with a broad array of physical, physiological, mechanical, technical, and tactical demands.[1] Namely, the intermittent high-intensity nature of most actions and basketball-specific movements (e.g. accelerating, decelerating, changing direction, jumping, shuffling, cutting, etc.) stress the aerobic and anaerobic energy systems.[2] Ultimately, this can lead to a considerable fatigue level,[3] where the ability to resist the development of fatigue could positively influence critical aspects of basketball performance.[4]

Basketball matches, by regulation, have a 10-minute break between halves that might not allow for a complete recovery from fatigue. Moreover, the passive activities that generally occur during these breaks could be detrimental to second-half performance.[5] Indeed, research has shown that passive half-time practices are not an optimal strategy for both professional[6] and amateur [7] players. For instance, there appears to be a relatively rapid decline in jumping and sprinting performance when elite male and female basketball players remain inactive after warm-up.[8]

In order to avoid a decline in the ability to perform high-intensity activities, in other intermittent team sports such as association football, it seems advisable to perform brief exercise bouts (e.g. running, cycling, or leg press) during the half-time break, usually known as re-warm-up (RW-U) activities.[9] However, despite scientific evidence indicating the positive impact RW-U activities had on the players' subsequent physical and technical performance,[10] most coaches continue to design their half-time strategies based on experience.[11]

In basketball, few investigations have sought to analyse the effects of RW-U practices on the players' physical performance.[12] Indeed, it seems that no research has informed about the prevalence of this practice during basketball half-time period. In addition, no study has sought to describe how basketball practitioners are applying RW-U activities. The lack of information poses a challenge when identifying whether RW-U strategies are usually implemented in basketball and determining which activities should be conducted during half-times. Making available such details would allow coaches and practitioners to make better-informed decisions about RW-U and develop half-time strategies that help basketball players meet the physical demands to compete at the highest level.

In light of the above, this study has a double-fold objective. Firstly, it aims to determine the prevalence, and main characteristics of RW-U practices typically carried out by the strength and conditioning (S&C) coaches of elite and sub-elite Spanish basketball teams. A secondary aim is to identify the reasoning and situational factors that underpin this practice in the prominent Spanish basketball leagues.

Methods

Design

A cross-sectional study was developed following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[13]

Participants

Strength and conditioning coaches of men's and women's basketball teams from the Spanish elite (ACB and Liga Femenina) and sub-elite (LEB Oro, LEB Plata, Liga Femenina 2, and EBA) leagues participated in this study. The first author of the current work identified the teams' contact information through the website of the Spanish Basketball Federation. A letter of invitation and guidelines for the online survey were distributed electronically and via mail to each team. Invitations to the survey were circulated in March of the 2020/21 basketball season, as we assumed that the coaching staff already had the half-time protocols. Two hundred fifty-two S&C coaches of teams competing in the ACB (men's top professional league, n = 19), LEB Oro (men's second professional league, n = 19), LEB Plata (men's third professional league, n = 28), EBA (men's fourth professional league n = 128), Liga Femenina (women's top professional league, n = 16) and Liga Femenina 2 (women's second professional league n = 42) were contacted, meaning that the total population was targeted. Namely, the person responsible for the player's conditioning level in the first team squad of the selected teams was asked to complete the survey. All participants were informed of the study requirements and provided written informed consent. The Local Ethics Committee of the Faculty of Education and Sports Science (University of Vigo) approved the study protocol with code 06-0721.

Procedure

Four authors of this manuscript (three doctors and one PhD student in Physical Activity and Sports Sciences), with expertise in basketball S&C research and practice, designed an ad-hoc survey to collect data on RW-U practices. The first author of this investigation initiated the survey development process by determining the key areas of the questionnaire. A second author supervised this process. These two researchers developed an initial questionnaire including 14 items after some debate on how

best to gather information through a survey. They deemed RW-U as the warm-up strategies carried out during half-time to mitigate physical performance decline and reduce injury risk. Subsequently, another two authors revised this preliminary version of the survey and then argued that the questionnaire should be shorter, brief, and concise. A substantive discussion took place, resulting in a survey comprising nine items considered the final version by these four authors. The survey was pre-tested with five Spanish S&C coaches from professional leagues in other countries to ensure face validity, using the Google Forms web survey platform. As a result of the pilot testing, the survey was slightly modified to clarify and improve the wording of a small number of questions. Additionally, some questions were shortened to create a survey that could be easily read and answered through a smartphone.

Survey

The refined version of the questionnaire consisted of nine dichotomous, categorical, or multiple-choice questions. The S&C coaches could choose the time (about 4 minutes or less) and mode (e.g. via computer or mobile phone) to fulfil it, and the web link remained open to the participants for one month. All data were collected anonymously without identifiers to ensure privacy.

The initial section of the questionnaire involved items regarding S&C coaches' age, how long they had been coaching, and the team's competitive level. After that, the survey evaluated the current status of the RW-U practice from the participant's perspective. It focused on four themes: 1) Knowledge about the concept of RW-U, 2) Strategies to improve the performance during the second half, 3) Motivations for performing RW-U; and 4) Time allocated to RW-U.

Data analysis

The analysis and presentation of data are predominantly descriptive due to the characteristics of this study. All statistical analyses were performed using SPSS 15.0. (SPSS Inc., Chicago, IL, USA). Summary statistics were calculated as dichotomous or categorical variables and presented as percentages.

Contingency tables were calculated to detect systematic associations of the assessed variables. All variables were analysed using a Chi-Square Test of Independence or Fisher's exact test when the contingency table was 2x2 ($\alpha = 0.05$). Adjusted standardized residuals were applied to isolate sources of variation among groups (using $\alpha = 0.05$). Adjusted standardized residuals were applied to isolate sources of variation among groups.[14] Responses from open-ended questions and other voluntary comments from respondents were transcribed and underwent content analysis for common themes.

Results

Thirty-three per cent of the invited teams responded to the survey with the highest response rate in ACB (84.2%) and the lowest in LEB Silver (17.9%). Contradictory answers were eliminated after data collection (n = 9). Therefore, 72 S&C coaches and three head coaches who also performed the role of S&C coach were finally included.

Table 1 shows the main findings of the research. Most of the respondents (94.7%) reported knowledge about the RW-U concept, although 45.3% of them recognized performing only traditional activities (e.g. shooting drills, 1x1). Aerobic and strength exercises were the most common RW-U activities mentioned by those who employed less conventional activities.

Technical and tactical activities (e.g. shooting drills, 1x1) were predominant, with 86.7% of the teams conducting them as part of their half-time routine. In contrast, static stretching/mobility was the least used strategy (12.0%). Finally, four respondents indicated that they carried out nutritional strategies.

Half of the respondents reported that they usually perform the same RW-U routine, while 40% tailored this practice according to the players' demands. In this aspect, sub-elite S&C coaches were more prone to modify the RW-U routine than their elite counterparts (44.4% vs 28.6%). Almost half of the respondents (46.7%) administered an R-WU routine of 1-3 minutes.

The fundamental rationale behind carrying out RW-U activities was "mental preparation" (74.7%), "increase body temperature" (61.3%), and "set a good rhythm in the third quarter" (53.3%). Conversely, "post-activation potentiation (PAP)" (38.6%), "decrease muscle and joint stiffness" (40.0%) and "injury prevention" (1.3%) were considered the least essential motives. Thirty-five teams not always conducted RW-U activities, with their S&C coaches detailing that the lack of time (45.7%) or letting the players do their preferred RW-U practice independently (62.9%) were reasons for it.

The statistical analysis indicated that years of coaching experience and age influence the level of the team they coached ($p = 0.045$ and $p < 0.01$, respectively). Despite this, no significant differences between elite and sub-elite teams were observed in all the variables analysed.

Discussion

This study aimed to determine the current RW-U practices during half-time in elite and sub-elite Spanish men's and women's basketball teams. Although several investigations have been conducted to date on this topic, we are not aware of any that have described the practices used by basketball S&C coaches in their teams. The present study provides information and recommendations in this regard, which could be helpful for those coaches and practitioners interested in improving their half-time RW-U activities. Besides, sports scientists might identify critical points for future research concerning RW-U practices.

Previous research indicates that passive rest is not an optimal strategy to use during the break.[11] Most of our respondents reported being familiar with the concept of RW-U and, interestingly, we observed that all the practitioners administered some active RW-U. At the same time, it must be noted that many S&C coaches continue to use traditional strategies exclusively, perhaps reflecting historical practices or the players' and coaches' preferences. However, when dealing with high-level teams, updating and designing evidence-based RW-U routines should be a paramount concern to basketball practitioners to ensure optimal player performance during the initial stages of the second half.

In recent years, some research has suggested that RW-U activities based on strength[15] or aerobic exercise[16] could improve muscular power and sprint performance, which may be suitable strategies for basketball. Nonetheless, only 41.3% of our participating teams reported implementing strength exercise, and this percentage dropped to 22.7% for aerobic exercise. Furthermore, only half of the respondents utilized passive RW-U strategies (e.g. heated jacket or tracksuit) combined with other active RW-U practices at half-time. These responses may be in line with Russell et al.[6], who demonstrated that integrating both types of strategies had additional positive performance effects, perhaps due to attenuated heat loss, although evidence is lacking in basketball.

Towlson et al.[17] point out that it is crucial to design short-time RW-U routines (~3 minutes) in association football. In addition, some research argues that very brief exercise bouts (1 minute) at high intensity may be sufficient to elicit physiological and performance benefits in the second half of intermittent team sports.[18,19] The latter is interesting, as more than half of the elite coaches surveyed reported spending between 1-3 minutes on this type of activity, even though the half-time period is shorter in Spanish basketball than in English association football.

Table 1. Summary of the survey responses of strength and conditioning coaches of Spanish men's and women's basketball teams according to competitive level (elite or sub-elite).

	Elite (n = 21)	Sub-elite (n = 54)	Total (N = 75)	*P*-value
Age (years)				**< 0.01**
21-45	**71.4 (15)**	**94.4 (51)**	**88.0 (66)**	
46-65	**28.6 (6)**	**5.6 (3)**	**12.0 (9)**	
Coaching experience (years)				**0.04**
1-3	**4.8 (1)**	**16.7 (9)**	**13.3 (10)**	
4-6	**14.3 (3)**	**33.3 (18)**	**28.0 (21)**	
7-11	**28.6 (6)**	**27.8 (15)**	**28.0 (21)**	
≥ 12	**52.4(11)**	**22.2 (12)**	**30.7 (23)**	
Knowledge about the concept of RW-U				0.89
Yes	95.2 (20)	94.4 (51)	94.7 (71)	
No	4.8 (1)	5.6 (3)	5.3 (4)	
Frequency of implementation RW-U activities				0.63
Always	61.9 (13)	46.3 (25)	50.7 (38)	
Only with those players starting the second half	0 (0)	1.9 (1)	1.3 (1)	
Depending on match context	4.8 (1)	1.9 (1)	2.7 (2)	
Depending on the head coach	4.8 (1)	5.6 (3)	5.3 (4)	
Depending on the player's demands	28.7 (6)	44.4 (24)	40.0 (30)	
Time allocated to RW-U practice (minutes)				**0.044**
1-3	**52.4 (11)**	**44.4 (24)**	**46.7 (35)**	
4-8	**38.1 (8)**	**55.6 (30)**	**50.7 (38)**	
≥ 8	**9.5 (2)**	**0 (0)**	**2.7 (2)**	
RW-U strategies				
Technical and tactical activities	90.5 (19)	85.2 (46)	86.7 (65)	0.53
Heated jacket or tracksuit	38.1 (8)	53.7 (29)	49.3 (37)	0.22
Tactical instructions	38.1 (8)	37.0 (20)	37.3 (28)	0.93
Strength exercise	52.4 (11)	37.0 (20)	41.3 (31)	0.23
Aerobic exercise	28.6 (6)	20.4 (11)	22.7 (17)	0.45
Static stretching/mobility	23.8 (5)	7.4 (4)	12.0 (9)	0.06
Nutritional strategies	14.3 (3)	1.9 (1)	5.3 (4)	0.06
Use of traditional RW-U strategies				0.79
Yes	42.9 (9)	46.3 (25)	45.3 (34)	
No	57.1 (12)	53.7 (29)	54.7 (41)	
The rationale for conducting the RW-U strategies				
Mental preparation	76.2 (16)	74.1 (40)	74.7 (56)	0.85
Increase body temperature	61.9 (13)	61.1 (33)	61.3 (46)	0.95
Set a good rhythm in the third quarter	52.4 (11)	53.7 (29)	53.3 (40)	0.92
Decrease muscle and joint stiffness	47.6 (10)	37.0 (20)	40.0 (30)	0.40
Post-activation potentiation (PAP)	33.3 (9)	37.0 (20)	38.7 (29)	0.64
Injury prevention	0 (0)	1.9 (1)	1.4 (1)	0.42
Reasons for not carrying out RW-U strategies*				
Lack of time	62.5 (5)	40.7 (11)	45.7 (16)	0.75
Avoid player's fatigue	12.5 (1)	11.1 (3)	11.4 (4)	0.89
Lack of space and/or material	12.5 (1)	3.7 (1)	5.7 (2)	0.51
Players are free to perform their preferred activities	37.5 (3)	70.4 (19)	62.9 (22)	0.06

** Elite (n = 8); Sub-elite (n = 27); Total (N = 35). Bold denotes statistical significance (P < 0.05).*

When asked about the most important reasons for performing RW-U practices, coaches indicated that they were "mental preparation" and "increased body temperature." The latter explanation seems to be supported by previous research showing that RW-U effectively preserved body temperature compared to passive rest.[20] Notably, only one coach detailed that "injury prevention" was a relevant factor, yet it seems that RW-U strategies could help to reduce the risk of injury during the second half in soccer.[21]

Time pressures and player demand were the main limiting factors mentioned by coaches who did not always perform the RW-U. In this sense, Galazoulas *et al.*[8] questioned the need for all players to warm up before the match because of the rapid drop in temperature when players are in passive rest. Hence, individualizing the RW-U according to the demands of the players could be an appropriate strategy to alleviate this situation during the break period, allowing those players who are going to start the third quarter to do it and respecting those players who demand to warm up for psychological reasons. Future research could shed light on this issue during the half-time in basketball.

Basketball is one of the most popular intermittent team sports globally, including Spain.[22] This popularity could explain why lack of space or equipment was not recognized as a limiting factor by most high-level S&C coaches participating in this research.

Sports scientists, coaches and practitioners should interpret the findings of this survey considering possible recall bias, the potential reluctance to share current practice and errors with a retrospective survey methodology. The questionnaire was designed to be user-friendly and straightforward to encourage the participation of the S&C coaches, despite the risk of losing information. However, we did not gather detailed information regarding specific RW-U strategies other than aerobic or strength exercise due to the short length of the questionnaire. Finally, we reached most of the top-level Spanish basketball teams, overcoming the challenge of accessing the physical conditioning practitioners working in them. Indeed, a strength of this research is that more than 80% of S&C coaches in ACB (the top professional basketball division of the Spanish basketball league system) teams answered the questionnaire. Nevertheless, the survey response rate might be deemed low, as it seems to be when web surveys are delivered.[23] In any case, it was still higher than that detected in other studies with similar target populations.[24] Therefore, we consider that our final sample was sufficiently representative.

In conclusion, although widespread in elite and sub-elite Spanish men's and women's basketball teams, our results suggest that active RW-U strategies continue to reproduce traditional practices by many teams. Therefore, the RW-U activities implemented during half-time do not reflect evidence-based practice in all cases. It does not seem that the competitive level of the teams influences the type of RW-U strategies performed during the half-time period.

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References

1. Petway AJ, Freitas TT, Calleja-González J, Leal DM, Alcaraz PE. Training load and match-play demands in basketball based on competition level: A systematic review. PLoS One. 2020;15(3):1–21.
2. Stojanović E, Stojiljković N, Scanlan AT, Dalbo VJ, Berkelmans DM, Milanović Z. The Activity Demands and Physiological Responses Encountered During Basketball Match-Play: A Systematic Review. Sport Med. 2018;48(1):111–35.
3. Edwards T, Spiteri T, Piggott B, Bonhotal J, Haff GG, Joyce C. Monitoring and Managing Fatigue in Basketball. Sports. 2018;6(1):19.
4. Mulazimoglu O, Yanar S, Tunca Evcil A, Duvan A. Examining the effect of fatigue on shooting accuracy in young basketball players. Anthropol. 2017;27(1–3):77–80.
5. Lovell RJ, Kirke I, Siegler J, Mcnaughton LR, Greig MP. Soccer half-time strategy influences thermoregulation and endurance performance. J Sports Med Phys Fitness. 2007;47(3):263–9.
6. Russell M, Tucker R, Cook CJ, Giroud T, Kilduff LP. A comparison of different heat maintenance methods implemented during a simulated half-time period in professional Rugby Union players. J Sci Med Sport. 2018;21(3):327–32.
7. Fashioni E, Langley B, Page RM. The effectiveness of a practical half-time re-warm-up strategy on performance and the physical response to soccer-specific activity. J Sports Sci. 2020;38(2):140–9.
8. Galazoulas C, Tzimou A, Karamousalidis G, Mougios V. Gradual decline in performance and changes in biochemical parameters of basketball players while resting after warm-up. Eur J Appl Physiol. 2012;112(9):3327–34.
9. Hammami A, Zois J, Slimani M, Russel M, Bouhlel E. The efficacy and characteristics of warm-up and re-warm-up practices in soccer players: A systematic review. J Sports Med Phys Fitness. 2018;58(1–2):135–49.
10. Russell M, West DJ, Harper LD, Cook CJ, Kilduff LP. Half-Time Strategies to Enhance Second-Half Performance in Team-Sports Players: A Review and Recommendations. Sport Med. 2015;45(3):353–64.
11. Silva LM, Neiva HP, Marques MC, Izquierdo M, Marinho DA. Effects of Warm-Up, Post-Warm-Up, and Re-Warm-Up Strategies on Explosive Efforts in Team Sports: A Systematic Review. Sport Med. 2018;48(10):2285–99.
12. Pociūnas R, Pliauga V, Lukonaitienė I, Bartusevičius D, Urbonavičius T, Stuknys A, et al. Effects of Different Half-Time Re-Warm Up on Vertical Jump During Simulated Basketball Game. Balt J Sport Heal Sci. 2018;2(109):35–40.
13. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol. 2008;61(4):344–9.
14. Haberman SJ. The analysis of residuals in cross-classified tables. Biometrics. 1973;29:205–20.
15. Zois J, Bishop D, Fairweather I, Ball K, Aughey RJ. High-intensity re-warm-ups enhance soccer performance. Int J Sports Med. 2013;34(9):800–5.
16. Yanaoka T, Kashiwabara K, Masuda Y, Yamagami J, Kurata K, Takagi S, et al. The effect of half-time re-warm up duration on intermittent sprint performance. J Sport Sci Med. 2018;17(2):269–78.
17. Towlson C, Midgley AW, Lovell R. Warm-up strategies of professional soccer players: Practitioners' perspectives. J Sports Sci. 2013;31(13):1393–401.
18. Yanaoka T, Iwata R, Yoshimura A, Hirose N. A 1-Minute Re-warm Up at High-Intensity Improves Sprint Performance During the Loughborough Intermittent Shuttle Test. Front Physiol. 2021;11.
19. Yanaoka T, Hamada Y, Fujihira K, Yamamoto R, Iwata R, Miyashita M, et al. High-intensity cycling re-warm up within a very short time-frame increases the subsequent intermittent sprint performance. Eur J Sport Sci [Internet]. 2020;0(0):1–33.
20. Mohr M, Krustrup P, Nybo L, Nielsen JJ, Bangsbo J. Muscle temperature and sprint performance during soccer matches - Beneficial effect of re-warm-up at half-time. Scand J Med Sci Sport. 2004;14(3):156–62.
21. Lovell R, Barrett S, Portas M, Weston M. Re-examination of the post half-time reduction in soccer work-rate. J Sci Med Sport [Internet]. 2013;16(3):250–4.
22. Reverter-Masía J, Legaz-Arrese A, Munguía-Izquierdo D, Barbany JR, Serrano-Ostáriz E. A profile of the resistance training practices of elite spanish club teams. Strength Cond. 2009;23(5):1537–47.
23. Van Mol C. Improving web survey efficiency: the impact of an extra reminder and reminder content on web survey response. Int J Soc Res Methodol. 2016;20(4):317–27.
24. Wilke J, Niederer D, Vogt L, Banzer W. Head coaches' attitudes towards injury prevention and use of related methods in professional basketball: A survey. Phys Ther Sport. 2018;32:133–9.

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Original

Association between VO2max, anthropometrical measures and change of direction test in young soccer players

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ABSTRACT

Objective: The use of the aerobic system is especially relevant due to the duration of the soccer game. In fact, the correct development of the aerobic system benefits the soccer player giving greater energy efficiency because the continuous change of energy system due to the intermittent nature of the game causes a high consumption of glycogen. The purpose of the present study was to evaluate oxygen consumption by means of the Yo-Yo intermittent test and anthropometrical measures, and different COD (change of direction) tests in young soccer players and to observe their possible relationship.
Methods: A total of forty-seven young male soccer players (age= 15.7 ± 1.2 years; height = 188.8 ± 5.8 cm, and body mass= of 75.7 ± 8.3 kg; 7.6 ± 2.0 years of experience) from the region of Baleares, Spain, performed the Yo-yo test and subsequently, COD was evaluated by tests in the following order (i) V-cut test; (ii) 505-COD test; and (iii) Illinois test.
Results: A correlation analysis between VO2max and BMI revealed a moderate negative correlation, r=-0.35, p=0.01, and between VO2max and 505-COD, showed a large negative correlation, r=-0.55, p=0.001.
Conclusions: The finding of the present study reveals that there is no relationship between VO2max and agility. Therefore, there is no single method to improve VO2max and agility since both are independent variables. The different agents involved should take this into account if they want to improve VO2max and plan some aerobic resistance exercises; and to improve agility they must plan agility exercises separately.
Keywords: Soccer; VO2max; Young soccer players; Change of direction; Agility.

Asociación entre V02max, medidas antropométricas y test de cambio de dirección en futbolistas jóvenes

RESUMEN

Objetivo: El uso del sistema aeróbico es especialmente relevante debido a la duración del partido de fútbol. De hecho, el correcto desarrollo del sistema aeróbico beneficia al futbolista otorgándole una mayor eficiencia energética ya que el continuo cambio de sistema energético debido a la naturaleza intermitente del juego provoca un alto consumo de glucógeno. El propósito del presente estudio fue evaluar el consumo de oxígeno mediante la prueba Yo-Yo intermitente y medidas antropométricas, y diferentes pruebas COD (cambio de dirección) en jóvenes futbolistas y observar su posible relación.
Métodos: Un total de cuarenta y siete jóvenes futbolistas masculinos (edad= 15.7 ± 1.2 años; altura = 188.8 ± 5.8 cm, y masa corporal= de 75.7 ± 8.3 kg; 7.6 ± 2.0 años de experiencia) de la región de Baleares, España, realizó la prueba Yo-yo y posteriormente, se evaluó la DQO mediante pruebas en el siguiente orden (i) prueba de corte en V; (ii) prueba 505-COD; y (iii) prueba de Illinois.
Resultados: Un análisis de correlación entre VO2max e IMC reveló una correlación negativa moderada, r=-0.35, p=0.01, y entre VO2max y 505-COD mostró una correlación negativa grande, r=-0.55, p=0.001.
Conclusiones: El hallazgo del presente estudio revela que no existe una relación entre el VO2max y la agilidad. Por lo tanto, no existe un método único para mejorar el VO2max y la agilidad ya que ambas son variables independientes. Los diferentes agentes implicados deberían tener esto en cuenta si quieren mejorar el VO2max y planificar algunos ejercicios de resistencia aeróbica; y para mejorar la agilidad deben planificar ejercicios de agilidad por separado.
Palabras clave: Fútbol; VO2máx; Jóvenes futbolistas; Cambio de direccion; Agilidad.

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Associação entre V02max, medidas antropométricas e teste de mudança de direção em jovens de futebol

RESUMO

Objetivo: A utilização do sistema aeróbico é especialmente relevante devido à duração do jogo de futebol. De facto, o correcto desenvolvimento do sistema aeróbico beneficia o jogador de futebol dando-lhe uma maior eficiência energética porque a mudança contínua do sistema energético devido à natureza intermitente do jogo provoca um elevado consumo de glicogénio. O objetivo do presente estudo foi avaliar o consumo de oxigênio por meio do teste Yo-Yo intermitente e medidas antropométricas e diferentes testes de COD (mudança de direção) em jovens jogadores de futebol e observar sua possível relação.
Métodos: Quarenta e sete jovens futebolistas masculinos (idade= 15,7 ± 1,2 anos; estatura = 188,8 ± 5,8 cm e massa corporal= 75,7 ± 8,3 kg; 7,6 ± 2,0 anos de experiência) da região de Baleares, Espanha, realizou o teste Yo-yo e, posteriormente, o COD foi avaliado por testes na seguinte ordem (i) teste V-cut; (ii) teste 505-COD; e (iii) teste de Illinois.
Resultados: Uma análise de correlação entre VO2max e IMC revelou uma correlação negativa moderada, r=-0,35, p=0,01, e entre VO2max e 505-COD, mostrou uma grande correlação negativa, r=-0,55, p=0,001.
Conclusões: O achado do presente estudo revela que não há relação entre VO2máx e agilidade. Portanto, não existe um método único para melhorar o VO2máx e a agilidade, pois ambos são variáveis independentes. Os diferentes agentes envolvidos devem ter isso em consideração se quiserem melhorar o VO2máx e planejar alguns exercícios aeróbicos de resistência; e para melhorar a agilidade devem planejar exercícios de agilidade separadamente.
Palavras-chave: Futebol; VO2max; Jovens jogadores de futebol; Mudança de direção; Agilidade.

Introduction

Soccer is an intermittent sport that requires different physical characteristics for the development of performance. This intermittence involves the use of the different metabolic substrates, both aerobic and anaerobic, as well as the different muscle fibers in a constant way.

The use of the aerobic system is especially relevant due to the duration of the game (more than 90 minutes) and the distance covered, between 10 and 13 km.[1] The correct development of the aerobic system benefits the soccer player giving greater energy efficiency because the continuous change of energy system, due to the intermittent nature of the game, causes a high consumption of glycogen. However, if the player has a good aerobic capacity, he/she will be able to attenuate glycogen depletion by utilizing the fat aerobic system in phases of the game where medium/high intensity is not required.[2] Therefore, a higher oxygen consumption will allow the player to recover better between actions of different intensity, thereby decreasing glycogen depletion.[3] Elsewhere, it has also been positively correlated that the higher the VO2max, the better the performance at medium/high intensities.[4] This can occur in counter-attack or retreat situations or when there is constant pressure on the opponent. Thus, the development of the aerobic capacity of soccer players in training becomes essential. In addition, in this phase of biological maturity, major changes occur at the cardiorespiratory level where the type of sport acquires special relevance. Thus, a study reported that in young people the post-exercise recovery capacity was higher in participants of mixed sports (such as soccer) versus sedentary subjects and those practicing other sports modalities.[5] Another recent study reported that soccer practice has a positive effect on the cardiorespiratory system expressed in VO_2max.[6] Although VO2max fluctuates in professional soccer players, those who compete at higher levels of play and in championships demonstrate greater values.[7] Therefore, the evaluation of maximal oxygen consumption to assess performance is essential in young soccer players. Furthermore, it is important to measure this parameter in a way that is related to the nature of the sport, i.e., intermittently. In this respect, the YO-YO intermittent test has been extensively used by different researchers to assess VO2max in soccer players.[8–12]

It is clear that performance in intermittent sports such as soccer is not only limited to high VO_2max levels; during matches players perform approximately 1,350 activities (every 4-6 s), such as accelerations/decelerations, COD and jumps, all interspersed with short recovery periods.[13,14] Therefore, there are other performance indices such as agility. This parameter requires COD and movement of the whole body in a precise and intentional manner, being of great use in activities that require speed and attention, such as in soccer.[15] In this regard, COD occur constantly in dribbling, unmarking and defensive situations. COD involve muscle action of the stretch-shortening cycle producing greater force in the shortest possible time.[16] Moreover, in game situations where spaces are limited, COD are one of the most effective solutions. In fact, COD are considered one of the most important physical qualities for predicting success in a wide variety of field sports.[17,18] Furthermore, it has been suggested that higher COD speed could be the most important performance factor during a match.[19] This highlights the importance of COD in high performance soccer. Nevertheless, the development of this parameter in the later stages of adolescence is not clear.[20] Hence, the assessment of COD by performing different tests is essential for the evaluation of the explosive strength and performance of the soccer player.[21,22]

Currently, the relationship between repeated sprints and VO2max is known. Da Silva et al.[23] found a positive correlation between these two parameters, and another previous study reported similar findings.[4] This is consistent because as previously reported, a higher VO2max will propitiate a change of energy system for the sparing of the phosphagen system. However, the literature on the relationship between VO2max and COD is limited, and still unclear. Therefore, given the importance of both parameters, it is of scientific interest to observe the possible correlation between these two parameters in young players. Thus, the main objective of this study was to evaluate oxygen consumption by means of the Yo-Yo intermittent test and anthropometrical measures, and different COD tests in young soccer players and to observe their possible relationship.

Methods

The research was carried out in March. Young soccer players were recruited at the end of 2020-2021 season. The data collection was previously followed by 48 hours of rest. The Yo-Yo test IR-Level 1 was evaluated. Subsequently, COD evaluation was performed in the following order (i) V-cut test; (ii) 505-COD; and (iii) Illinois test. Two attempts were made with a 3-minute recovery. A standardized 12-minute warm-up was performed prior to the measurements. This consisted of several exercises including ballistic stretching.

Participants

Forty-seven young male soccer players (age= 15.68 ± 1.20 years; height = 188.84 ± 5.81 cm, and body mass= of 75.74 ± 8.37 kg; 7.64 ± 2.02 years' experience) from the region of Baleares, Spain, were recruited from the city of Palma de Mallorca. These players trained three times a week (90 min per session) and played one match a week. The training sessions were based on technical and tactical content development (70% of training time), technical skill improvements (10% of training time), and general

improvements in physical condition (20% of training time). Generally, training sessions comprised a warm-up, main part, and cooldown.

The participants' parents obtained information about the main aims of the investigation and signed informed consent forms. The study was conducted in accordance with the ethical principles of the Helsinki declaration for human research and was approved by the Research Ethics Committee of the Pontifical University of Comillas (2021/74). Inclusion criteria for the participants in this study were (i) reporting normal vision and no history of any neuropsychological impairments that could affect the results of the experiment, (ii) being an active player with a federation license, (iii) not presenting any injuries during the previous two months, and (iv) giving their consent.

Anthropometric measurements

Body mass (kg) was assessed by bioelectric meter (Tanita BC-730) with an accuracy of 0.1 kg. Height (cm) was determined with a stadiometer (type SECA 225, Hamburg, Germany) with an accuracy of 0.1 cm. Body mass index values were also obtained.

Yo-Yo Intermittent Recovery Test – Level 1 (YYIRT Level 1)

The test was carried out in accordance with the guidance given by González-Fernández et al..[12] The YYIRT Level 1 consists of 4 initial out-and-back runs (0 to 160 meters) at 10-13 km/h and 7 runs (160 to 440 meters) at 13.5-14 km/h. Subsequently, the running speed continues to increase progressively by 0.5 km/h after every 8 runs until the participant is unable to reach the finish line in time twice. The completed number of levels and the total distance travelled in meters at the end of the test were recorded.

Change-of-direction assessment

Data collection was performed by the same researchers. The participants performed a total of three COD tests. The tests are described below. Time was stopped once the athlete passed the finish line in every test and between the timing gates using the Chronojump-Boscosystem® (Barcelona, Spain) photocells developed by de Blas et al..[24]

V-Cut

Along the lines established by Gonzalo-Skok et al.,[25] the test consists of running a distance of 25 m., performing 4 changes of direction of 45 degrees every 5 m. A line is placed separated by two cones, spaced 0.7 m apart, where each player must step beyond the line with at least one foot for the test to be valid. The best record of two attempts was collected. The coefficient of within-subject variation was 0.43%.

505-COD

This test was performed under the guidelines of Nimphius et al..[26] The test consisted of performing a 15 m sprint and a 180º turn with the dominant leg. For the turn to be valid the participants had to step on the line located at 15. The time was recorded from 10 m from the start and 5 m after the change of direction. A photocell was placed at 10 m from the start to record the time. Two attempts were made, separated by 3 minutes. The best time (s) was recorded. The coefficient of within-subject variation was 2.01%.

Ilinois agility test

This test was performed as described by Šimonek et al.,[27] a total of 5 direction changes are performed in a period of between 13 and 19 s and a total distance of 60m. There are 90º and 180º direction changes. Each participant performed two attempts separated by 3 min. The best of the two attempts was recorded. The coefficient of within-subjects variation was low (2%).

Statistical analysis

All analysis were conducted using Statistica (version 13.1; Statsoft, Inc., Tulsa, OK, USA) and the significance level was set at $p<0.05$. Descriptive statistics were calculated for each variable. Normal distribution and homogeneity tests (Kolmogorov–Smirnov and Levene's, respectively) were conducted on all metrics. The data presented a normal distribution. Subsequently, Pearson's correlation coefficient rho was used to examine the relationship between the VO2max and anthropometrical measures (BMI), and physical fitness (505-COD, VCut test and Illinois Agility test). We adopted the following criteria to interpret the magnitude of these correlations: Trivial: ≤0.10; small: 0.10 to 0.29; moderate: 0.30 to 0.49; large: 0.50 to 0.69; very large: 0.70 to 0.89; almost perfect: ≥ 0.90.

Descriptive statistics were calculated for each variable (Table 1).

Table 1. Anthropometrical measures and physical fitness parameters in the experiments (mean ± SD).

Young soccer players (*n*=47)				
	Mean (SD)	IC Lower 95%	IC	IC Upper 95%
Anthropometrical measures				
Age (years)	16.23±1.07	15.92	0.31	16.54
Height (cm)	171.65±4.73	170.30	1.35	173.00
Body mass (kg)	66.00±10.51	63.00	3.00	69.01
BMI (%)	21.11±3.20	20.20	0.92	22.03
Physical fitness parameters				
VO2max (mL/min/kg)	39.99±5.57	38.40	1.59	41.59
CMJ (cm)	33.11±5.45	31.55	1.56	34.67
Illinois (sec)	18.90±1.41	18.50	0.40	19.31
505-COD (sec)	2.56±0.60	2.39	0.17	2.73

VO2max was estimated by the next equation: Yo-Yo IR1 test: VO2max (mL/min/kg) = IR1 distance (m) × 0.0084 + 36.4 28. BMI: Body Mass Index; CMJ: Countermovement Jump

First, a correlation analysis was performed between VO2max and anthropometric measures (BMI) and physical fitness parameters (CMJ, Illinois and 505-COD) and the values revealed a negative moderate correlation between VO2max and BMI (r=-0.35, p=0.01) and a large negative correlation between VO2max and 505-COD (r=-0.55, p=0.001). However, the results did not show any significant correlation among physical fitness parameters. (More information in Table 2, Figure 1 and 2).

Table 2. Correlation between VO2max and anthropometric measures and physical fitness parameters.

	Young soccer players (*n*=47)			
	BMI (%)	CMJ (cm)	Illinois (sec)	505-COD (sec)
VO2max (mL/min/kg)	r=-.24	r=.19	r=.24	r=-.55
	p=.01*	*p*=.19	*p*=.11	*p*=.001**

*Denotes significance at p<0.05, and ** denotes significance at p<0.01.

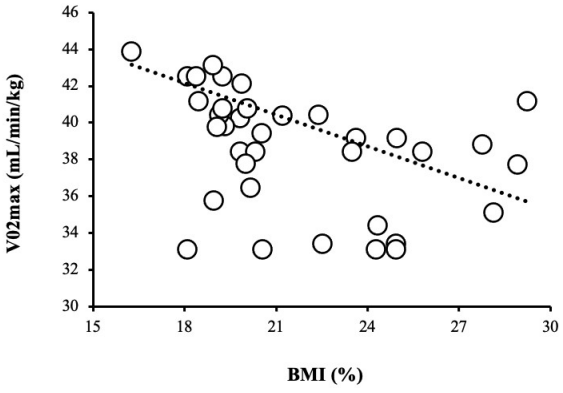

Figure 1. Correlations analysis between VO2max and BMI.

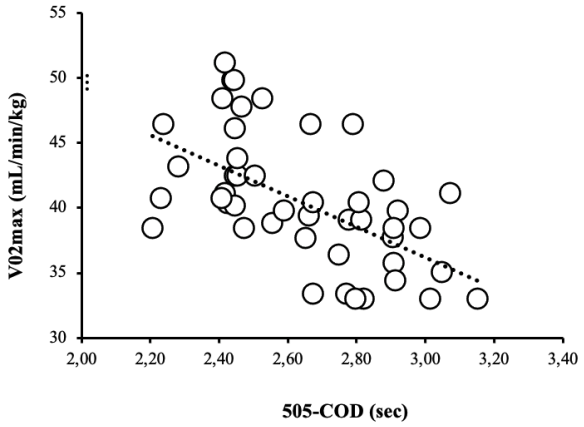

Figure 2. Correlations analysis between VO2max and 505-COD.

Discussion

The main aim of this study was to evaluate oxygen consumption by means of the Yo-Yo intermittent test and COD in young soccer players and to observe their possible relationship.

One of the main findings is the significant correlation between VO2max and BMI (r=-0.24). This relationship indicates that BMI is inversely proportional to VO2max. Therefore, it could be determined that those people with a lower BMI have a greater capacity to process a greater amount of oxygen during the practice of physical exercise. This means that the lower the BMI, the greater the respiratory capacity to maintain the intensity and duration of the exercise. These data agree with those found by Nevill et al.,[29] in which they related BMI to VO2max and showed how a lower BMI, within healthy parameters, is essential to achieve optimum VO2max. In this context, it is known that aerobic fitness (VO2max) increases with a greater practice of physical exercise. However, it has been identified that this association is curvilinear, with greater initial benefits (gains in physical condition) with sedentary adolescents (those who report low levels of exercise) also considering factors such as weight, age and sex.[30,31] This message should be received by those physical activity and sport professionals who are trying to encourage sedentary adolescents to improve their sports performance. Besides, Alonso-Fernández et al.[32] reported that the association between VO2max and BMI was more pronounced in the lower weight groups.

The data from the present study show a significant negative correlation between VO2max and the agility observed by the 505-COD (r=-0.55). Therefore, the relationship between VO2max and agility was inversely proportional. Agility has been shown to be a relevant factor that can improve the quality of performance of any athlete.[33] In contrast to the results found and following Handaru et al.[34] VO2max can affect agility performance in the game, the greater the aerobic capacity, the greater the ability to repeat an effort with a perfect technical execution after recovering from the previous effort. The finding of the present study contrasts with the findings of de Arazi et al.,[35] who suggested that aerobic power and agility were significantly related. This is determined by the fact that VO2max is one of the most important factors in the performance of the athlete. However, agile movements focused on change of direction are actions that require anaerobic metabolism in high-intensity situations, which are really the actions that determine success in a match.[36] This could be explained by the fact that players with a greater aerobic capacity tend to be the midfielders who cover greater distances during soccer matches, while attackers tend to be more specialized in COD to perform dribbling and passing.[37,38] In addition, adaptations to longer distances cause changes in type II muscle fibers, like greater capillarization and oxidative capacity, also producing a loss of explosive strength.[39] In contrast, COD could lead to neural nerve adaptations and linear sarcomeric hypertrophy, which in turn leads to an increase in power.[40]

In this respect, it could be discerned that trying to improve VO2max will not entail any benefits in agility and if the objective is to improve this skill, it will be necessary to follow a specific training program for its enhancement.

It this respect, soccer skills such as dribbling or feinting actions are also essential when carrying or driving the ball from one place to another, to take advantage of free space or to deceive the opponent and gain a competitive advantage. Furthermore, VO2max plays a key role in maintaining the ATP-PCr stores and makes it possible to carry out actions of COD and agility, aspects of the game that are decisive for performance[17]. Thus, the above-mentioned skills have a direct relationship with the capacity to repeat short efforts and high intensity actions. Therefore, COD depend more on VO2max, thus smaller variations in BMI and 505-COD are a better representation of COD ability with less dependency on sprinting and illinois and CMJ values.

This study has several limitations such as the sample size. other limitations are that measurements were not taken at different times of the season to assess improvement due to maturity, as well as comparing players by age ranges and position. In addition, one of the limitations of the study is the lack of data on the body composition of the participants, data that would make the relationships found between the different variables more reliable.

As conclusion, the results of this study show that maximal oxygen uptake or VO2max and BMI, are inversely related. A minimum and appropriate BMI is essential to achieve a higher VO2max. Therefore, in order to increase VO2max, it is necessary to reduce BMI to be able to achieve improvements. This finding may help athletes, coaches, physical therapists, and club managers to become familiar with the need for proper weight maintenance for athletes to control their BMI and ultimately increase VO2max.

Furthermore, the finding of this present study also reveals that there is no relationship between VO2max and agility. COD-focused agility movements are actions that require anaerobic metabolism in high-intensity situations, which are different from VO2max capacity. Therefore, there is no single method to improve VO2max and agility, since both are independent variables. Consequently, the different agents involved must take this into account if they want to improve VO2max and agility, and must plan some exercises separately. Although, correlations appear between the study variables, they may be influenced by other aspects that have not been considered and, therefore, it is necessary to continue research in this line.

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References

1. Mohr M, Nybo L, Grantham J, Racinais S. Physiological Responses and Physical Performance during Football in the Heat. PLoS One. 2012;7(6).
2. Christensen PM, Krustrup P, Gunnarsson TP, Kiilerich K, Nybo L, Bangsbo J. VO2 kinetics and performance in soccer players after intense training and inactivity. Med Sci Sports Exerc. 2011;43(9):1716-1724.
3. Rønnestad BR, Hansen EA, Raastad T. Strength training improves 5-min all-out performance following 185 min of cycling. Scand J Med Sci Sports. 2011;21(2):250-259.
4. Tomlin DL, Wenger HA. The relationships between aerobic fitness, power maintenance and oxygen consumption during intense intermittent exercise. J Sci Med Sport. 2002;5(3):194-203.
5. Siquier Coll J, Collado Martín Y, Sánchez Puente M, Grijota Pérez FJ, Pérez Quintero M, Bartolomé Sánchez I, et al. Comparative study of the variables of physical fitness and health among young athletes and sedentary males. Nutr Hosp. 2018;35(3).
6. Mandroukas A, Metaxas TI, Michailidis Y, Christoulas K, Heller J. The effects of soccer training in aerobic capacity between trained and untrained adolescent boys of the same biological age. J Sports Med Phys Fitness. 2021;61(2):252-260.
7. Michaelides MA, Parpa KM, Zacharia AI. Effects of an 8-Week Pre-seasonal Training on the Aerobic Fitness of Professional Soccer Players. J Strength Cond Res. 2021;35(10).
8. Krustrup P, Mohr M, Amstrup T, Rysgaard T, Johansen J, Steensberg A., et al. The Yo-Yo intermittent recovery test: Physiological response, reliability, and validity. Med Sci Sports Exerc. 2003;35(4):697-705.
9. Albuquerque Freire L de, Tannure M, Sampaio M, Slimani M, Znazen H, Bragazzi NL, et al. COVID-19-Related Restrictions and Quarantine COVID-19: Effects on Cardiovascular and Yo-Yo Test Performance in Professional Soccer Players. Front Psychol. 2020;11.
10. Markovic G, Mikulic P. Discriminative ability of the Yo-Yo intermittent recovery test (level 1) in prospective young soccer players. J Strength Cond Res. 2011;25(10):2931-2934.
11. Bradley PS, Bendiksen M, Dellal A, Mohr M,Wilkie A,Datson N, et al. The Application of the Yo-Yo Intermittent Endurance Level 2 Test to Elite Female Soccer Populations. Scand J Med Sci Sports. 2014;24(1):43-54.
12. González Fernández FT, Adalid-Leiva JJ, Baena-Morales S, Falces-Prieto M. Resistencia intermitente y rendimiento en el Yo-Yo test en jóvenes jugadores de fútbol y aplicación de la percepción subjetiva del esfuerzo en el control del entrenamiento. Published online 2020.
13. Mohr M, Krustrup P, Bangsbo J. Fatigue in soccer: a brief review. J Sports Sci. 2005;23(6):593-599.
14. Falces-Prieto M, González-Fernández FT, García-Delgado G, Silva R, Nobari H, Clemente FM. Relationship between sprint, jump, dynamic balance with the change of direction on young soccer players' performance. Sci Rep. 2022;12(1):1-9.
15. Kumar N, Laroiya N. Association of VO2 Max, Agility and BMI among collegiate athletes. Ann Sports Med Res. 2017;4(5):1121.
16. Beato M, Bianchi M, Coratella G, Merlini M, Drust B. Effects of Plyometric and Directional Training on Speed and Jump Performance in Elite Youth Soccer Players. J Strength Cond Res. 2018;32(2):289-296.
17. Loturco I, Jeffreys I, Abad CCC, Kobal R, Zanetti V, Pereira LA, et al. Change-of-direction, speed and jump performance in soccer players: a comparison across different age-categories. J Sports Sci. 2020;38(11-12):1279-1285.
18. Hachana Y, Chaabène H, Nabli MA, Attia A, Moualhi J, Farhat N, et al. Test-retest reliability, criterion-related validity, and minimal detectable change of the Illinois agility test in male team sport athletes. J Strength Cond Res. 2013;27(10):2752-2759.
19. Di Salvo V, Pigozzi F, González-Haro C, Laughlin MS, De Witt JK. Match performance comparison in top English soccer leagues. Int J Sports Med. 2013;34(6):526-532.
20. Loturco I, Kobal R, Gil S, Pivetti B, Kitamura K, Pereira LA, et al. Differences in loaded and unloaded vertical jumping ability and sprinting performance between Brazilian elite under-20 and senior soccer players. Am J Sports Sci. 2014;2(6):8-13.
21. Martín-Moya R, González-Fernández FT. Test for the improvement and evaluation of change of direction in team sports: A systematic review. JPES. 2022;22(7).
22. Clemente FM, González-Fernández FT, García-Delgado G, et al. Leg dominance and performance in change of directions tests in young soccer players. Sci Rep. 2022;12(1):1-9.
23. Da Silva JF, Guglielmo LGA, Bishop D. Relationship between different measures of aerobic fitness and repeated-sprint ability in elite soccer players. J Strength Cond Res. 2010;24(8):2115-2121.
24. de Blas X, Padullés JM, del Amo JLL, Guerra-Balic M. Creation and validation of chronojump-boscosystem: A free tool to measure vertical jumps. RICYDE: Revista Internacional de Ciencias del Deporte. 2012;8(30).
25. Gonzalo-Skok O, Tous-Fajardo J, Suarez-Arrones L, Arjol-Serrano JL, Casajús JA, Mendez-Villanueva A. Validity of the V-cut Test for Young Basketball Players. Int J Sports Med. 2015;36(11).
26. Nimphius S, Callaghan SJ, Spiteri T, Lockie RG. Change of Direction Deficit: A More Isolated Measure of Change of Direction Performance Than Total 505 Time. J Strength Cond Res. 2016;30(11):3024-3032.
27. Šimonek J, Horička P, Hianik J. Differences in pre-planned agility and reactive agility performance in sport games. Acta Gymnica. 2016;46(2).
28. Bangsbo J, Iaia FM, Krustrup P. The Yo-Yo Intermittent Recovery Test. Sports Medicine. 2008;38(1).
29. Nevill AM, Duncan MJ, Sandercock G. Modeling the dose–response rate/associations between VO2max and self-reported Physical Activity Questionnaire in children and adolescents. J Sport Health Sci. 2020;9(1):90-95.
30. Dagan SS, Segev S, Novikov I, Dankner R. Waist circumference vs body mass index in association with cardiorespiratory fitness in healthy men and women: a cross sectional analysis of 403 subjects. Nutr J. 2013;12(1):1-8.
31. Johansson L, Brissman M, Morinder G, Westerståhl M, Marcus C. Reference values and secular trends for cardiorespiratory fitness in children and adolescents with obesity. Acta Paediatr. 2020;109(8):1665-1671.
32. Alonso-Fernández D, Fernández-Rodríguez R, Taboada-Iglesias Y, Gutiérrez-Sánchez Á. Impact of a HIIT protocol on body composition and VO2max in adolescents. Sci Sports. 2019;34(5):341-347.
33. Padrón-Cabo A, Rey E, Kalén A, Costa PB. Effects of training with an agility ladder on sprint, agility, and dribbling performance in youth soccer players. J Hum Kinet. 2020;73(1):219-228.
34. Handaru GY, Rika I, Prastowo NA. The correlation between VO2max with agility and musculoskeletal injury profile among teenage badminton athletes. Qual Sport. 2019;1:44-52.
35. Nevill AM, Duncan MJ, Sandercock G. Modeling the dose–response rate/associations between VO2max and self-reported Physical Activity Questionnaire in children and adolescents. J Sport Health Sci. 2020;9(1):90-95.
36. Fiorilli G, Mitrotasios M, Iuliano E, Pistone EM, Aquino G, Calcagno G, et al. Agility and change of direction in soccer: differences according to the player ages. J Sports Med Phys Fitness. 2017;57(12):1597-1604.
37. Gaurav V, Singh A, Singh S. Comparison of selected physical fitness components among male football players of different

playing positions. Turkish journal of sport and exercise. 2015;17(2):22-25.
38. Modric T, Versic S, Sekulic D. Aerobic fitness and game performance indicators in professional football players; playing position specifics and associations. Heliyon. 2020;6(11):e05427.
39. Modric T, Versic S, Sekulic D, Liposek S. Analysis of the Association between Running Performance and Game Performance Indicators in Professional Soccer Players. Int J Environ Res Public Health. 2019;16(20).
40. Murtagh CF, Brownlee TE, Rienzi E, Roquero S, Moreno S, Huertas G, et al. The genetic profile of elite youth soccer players and its association with power and speed depends on maturity status. PLoS One. 2020;15(6).

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Revisión

Influencia de los parámetros antropométricos y la composición corporal en las imágenes termográficas

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RESUMEN

La termografía infrarroja está siendo utilizada en la actualidad para medir la temperatura de la piel (Tsk) tanto en medicina como en ciencias del ejercicio. Sin embargo, para obtener una imagen termográfica de calidad, es necesario tener en cuenta factores que intervienen para evitar una interpretación errónea de los resultados observados, incluidos los factores antropométricos y de la composición corporal. Por lo tanto, el objetivo de esta revisión narrativa, es establecer cómo los parámetros antropométricos y de composición corporal pueden afectar los valores de Tsk, repercutiendo así en la evaluación de las imágenes termográficas. Los resultados de este estudio apuntan a un alto nivel de influencia de la superficie corporal y, especialmente, de la cantidad de grasa corporal en el patrón de normalidad esperado de la Tsk evaluada por termografía infrarroja, siendo los sujetos con mayor cantidad de grasa corporal quienes presentan menores valores de Tsk comparados con los de menor cantidad de grasa, algo que debería considerarse al evaluar a la población general y a los atletas con diferentes patrones de composición corporal.
Palabras clave: Termografía; Mapeo de temperatura; Antropometría; Tejido adiposo.

Influence of anthropometric parameters and body composition in thermographic images

ABSTRACT

Infrared thermography has been recently used to measure skin temperature (Tsk) in both medicine and sports medicine. However, to obtain a quality thermographic image, it is necessary to observe intervening factors to avoid misinterpretation of the results, including anthropometric and body composition factors. Therefore, the objective of this narrative review is to establish how anthropometric and body composition parameters can affect the Tsk response, thus influencing the assessement of thermographic images. The results of this study point to a high level of influence of the body surface and, especially, of the amount of body fat in the expected Tsk pattern of normality evaluated by infrared thermography, being the subjects with higher amount of body fat who present lower Tsk values compared to those with lower body fat, which is something that should be considered when evaluating the general population and athletes with different body composition patterns.
Keywords: Thermography; Temperature mapping; Anthropometry; Adipose tissue.

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Influência de parâmetros antropométricos e de composição corporal em imagens termográficas

RESUMO

A termografia infravermelha tem sido empregada de forma mais recente para mensurar a temperatura da pele (Tsk) sendo utilizada na medicina e também na medicina esportiva. Entretanto, para se obter uma imagem termográfica de qualidade, vários fatores intervenientes precisam ser observados para que se evite um erro de interpretação sobre os resultados observados, dentre eles os fatores antropométricos e de composição corporal. Assim que, o objetivo desta revisão narrativa é estabelecer de que forma os parâmetros antropométricos e de composição corporal podem afetar a resposta da Tsk, impactando assim na avaliação de imagens termográficas. Têm-se como principais conclusões que as evidências apontam para um elevado nível de influência da superfície corporal e especialmente da quantidade de gordura corporal sobe o padrão de normalidade esperada da Tsk avaliada por termografia infravermelha, de modo que indivíduos com maior quantidade de gordura corporal apresentam valores menores de Tsk quando comparados a indivíduos com menor quantidade, devendo assim ser considerado ao avaliar a população em geral e atletas com diferentes padrões de gordura corporal.
Palavras-chave: Termografia; Mapeamento de temperatura; Antropometria; Tecido adiposo.

Introducción

Actualmente una de las formas de evaluar la temperatura de la piel (Tsk) es mediante el uso de imágenes termográficas[1,2]. Este tipo de imagen se ha utilizado como herramienta auxiliar en el diagnóstico de enfermedades como el cáncer, la neuropatía diabética, los trastornos vasculares y las lesiones musculares[3–5]. Más recientemente, se ha utilizado para determinar las alteraciones termorreguladoras resultantes de COVID-19[6]. Específicamente en el deporte, la termografía infrarroja (IRT) se ha utilizado como herramienta para detectar lesiones y procesos inflamatorios[7] del conocimiento previo sobre el patrón de normalidad térmica del individuo, que puede incidir directamente en la interpretación de la carga física realizada durante el entrenamiento físico del deportista[8–10].

Para una evaluación cualificada de la normalidad térmica de la Tsk en reposo hay que tener en cuenta varios factores[11] como el género[12], edad[12], región corporal analizada[13] y la hora del día[14]. Esta combinación de factores aumenta la complejidad en la búsqueda de un diagnóstico correcto para identificar si una zona determinada está hipo- o híper-irradiada, lo que indica la necesidad de realizar pruebas de imagen más elaboradas.

Es posible encontrar en la literatura estudios que evaluaron el perfil de normalidad térmica de ciertas poblaciones, como los de Marins et al.[12] con la población brasileña, de Zaproudina et al.[15] con la población finlandesa, de Zhu y Xin[16] con el chino y de Kolosovas-Machuca y González[17] con niños mexicanos. Sin embargo, en ninguno de estos estudios se tuvieron en cuenta factores intervinientes, como las características antropométricas y la composición corporal, a la hora de estandarizar los valores de normalidad térmica, lo que puede llevar a un error de interpretación, especialmente porque hay estudios que observan la tendencia a que un mayor porcentaje de grasa pueda interferir en la Tsk, como los estudios de Chudecka et al.[18], Chudecka y Lubkowska[19], Neves et al.[20] y Salamunes et al.[21].

Por lo tanto, para tener una interpretación correcta de los valores de normalidad de la Tsk es importante establecer cómo la grasa corporal puede influir en esta lectura. Esto mejorará la capacidad de los profesionales de la medicina deportiva para interpretar estas imágenes, ya que dependiendo del deporte practicado, es natural que el porcentaje de grasa sea muy diferente, por ejemplo, un corredor de maratón[22] frente a un lanzador de peso[23]. Además, también puede aportar una forma de análisis crítico al registro de la Tsk de forma masiva, como se ha hecho, de forma exploratoria, en la identificación de COVID-19.

Este artículo de revisión se propone presentar las bases teóricas y las evidencias que señalan la magnitud de la influencia de los parámetros antropométricos y de la grasa corporal como factores que tienen el potencial de alterar la Tsk, modificando así la forma de análisis de las imágenes termográficas y, en consecuencia, la caracterización de un estado de normalidad o anormalidad térmica. Por lo tanto, el objetivo de este estudio es describir en que forma los parámetros antropométricos y de composición corporal pueden afectar a la respuesta de Tsk, repercutiendo así en la interpretación de las imágenes termográficas.

Comprender los principios fisiológicos del tejido adiposo, así como las características relacionadas a la grasa corporal, antropometría y su influencia en el mecanismo de termorregulación humana y, consecuentemente, en la Tsk, es fundamental para realizar una evaluación termográfica de calidad. Este trabajo lleva a cabo una revisión narrativa estructurada en cuatro apartados: 1) Tejido adiposo y ajustes termorreguladores; 2) El tejido adiposo como barrera física de transferencia de calor; 3) Parámetros antropométricos y ajustes térmicos; 4) Evidencias sobre la influencia de la grasa corporal con la Tsk. Cada uno de estos temas será presentado con mayor detalle a continuación.

1. Tejido adiposo y ajustes termorreguladores.

El tejido adiposo es un órgano endocrino complejo, muy activo y que segrega hormonas, como la leptina, la adiponectina y las citoquinas[24]. Estas hormonas tienen una fuerte influencia en la termogénesis y la homeostasis energética, principalmente a través del aumento de la producción de calor en el músculo esquelético[25,26] y en la activación de las neuronas hipotalámicas implicadas en la regulación de la termogénesis sin temblores[27].

En el organismo, los lípidos se almacenan en 2 tipos de tejido: el tejido adiposo blanco (TAB) y el tejido adiposo marrón (TAM). El TAB es la estructura que promueve una mayor cantidad de energía para el cuerpo, además de tener la función de aislamiento y protección mecánica para algunos órganos vitales[28,29]. El TAM, a su vez, actúa, sobre todo, en la metabolización de los ácidos grasos, secretando también una serie de factores reguladores, principalmente impulsados por la termogenina[30], una proteína desacopladora que tiene como función promover un mayor bombeo de protones localizados en la membrana mitocondrial interna, trasportando los protones e electrones del espacio intermembrana hacia la matriz mitocondrial, disipando el gradiente de protones por medio de la membrana interna de la mitocondria y desprendiendo energía en forma de calor[29–31]. Este equilibrio de acciones entre el TAB y el TAM contribuye directamente al mantenimiento del equilibrio energético del organismo.

Estos factores, cuando se observan, pueden afectar directamente a una de las principales estructuras fisiológicas encargadas de mantener el equilibrio térmico, la piel, que, a través de sus receptores térmicos superficiales, ayuda a controlar la temperatura para preservar la funcionalidad vital del organismo[32]. Los depósitos de tejido adiposo en la hipodermis pueden actuar como aislante térmico, interfiriendo en la transferencia de calor entre el cuerpo y el ambiente y, por consiguiente, disminuyendo la Tsk[33,34], lo que puede afectar directamente a los valores de

temperatura observados en esta región, afectando así al rango normal esperado de Tsk registrado durante las imágenes termográficas. Las personas con obesidad tienen una mayor tasa metabólica en reposo[35], pues al tener mayor cantidad de tejido adiposo, secretan más leptina, adiponectina y citoquinas, lo que genera un aumento de la temperatura interna[24–26]. Además, también pueden presentar alteraciones en la microbiota intestinal[36], que podría tener una relación directa en el control de la termogénesis humana[37], modificando el metabolismo del individuo por medio de señales procedentes del intestino, produciendo mayores niveles de inflamación, resistencia a la insulina y aumento en la cantidad de grasa local[38].

2. El tejido adiposo como barrera física de transferencia de calor.

La temperatura corporal (TC) está controlada por el centro termorregulador situado en la parte anterior del hipotálamo y es el resultado de un complejo equilibrio entre los procesos metabólicos y la actividad muscular[39,40], junto con las condiciones climáticas en las que se encuentra el sujeto. Para el buen funcionamiento del organismo, la temperatura interna del cuerpo debe mantenerse aproximadamente a 37,0°C[41]. Existen mecanismos físicos que actúan en la regulación de esta temperatura, como la radiación, la convección, la conducción y la evaporación. La generación de calor interno - especialmente cuando se genera por el ejercicio físico-, el entorno en el que se inserta la persona -tierra o agua -, además de la temperatura, la humedad, la velocidad del viento y la radiación solar, influirán en la acción de estos mecanismos. La figura 1 muestra los principales factores relacionados con el equilibrio térmico.

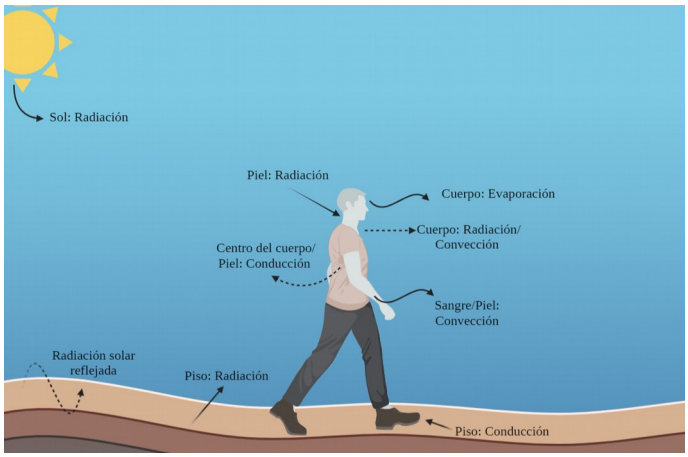

Figura 1. Mecanismos de intercambio de calor y su acción en el ser humano. *Fuente: Elaboración propia.*

Uno de los factores que influyen de forma diferente en Tsk en las personas obesas es el proceso de conducción[42]. Este proceso de transferencia de calor se produce de un cuerpo a otro a través de un agente líquido, sólido o gaseoso. Este intercambio de calor está directamente asociado con el gradiente de temperatura entre las superficies, la conductividad térmica del material, el espesor y el área de contacto entre las superficies[42]. El nivel de actividad metabólica de una determinada zona central del cuerpo es una fuente de generación de calor[43]. Este calor se transfiere entre los tejidos hacia la piel por la diferencia de gradiente desde la región más caliente a la más fría, por lo que se produce una reducción gradual de la temperatura en función de las capas de tejido que existen entre la piel y la región productora de calor.

Una persona con una mayor acumulación de grasa corporal creará una mayor barrera física, disminuyendo la capacidad de perder calor debido a este mecanismo físico[44,45]. Esto ocurre porque el tejido adiposo presenta valores de conductividad térmica menores[46,47] que el tejido muscular[46,48,49], dermis[49] e epidermis[50], haciendo que sujetos con mayores cantidades de grasa retengan más el calor, dificultando su intercambio entre el organismo y ambiente. Ésta es una adaptación positiva en ambientes fríos, porque la grasa actúa como agente aislante, reduciendo el riesgo de hipotermia[45]. La figura 2 presenta este aspecto del grosor de la grasa corporal como agente influyente en el proceso físico de la conducción.

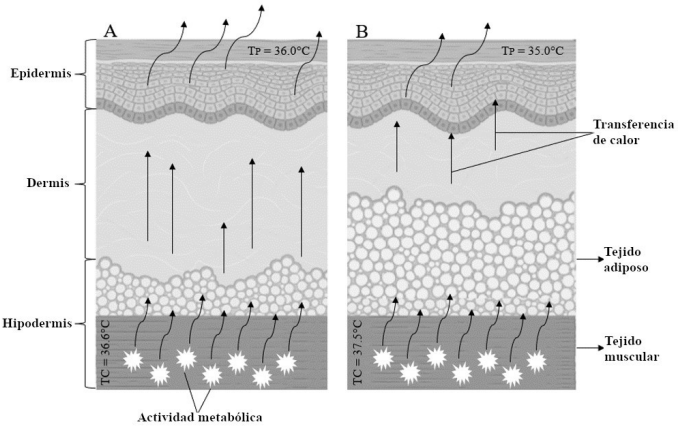

Figura 2. Representación del proceso de generación y transferencia de calor en un individuo con bajo (A) y alto porcentaje de grasa (B). TC: Temperatura Corporal. *Fuente: Elaboración propia.*

3. Parámetros antropométricos y ajustes térmicos;

Se han relacionado algunos aspectos antropométricos como posibles influyentes en el TC, como el tamaño de la superficie corporal, la cantidad de masa corporal, el índice de masa corporal (IMC) y la composición corporal.

3.1 Área de Superficie Corporal (SC)

Cuando se expone a la temperatura ambiente, la superficie corporal es un factor importante que está directamente relacionado con la capacidad de intercambiar calor con el entorno. Los individuos con mayores dimensiones presentan una mayor tasa de convección, radiación y evaporación que los individuos con menores dimensiones, lo que permite una mayor pérdida o absorción de calor[51].

De este modo, los individuos con una mayor superficie corporal, al salir de un ambiente cálido a un ambiente frío son capaces de mantener los valores de TC de forma más eficiente que los individuos con una menor superficie corporal[51]. Además, dado que esta característica influye directamente en el intercambio de calor, los individuos con una menor área de exposición tienen un efecto de disipación de calor mucho más limitado, lo que, analizando exclusivamente por este factor, puede llevar a problemas en el control termorregulador[51].

La SC parece ser un factor importante a considerar ya que tiene un efecto potencial en el rango normal de Tsk captado por las imágenes termográficas. Esto hace que sea necesario realizar un perfil térmico específico al evaluar a los niños y a los adultos.

3.2 Masa Corporal

Desde una perspectiva termodinámica, la masa corporal desempeña dos importantes funciones en el intercambio de energía térmica del ser humano. En primer lugar, la masa es la parte interna del cuerpo que disipa el calor y, por tanto,

contribuye a su variación térmica y a su mantenimiento. En segundo lugar, el coste energético necesario para realizar el intercambio de calor con el entorno es mayor en los individuos más pesados[52].

Durante el estrés térmico elevado, una mayor cantidad de masa corporal también puede influir en la tasa de aumento de la temperatura central[53,54]. Teóricamente, a una temperatura ambiente elevada, las tasas de intercambio de calor en relación con la cantidad de superficie corporal son similares, independientemente del tamaño del cuerpo. Sin embargo, las correspondientes tasas de intercambio de calor por unidad de masa son mayores en los individuos más ligeros. Como resultado, la tasa de almacenamiento de calor debería ser mayor para una carga de calor metabólica equivalente y debería dar lugar a mayores cambios de temperatura central entre los individuos con una menor relación entre la masa y la superficie corporal[54,55].

Hasta la fecha (agosto de 2022), no se han identificado estudios de perfil térmico en poblaciones con gran masa muscular como los fisicoculturistas para observar, por ejemplo, si mayores cantidades de la masa corporal magra podrían repercutir en la Tsk, en comparación con personas con valores normativos de masa muscular, lo que genera un interesante campo de estudio en el futuro próximo.

3.3 Índice de Masa Corporal

En algunos estudios se ha demostrado que el IMC se asocia positivamente con la temperatura corporal[35,56,57], un hecho que puede atribuirse a un mayor aislamiento térmico debido a una capa más gruesa de tejido adiposo subcutáneo[44,45], lo que hace que los individuos con obesidad sean capaces de mantener su CT mejor controlado en ambientes fríos, pero tienen mayor dificultad para disipar este calor interno en ambientes calientes, haciéndolos más susceptibles a situaciones de hipertermia[58]. De forma práctica, el impacto en la Tsk en las regiones con acumulación de grasa corporal puede observarse como se muestra en la Figura 3, en la que la temperatura de la región anterior del tronco puede variar hasta 3,5°C al comparar sujetos con diferentes rangos de IMC.

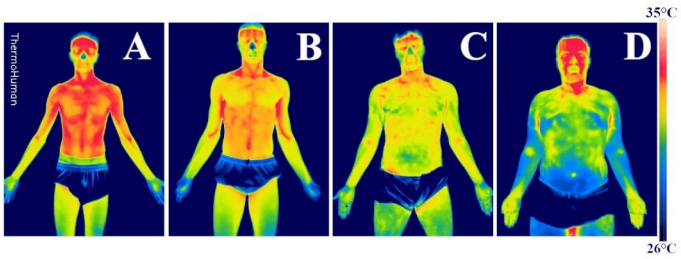

Figura 3. *Efectos promovidos por diferentes rangos de IMC en Tsk. Nota: A - Peso bajo; B - Peso normal; C - Sobrepeso y; D - Obesidad. Fuente: Imágenes de la base de datos del Laboratorio de Rendimiento Humano - Universidad Federal de Viçosa – Brasil.*

3.4 Composición Corporal

La relación entre la cantidad de tejido muscular magro, grasa corporal y hueso y la masa corporal total determina la capacidad térmica media del cuerpo. El calor específico de la grasa es mayor que el de otros tejidos adyacentes, lo que hace que se considere un aislante térmico al tener una menor capacidad de disipar el calor, afectando directamente al mantenimiento de la homeostasis corporal[48]. En consecuencia, los individuos con mayor cantidad de tejido adiposo acumulan valores de temperatura central más elevados[35].

Los cambios en estos tres patrones de influencia suelen observarse en personas con obesidad, una condición asociada a una mayor cantidad de calor interno total en el cuerpo, hace que los valores metabólicos en reposo de los individuos obesos sean más altos que en los individuos con bajo índice de adiposidad debido a la mayor cantidad de masa libre de grasa, que es mayor en las personas obesas, lo que aumenta la cantidad de calor generado[35]. Al mismo tiempo, el alto contenido de grasa crea una barrera aislante para la conducción y el intercambio de calor y, por lo tanto, reduce la capacidad del cuerpo para responder eficazmente a los cambios de la temperatura ambiente, de modo que el tejido adiposo atenúa la transferencia de calor[59]. Así, existe un importante indicio de que la anormalidad térmica por IRT será diferente según la cantidad de grasa corporal, lo que generará la necesidad de establecer estándares de normalidad térmica específicos según la grasa corporal, ayudando a la interpretación de las imágenes.

Otro componente de la composición corporal afectado por la obesidad es la densidad mineral ósea (DMO), principalmente el contenido mineral óseo[60–62]. La DMO en personas con obesidad es mayor que la personas sin sobrepeso debido a la mayor sobrecarga mecánica a la que se ve sometido el tejido óseo y a alteraciones hormonales, principalmente unos altos niveles de adipocinas comúnmente asociados a la obesidade[63,64], y que pueden promover acciones tanto de carácter anabólico como catabólico en el osteoblasto[65,66]. Además, la DMO parece tener una relación positiva con la cantidad de TAM en el organismo, lo que puede promover una mayor producción de calor y, como consecuencia, aumentar la temperatura corporal del individuo, influenciando directamente el mecanismo de termorregulación[67–69].

Otro factor que afecta a los procesos de emisión de calor es la microcirculación cutánea que, debido a los procesos inflamatorios derivados de la obesidad, acaba viéndose perjudicada y generando un proceso vasoconstrictor[70]. Esta situación genera una alteración directa en los valores de perfusión sanguínea de la superficie de la piel, provocando una reducción de su temperatura[33,34].

Por lo tanto, la obesidad, asociada a un aumento de la superficie corporal, de la masa corporal, de la cantidad de grasa y de los parámetros inflamatorios, tiene el potencial de influir directamente en el control de la temperatura central, haciendo que todo el mecanismo de ganancia y pérdida de calor sea diferente y alterando la respuesta de varias estructuras fisiológicas responsables de la termorregulación, incluida la piel.

Finalmente, el factor edad puede influir de manera muy importante en la Tsk de los humanos. En el caso de los niños, el control térmico se ve muy afectado por la proporción de superficie corporal, que es muy distinta a la del adulto. Además, el sistema nervioso central y periférico de los niños aún no están totalmente maduro para generar una respuesta térmica apropiada[71–73].

Es importante destacar que, a lo largo del proceso de envejecimiento, el organismo presenta diversas alteraciones relacionadas con el control de la TC y, consecuentemente, de la Tsk[74]. Factores como la variación de la composición corporal (pérdida de masa magra y ganancia de grasa), la disminución de la capacidad de producción y disipar de calor, el cambio del área de superficie corporal en relación al peso, las modificaciones en la actividad del sistema nervioso central, además de aspectos termo-sensoriales periféricos deben ser considerados durante una valoración de la TC a lo largo de la vida[75].

La menor cantidad de masa corporal magra en sujetos mayores produce una reducción de la actividad metabólica, un factor importante en la producción de calor, además de una disminución de la cantidad de agua en el organismo, factor que ayuda en la transferencia de calor[76]. Se puede añadir, una tendencia a padecer trastornos vasculares, especialmente en sujetos diabéticos[77], perjudicando la circulación sanguínea y, consecuentemente, la perfusión de los tejidos, influyendo negativamente en la pérdida de calor tanto por radiación como por convección[78]. Por último, las alteraciones endócrinas que aparecen con la edad también pueden producir alteraciones en el metabolismo de los individuos[24–26] que pueden alterar la Tsk.

4. Pruebas sobre la influencia de la grasa corporal con Tsk

Se han desarrollado una serie de estudios que buscan identificar la relación entre la grasa corporal y la Tsk, encontrando evidencias muy interesantes que pueden ayudar a entender este proceso e incluso a interpretar las imágenes termográficas.

Livingstone et al.[79] dividieron a 17 hombres de entre 21 y 56 años en tres grupos según el porcentaje de grasa: 7.6-13.6%, 17.4-22.1% y 27.1-46.4%, clasificados respectivamente como delgados, intermedios y obesos. Las regiones anterior y posterior del cuerpo, en las porciones superior e inferior, fueron evaluadas, y se observó que los individuos que tenían un mayor porcentaje de grasa tenían un Tsk más bajo.

Chudecka et al.[18] y Chudecka y Lubkowska[80] evaluaron la influencia de diferentes rangos de clasificación del IMC en Tsk. En el primer estudio[18] la Tsk de 20 mujeres consideradas obesas (IMC > 30kg/m^2) se comparó con la de 20 mujeres con IMC considerado normal (18,5-24,99 kg/m^2), se observó una diferencia de temperatura en la región de los brazos, la espalda, el abdomen, los muslos y las piernas, además de una correlación negativa entre la Tsk y el porcentaje de grasa para las regiones del abdomen y el muslo. En el segundo estudio[80] al comparar la influencia de un IMC considerado normal (18,5-24,99 kg/m^2) con el IMC de las mujeres con anorexia (< 17 kg/m^2), con edades comprendidas entre los 18 y los 24 años, verificó un aumento de la Tsk en la región de la espalda, abdomen, muslos y pantorrillas en las mujeres con anorexia, además de una correlación negativa entre el IMC y el porcentaje de grasa para la región del abdomen. En ambos estudios se evaluaron las regiones del tórax, el abdomen, los brazos, las manos, los muslos y las piernas, tanto en la vista anterior como en la posterior, además de obtener los valores del porcentaje de grasa mediante la evaluación de la bioimpedancia.

Siah y Childs[81] utilizando también la IRT para verificar la Tsk de la región del abdomen, evaluó a 30 participantes (23 hombres y 7 mujeres), divididos en tres rangos de clasificación del IMC: delgado (<18.5 kg/m^2), normal (18.6-24.9 kg/m^2) y con sobrepeso (>25.0 kg/m^2). Como resultado, observaron que la Tsk presentaba un parámetro decreciente para los individuos con sobrepeso en comparación con los otros rangos de clasificación en la región analizada.

Salamunes et al.[21] y Neves et al.[20] utilizaron la técnica de Dual-Energy X-Ray Absorptiometry (DXA) para comparar los efectos del porcentaje de grasa en los valores de Tsk, evaluados mediante la IRT. Salamunes[21], evaluando a 130 mujeres de entre 18 y 35 años, observó una correlación negativa entre los valores de Tsk y el porcentaje de grasa para las regiones de brazos, abdomen, espalda, muslos y pantorrillas. Asimismo, Neves et al.[20] al evaluar a 94 participantes (47 hombres y 47 mujeres), con edades comprendidas entre los 18 y los 28 años, se observó un patrón de correlación negativa entre la Tsk y el porcentaje de grasa para las regiones de tronco, brazos y piernas, en las vistas anterior y posterior, en los hombres, y en las regiones de brazos y piernas, en la vista anterior, y tronco y piernas, en la vista posterior, en las mujeres. Todos estos estudios señalan que es necesario que los trabajos en los que se establece el perfil térmico, es necesario considerar el impacto de la grasa corporal en la Tsk, con el objetivo de evitar interpretaciones inadecuadas de las imágenes.

La cantidad de grasa corporal en Tsk también parece afectar el proceso de termorregulación en durante el ejercicio. Weigert et al.[82] a su vez, evaluó el impacto del porcentaje de grasa, evaluado a través de la técnica de pliegues cutáneos, en la Tsk en 38 hombres, con edad entre 19 y 32 años, tras la realización de ejercicios resistidos y comprobó que los participantes considerados obesos (≥25% de grasa) presentaron una menor elevación de la Tsk que los individuos considerados normales (<25% de grasa) al final del protocolo de ejercicios, presentando, además, un patrón más heterogéneo en la distribución de los puntos de calentamiento. Además, al observar el comportamiento de la Tsk a lo largo del tiempo, comprobaron que, incluso con una elevación menor de la Tsk al final de la sesión de ejercicio resistido, los individuos considerados obesos mantenían este patrón de elevación durante un periodo de tiempo más largo.

Por otro lado, un artículo señaló resultados contradictorios utilizando la termografía dinámica, que, a diferencia del modelo tradicional, monitoriza la respuesta de una determinada región corporal de interés a un estrés térmico, ya sea de frío o calor, evaluando la respuesta de la Tsk[83]. Payne et al.[84] utilizó la técnica IRT para verificar si el tamaño y la composición corporal, medidos por bioimpedancia, influirían en el recalentamiento de la región de la mano tras la exposición al frío. Las manos de 114 participantes (63 mujeres y 51 hombres), con edades comprendidas entre los 18 y los 48 años, se sumergieron en agua helada y se evaluó la Tsk en los momentos posteriores a la inmersión. No se encontró ninguna relación entre los parámetros evaluados y la capacidad de recalentamiento de las manos en Tsk, lo que indica que, en estas condiciones, para esta región de interés, el tamaño corporal y el porcentaje de grasa no tienen ninguna influencia. Es posible que esta región, por estar ricamente vascularizada, y por la técnica utilizada para el registro (termografía dinámica), no tenga efecto de la grasa corporal.

Implicaciones Prácticas

La valoración correcta de las imágenes termográficas es esencial para establecer un estándar de normalidad térmica, ya sea individualmente o en una población específica.

En el caso de la evaluación individual, especialmente en los atletas, es necesario tener en cuenta los factores presentados en esta revisión, sobre todo en aquellos en los que el porcentaje de grasa suele ser mayor, como los deportistas de atletismo en las pruebas de lanzamiento y los luchadores de categoría de peso más altas.

Otra condición especial es cuando el deportista de ja de realizar actividad física durante un determinado período de tiempo (entre temporadas o por lesión). En estos casos se espera un aumento de peso debido a la inactividad, lo que promueve cambios en la composición corporal y la consiguiente variación de los valores de Tsk. Si durante el seguimiento de este atleta a través de la IRT no se observan los aspectos presentados en este trabajo, la interpretación de un cuadro de normalidad térmica podría ser inadecuada.

Asimismo, en situaciones de diagnóstico poblacional, es importante que los investigadores consideren los factores antropométricos y de composición corporal en el momento de la caracterización, por lo que cada región específica puede presentar un perfil poblacional de composición corporal totalmente diferente, lo que dará lugar variaciones en los valores de Tsk, las cuales, en un estudio de gran envergadura, puede generar problemas de interpretación y consideración de las imágenes obtenidas por la cámara termográfica.

Como recomendación final, considerando la importancia de establecer el perfil térmico mediante IRT en la población general y de los atletas de diferentes modalidades deportivas en particular es necesario que en la información metodológica de los artículos se indiquen los parámetros antropométricos relacionados con la superficie corporal, el grosor de los pliegues cutáneos y el porcentaje de grasa, para que pueda ayudar en la evaluación de las imágenes térmicas obtenidas, además de proporcionar una base documental para estudios más detallados sobre el tema. También es importante que se lleven a cabo estudios empleando IRT para establecer el efecto del factor edad, especialmente en jóvenes antes de la pubertad o personas mayores con más de 60 años, ya que los factores antropométricos, especialmente la relación de "masa magra vs. masa grasa" corporal, puede cambiar mucho en función de la edad. Otra posibilidad de estudio que podría ser verificar la relación entre la DMO y la Tsk evaluada por IRT, debido

a que esta variable también parece presentar ligada al proceso de termorregulación en los seres humanos.

Conclusión

Existen fuertes evidencias de que la obesidad es una condición que afecta directamente a la temperatura de la piel debido a la influencia de ciertas características antropométricas como la superficie corporal y la composición corporal, específicamente la cantidad de grasa corporal, la cual presenta una relación inversa con la Tsk. Por lo tanto, es necesario tener en cuenta estos factores especialmente cuando se interpreta el patrón de normalidad térmica de un sujeto obtenido por IRT, tanto en la población general como en deportistas con diferentes valores de grasa corporal.

Autoría. Todos los autores han contribuido intelectualmente en el desarrollo del trabajo, asumen la responsabilidad de los contenidos y, asimismo, están de acuerdo con la versión definitiva del artículo. ***Financiación.*** FAPEMIG. ***Agradecimientos.*** CAPES. ***Conflicto de intereses.*** Los autores declaran no tener conflicto de intereses. ***Origen y revisión.*** No se ha realizado por encargo, la revisión ha sido externa y por pares. ***Responsabilidades éticas.*** Protección de personas y animales: Los autores declaran que los procedimientos seguidos están conforme a las normas éticas de la Asociación Médica Mundial y la Declaración de Helsinki. Confidencialidad: Los autores declaran que han seguido los protocolos establecidos por sus respectivos centros para acceder a los datos de las historias clínicas para poder realizar este tipo de publicación con el objeto de realizar una investigación/divulgación para la comunidad. Privacidad: Los autores declaran que no aparecen datos de los pacientes en este artículo.

Bibliografía

1. Adams S, Bucknall T, Kouzani A. An initial study on the agreement of body temperatures measured by infrared cameras and oral thermometry. Sci Rep [Internet]. 2021;11(1):1–10.
2. Wang Q, Zhou Y, Ghassemi P, McBride D, Casamento JP, Pfefer TJ. Infrared thermography for measuring elevated body temperature: Clinical accuracy, calibration, and evaluation. Sensors. 2022;22(1):1–25.
3. Lahiri BB, Bagavathiappan S, Jayakumar T, Philip J. Medical applications of infrared thermography: A review. Infrared Phys Technol [Internet]. 2012;55(4):221–35.
4. Shimatani A, Hoshi M, Oebisu N, Iwai T, Takada N, Nakamura H. Clinical significance of thermal detection of soft-tissue tumors. Int J Clin Oncol [Internet]. 2020;25(7):1418–24.
5. dos Santos Bunn P, Miranda MEK, Rodrigues AI, de Souza Sodré R, Neves EB, Bezerra da Silva E. Infrared thermography and musculoskeletal injuries: A systematic review with meta-analysis. Infrared Phys Technol [Internet]. 2020;109(April):103435.
6. Perpetuini D, Filippini C, Cardone D, Merla A. An overview of thermal infrared imaging-based screenings during pandemic emergencies. Int J Environ Res Public Health. 2021;18(6):1–12.
7. Hillen B, Pfirrmann D, Nägele M, Simon P. Infrared thermography in exercise physiology: the dawning of exercise radiomics. Sports Med [Internet]. 2020;50(2):263–82.
8. Matta L, Rhea M, Maior S. Physiological evaluation post-match as implications to prevent injury in elite soccer players. Arch Med Deporte. 2019;36(4):220–6.
9. Fernandes AA, Pimenta EM, Moreira DG, Marins JCB, Garcia ES. Application of infrared thermography in the assessment of muscle damage in elite soccer athletes. MOJ Orthop Rheumatol. 2017;8(5):5–6.
10. Korman P, Kusy K, Kantanista A, Straburzyńska-Lupa A, Zieliński J. Temperature and creatine kinase changes during a 10d taper period in sprinters. Physiol Meas. 2021;42(12):124001.
11. Fernández-Cuevas I, Bouzas Marins JC, Arnáiz Lastras J, Gómez Carmona PM, Piñonosa Cano S, García-Concepción MÁ, et al. Classification of factors influencing the use of infrared thermography in humans: A review. Infrared Phys Technol. 2015;71:28–55.
12. Marins JCB, Fernandes AA, Cano SP, Moreira DG, da Silva FS, Costa CMA, et al. Thermal body patterns for healthy Brazilian adults (male and female). J Therm Biol [Internet]. 2014;42(1):1–8.
13. Marins JCB, Formenti D, Costa CMA, de Andrade Fernandes A, Sillero-Quintana M. Circadian and gender differences in skin temperature in militaries by thermography. Infrared Phys Technol [Internet]. 2015;71:322–8.
14. Costa CMA, Sillero-Quintana M, Piñonosa Cano S, Moreira DG, Brito CJ, Fernandes AA, et al. Daily oscillations of skin temperature in military personnel using thermography. J R Army Med Corps. 2016;162(5):335–42.
15. Zaproudina N, Varmavuo V, Airaksinen O, Närhi M. Reproducibility of infrared thermography measurements in healthy individuals. Physiol Meas. 2008;29(4):515–24.
16. Zhu WP, Xin XR. Study on the distribution pattern of skin temperature in normal Chinese and detection of the depth of early burn wound by infrared thermography. Ann N Y Acad Sci. 1999;888:300–13.
17. Kolosovas-Machuca ES, González FJ. Distribution of skin temperature in Mexican children. Skin Res Technol. 2011;17(3):326–31.
18. Chudecka M, Lubkowska A, Kempińska-Podhorodecka A. Body surface temperature distribution in relation to body composition in obese women. J Therm Biol. 2014;43(1):1–6.

19. Chudecka M, Lubkowska A. Thermal maps of young women and men. Infrared Phys Technol [Internet]. 2015;69:81–7.
20. Neves EB, Salamunes ACC, de Oliveira RM, Stadnik AMW. Effect of body fat and gender on body temperature distribution. J Therm Biol [Internet]. 2017;70:1–8.
21. Salamunes ACC, Stadnik AM, Neves EB. The effect of body fat percentage and body fat distribution on skin surface temperature with infrared thermography. J Therm Biol [Internet]. 2017;66(November 2016):1–9.
22. Citarella R, Itani L, Intini V, Zucchinali G, Scevaroli S, Tannir H, et al. Association between dietary practice, body composition, training volume and sport performance in 100-Km elite ultramarathon runners. Clin Nutr ESPEN. 2021 Apr 1;42:239–43.
23. Kyriazis T, Terzis G, Karampatsos G, Kavouras S, Georgiadis G. Body composition and performance in shot put athletes at preseason and at competition. Int J Sports Physiol Perform. 2010;5:417–21.
24. Kershaw EE, Flier JS. Adipose tissue as an endocrine organ. J Clin Endocrinol Metab. 2004;89(6):2548–56.
25. Fischer AW, Hoefig CS, Abreu-Vieira G, de Jong JMA, Petrovic N, Mittag J, et al. Leptin raises defended body temperature without activating thermogenesis. Cell Rep [Internet]. 2016;14(7):1621–31.
26. Henry BA, Andrews ZB, Rao A, Clarke IJ. Central leptin activates mitochondrial function and increases heat production in skeletal muscle. Endocrinology. 2011;152(7):2609–18.
27. Yu S, Qualls-Creekmore E, Rezai-Zadeh K, Jiang Y, Berthoud HR, Morrison CD, et al. Glutamatergic preoptic area neurons that express leptin receptors drive temperature-dependent body weight homeostasis. J Neurosci. 2016;36(18):5034–46.
28. Vaughan M. The production and release of glycerol by adipose tissue incubated in vitro. J Biol Chem [Internet]. 1962;237(11):3354–8.
29. Blondin DP, Labbé SM, Phoenix S, Guérin B, Turcotte ÉE, Richard D, et al. Contributions of white and brown adipose tissues and skeletal muscles to acute cold-induced metabolic responses in healthy men. J Physiol. 2015;593(3):701–14.
30. Kitahara T, Li HS, Balaban CD. Localization of the mitochondrial uncoupling protein family in the rat inner ear. Hear Res. 2004 Oct;196(1–2):39–48.
31. Cannon B, Nedergaard J. Brown adipose tissue: function and physiological significance. Physiol Rev. 2004;84(1):277–359.
32. Charkoudian N. Mechanisms and modifiers of reflex induced cutaneous vasodilation and vasoconstriction in humans. J Appl Physiol [Internet]. 2010;109(4):1221–8.
33. Gatidis S, Schmidt H, Pfannenberg CA, Nikolaou K, Schick F, Schwenzer NF. Is it possible to detect activated brown adipose tissue in humans using single-time-point infrared thermography under thermoneutral conditions? Impact of BMI and subcutaneous adipose tissue thickness. PLoS One. 2016;11(3).
34. Neves EB, Moreira TR, Lemos RJ, Vilaça-Alves J, Rosa C, Reis VM. The influence of subcutaneous fat in the skin temperature variation rate during exercise. Res Biomed Eng. 2015;31(4):307–12.
35. Hoffmann ME, Rodriguez SM, Zeiss DM, Wachsberg KN, Kushner RF, Landsberg L, et al. 24-h core temperature in obese and lean men and women. Obesity (Silver Spring). 2012;20(8):1585–90.
36. Seganfredo FB, Blume CA, Moehlecke M, Giongo A, Casagrande DS, Spolidoro JVN, et al. Weight-loss interventions and gut microbiota changes in overweight and obese patients: a systematic review. Obes Rev. 2017;18(8). 832–51.
37. Chevalier C, Stojanović O, Colin DJ, Suarez-Zamorano N, Tarallo V, Veyrat-Durebex c, et al. Gut microbiota orchestrates energy homeostasis during cold. Cell. 2015;163(6):1360–74.
38. Bleau C, Karelis AD, St-Pierre DH, Lamontagne L. Crosstalk between intestinal microbiota, adipose tissue and skeletal muscle as an early event in systemic low-grade inflammation and the development of obesity and diabetes. Diabetes Metab Res Rev. 2015;31(6):545–61.
39. Burton C. Temperature Regulation. Annu Rev Physiol. 1939;1:109–30.
40. Moorhouse VHK. Effect of increased temperature of the carotid blood. Am J Physiol. 1911;28:223–34.
41. Sund-Levander M, Forsberg C, Wahren LK. Normal oral, rectal, tympanic and axillary body temperature in adult men and women: a systematic literature review. Scand J Caring Sci. 2002;16(2):122–8.
42. Lim CL. Fundamental concepts of human thermoregulation and adaptation to heat: A review in the context of global warming. Int J Environ Res Public Health. 2020;17(21):1–33.
43. Daanen HA, van Es EM, de Graaf JL. Heat strain and gross efficiency during endurance exercise after lower, upper, or whole body precooling in the heat. Int J Sports Med. 2006;27(5):379–88.
44. Jequier E, Gygax PH, Pittet P, Vannotti A. Increased thermal body insulation: relationship to the development of obesity. J Appl Physiol. 1974;36(6):674–8.
45. Castellani JW, Young AJ. Human physiological responses to cold exposure: Acute responses and acclimatization to prolonged exposure. Auton Neurosci [Internet]. 2016;196:63–74.
46. Hatfield H, Pugh L. Thermal conductivity of human fat and muscle. Nature (Lond). 1951;168:918–9.
47. Hardy J, Soderstrom G. Heat loss from de nude body and peripheral blood flow. J Nutr. 1938;16:493–510.
48. Breuer H. The thermal conductivity of muscle and fat. Pflüg Arch ges Physiol. 1924;204:442–7.
49. Lipkin M, Hardy J. Measurement of some thermal properties of human tissues. J Appl Physiol. 1954;7:212–7.
50. Lefreve J. Studies of the thermal conductivity of skin in-vivo and the variations induced by changes in the surrounding temperature. J Phys Theor Appl. 1901;10(1):380–8.
51. Cramer MN, Jay O. Biophysical aspects of human thermoregulation during heat stress. Auton Neurosci [Internet]. 2016;196:3–13.
52. Passmore R, Durnin JVGA. Human energy expenditure. Physiol Rev. 1955;35:801–40.
53. Shvartz E, Saar E, Benor D. Physique and heat tolerance in hot-dry and hot-humid environments. J Appl Physiol. 1973;34(6):799–803.
54. Marino FE, Mbambo Z, Kortekaas E, Wilson G, Lambert MI, Noakes TD, et al. Advantages of smaller body mass during distance running in warm, humid environments. Pflugers Arch. 2000;441:359–67.
55. Ravanelli N, Cramer M, Jay O. Comparing changes in core temperature between groups differing greatly in body morphology during exercise in an uncompensable environment. Med Sci Sports Exercise. 2015;47:496.
56. Waalen J, Buxbaum JN. Is older colder or colder older? The association of age with body temperature in 18,630 individuals. J Gerontol A Biol Sci Med Sci. 2011;66(5):487–92.
57. Bastardot F, Marques-Vidal P, Vollenweider P. Association of body temperature with obesity. The CoLaus study. Int J Obes [Internet]. 2019;43(5):1026–33.
58. Speakman JR. Obesity and thermoregulation. En: Romanovsky AA,editor. Handbook of Clinical Neurology. Ámsterdam: Elsevier B.V.;2018. p. 431-43.
59. Dervis S, Coombs GB, Chaseling GK, Filingeri D, Smoljanic J, Jay O. A comparison of thermoregulatory responses to exercise between mass-matched groups with large differences in body fat. J Appl Physiol. 2016;120:615–23.
60. Frost HM. Obesity, and bone strength and "mass": a tutorial based on insights from a new paradigm. Bone. 1997;21(3):211–4.

61. Zhao LJ, Liu YJ, Liu PY, Hamilton J, Recker RR, Deng HW. Relationship of obesity with osteoporosis. J Clin Endocrinol Metab. 2007;92(5):1640–6.
62. Shapses SA, Sukumar D. Bone metabolism in obesity and weight loss. Annu Rev Nutr. 2012;32:287–309.
63. Dimitri P, Wales JK, Bishop N. Adipokines, bone-derived factors and bone turnover in obese children; evidence for altered fat-bone signalling resulting in reduced bone mass. Bone. 2011;48(2):189–96.
64. Shapses SA, Riedt CS. Bone, body weight, and weight reduction: what are the concerns? J Nutr. 2006;136(6):1–8.
65. Pistilli EE, Gordish-Dressman H, Seip RL, Devaney JM, Thompson PD, Price TB, et al. Resistin polymorphisms are associated with muscle, bone, and fat phenotypes in white men and women. Obesity (Silver Spring). 2007;15(2):392–402.
66. Peng XD, Xie H, Zhao Q, Wu XP, Sun ZQ, Liao EY. Relationships between serum adiponectin, leptin, resistin, visfatin levels and bone mineral density, and bone biochemical markers in Chinese men. Clinica Chimica Acta. 2008;387(1–2):31–5.
67. Ponrartana S, Aggabao PC, Hu HH, Aldrovandi GM, Wren TAL, Gilsanz V. Brown adipose tissue and its relationship to bone structure in pediatric patients. J Clin Endocrinol Metab.2012;97(8):2693–8.
68. Bredella MA, Fazeli PK, Freedman LM, Calder G, Lee H, Rosen CJ, et al. Young women with cold-activated brown adipose tissue have higher bone mineral density and lower Pref-1 than women without brown adipose tissue: A study in women with anorexia nervosa, women recovered from anorexia nervosa, and normal-weight women. J Clin Endocrinol Metab. 2012;97(4):584-90.
69. Bredella MA, Gill CM, Rosen CJ, Klibanski A, Torriani M. Positive effects of brown adipose tissue on femoral bone structure. Bone. 2014;58:55–8.
70. Antonios TFT, Singer DRJ, Markandu ND, Mortimer PS, MacGregor GA. Structural skin capillary rarefaction in essential hypertension. Hypertension. 1999;33(4):998–1001.
71. Shibasaki M, Inoue Y, Kondo N. Mechanisms of underdeveloped sweating responses in prepubertal boys. Eur J Appl Physiol Occup Physiol. 1997;76(4):340–5.
72. Inoue Y, Kuwahara T, Araki T. Maturation- and aging-related changes in heat loss effector function. J Physiol Anthropol Appl Human Sci. 2004;23(6):289–94.
73. Gomes LHLS, Carneiro-Júnior MA, Marins JCB. Thermoregulatory responses of children exercising in a hot environment. Rev Paul Pediatr. 2013;31(1):104–14.
74. Wagner JA, Horvath SM. Influences of age and gender on human thermoregulatory responses to cold exposures. J Appl Physiol (1985). 1985;58(1):180–6.
75. Marins JCB. Acción termorreguladora en el calor durante el reposo y ejercicio en personas mayores. Scientia (Granada). 1999;4(2):89–99.
76. Colin J, Houdas Y. Experimental determination of coefficient of heat exchanges by convection of human body. J Appl Physiol 1967;22(1):31–8.
77. Horton WB, Barrett EJ. Microvascular dysfunction in diabetes mellitus and cardiometabolic disease. Endocr Rev. 2021;42(1):29–55.
78. Blatteis CM. Age-dependent changes in temperature regulation - A mini review. Gerontology. 2012;58(4):289–95.
79. Livingstone SD, Nolan RW, Frim J, Reed LD, Limmer RE. A thermographic study of the effect of body composition and ambient temperature on the accuracy of mean skin temperature calculations. Eur J Appl Physiol Occup Physiol. 1987;56(1):120–5.
80. Chudecka M, Lubkowska A. Thermal imaging of body surface temperature distribution in women with anorexia nervosa. Eur Eat Disord Rev. 2016;24(1):57–61.
81. Siah CJR, Childs C. Thermographic mapping of the abdomen in healthy subjects and patients after enterostoma. J Wound Care. 2015;24(3):112–20.
82. Weigert M, Nitzsche N, Kunert F, Lösch C, Schulz H. The influence of body composition on exercise-associated skin temperature changes after resistance training. J Therm Biol [Internet]. 2018;75:112–9.
83. Wilson SB, Spence VA. Dynamic thermographic imaging method for quantifying dermal perfusion: potential and limitations. Med Biol Eng Comput. 1989;27(5):496–501.
84. Payne S, Macintosh A, Stock J. Body size and body composition effects on heat loss from the hands during severe cold exposure. Am J Phys Anthropol. 2018;166(2):313–22.

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Revision

The limit of physiological adaptation of the right ventricle to endurance training

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ABSTRACT

The study aims to conduct a review of right ventricle, measured by echocardiography or magnetic resonance imaging, in athletes with high dynamic component and moderate static, the limit of the physiological adaptation. A search was carried out in the Medline database up to the end of 2017. This study showed that the mean values for the different measurements of the right ventricle in athletes are significantly greater than that of sedentary controls. In two of the 12 studies that analyzed mean diameter of the right ventricle in apical 4C, including 1477 endurance athletes and 498 controls, with high heterogeneity. Endurance athletes presented significantly higher longitudinal diameter of the RV in apical absolutes scores compared to control. The end diastolic volume and end systolic volume measured by magnetic resonance imaging, showed a significant standardized mean difference favoring athletes with a moderate heterogeneity.
Keywords: Physiological adaptation; Right ventricle; Meta-analysis; Endurance athletes; High dynamic component.

El límite de la adaptación fisiológica del ventrículo derecho al entrenamiento de resistencia

RESUMEN

El estudio tiene como objetivo realizar una revisión del ventrículo derecho, medido por ecocardiografía o resonancia magnética, en deportistas con alto componente dinámico y estático moderado, el límite de la adaptación fisiológica. Se realizó una búsqueda en la base de datos Medline hasta finales de 2017. Este estudio mostró que los valores medios de las diferentes mediciones del ventrículo derecho en los deportistas son significativamente mayores que los de los controles sedentarios. En dos de los 12 estudios que analizaron el diámetro medio del ventrículo derecho en apical 4C, incluyendo 1477 atletas de resistencia y 498 controles, con alta heterogeneidad. Los atletas de resistencia presentaron un diámetro longitudinal del VD en absolutas apicales significativamente mayor en comparación con los controles. El volumen diastólico final y el volumen sistólico final medidos por resonancia magnética, mostraron una diferencia media estandarizada significativa a favor de los atletas con una heterogeneidad moderada.
Palabras clave: Adaptación fisiológica; Ventrículo derecho; Meta-análisis; Atletas de resistencia; Alto componente dinámico.

O limite da adaptação fisiológica do ventrículo direito ao treino de resistência

RESUMO

O estudo visa conduzir uma revisão do ventrículo direito, medido por ecocardiografia ou ressonância magnética, em atletas com elevada componente dinâmica e estática moderada, o limite da adaptação fisiológica. Foi realizada uma pesquisa na base de dados Medline até ao final de 2017. Este estudo mostrou que os valores médios das diferentes medidas do ventrículo direito em atletas são significativamente superiores aos dos controlos sedentários. Em dois dos 12 estudos que analisaram o diâmetro médio do ventrículo direito em 4C apical, incluindo 1477 atletas de endurance e 498 controlos, com elevada heterogeneidade. Os atletas de resistência apresentaram um diâmetro longitudinal do VD significativamente mais elevado nas pontuações absolutas apicais, em comparação com os controlos. O volume diastólico final e o volume sistólico final medido por ressonância magnética, mostraram uma diferença média padronizada significativa, favorecendo os atletas com uma heterogeneidade moderada.
Palavras chave: Adaptação fisiológica; Ventrículo direito; Meta-análise; Atletas de resistência; Componente altamente dinâmica.

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Introduction

Although the right ventricle is situated anatomically parallel to the left ventricle, functionally it is "connected" in series, as both ventricles have the same cardiac output (CO) in average values.[1] The equality in cardiac output means that the systolic volume of the right ventricle is the same as that of the left ventricle in spite of considerable anatomical and physiological differences.[2,3] However, both pumps exert a different pressure on their respective vascular tree. The right ventricle exerts about 4 times less pressure, so that the resistance of the respiratory vascular tree is about 10 times lower than the systemic vascular tree. During dynamic exercise of moderate to high intensity there is an increase in CO and central venous pressure (CVP).[4] A sustained increase in CVP as occurs in sports with high dynamic and moderate static components could condition the maximum physiological limit of cardiac adaptation to training.

The described conditions mean that the phenomena of physiological adaptation to training are exerted in a similar fashion on both sides of the heart. Thus, the right ventricle should experience similar modifications to the left ventricle in order to satisfy the same demand produced during exercise, as Henschen[5] proposed intuitively. However, in spite of the development of echocardiography since 1970, interest in the adaptation of the right ventricle to training has been practically non-existent. In fact, in a review study published in 1986 on athlete's heart, of the 29 articles reviewed, only 8 had taken measurements of the right ventricle using one-dimensional echocardiography.[6] As Vitarelli affirms the right ventricle has been the "forgotten ventricle" and it is only since the last two decades that interest in the field of cardiology has also focused on evaluating the function of the right ventricle.[3] As a consequence, there has been a considerable increase in studies devoted to understanding the adaptation of the right ventricle to training.

The objective of this study was to perform a meta-analysis on articles dealing with the dimensions of the right ventricle in athletes who develop a high dynamic and moderate static component. The review considered articles where the measurement of the right ventricle (RV) were made either by echocardiography or by nuclear magnetic resonance considered the gold standard for evaluating cardiac dimensions.[7]

Methods

This paper reviews the adaptation of the right ventricle to endurance training from a strictly physiological perspective. A search was carried out in the Medline database up to the end of 2017, including printed articles. The initial search term was: "right ventricle and athletes OR sport and echocardiography OR magnetic resonance" only of human subjects and in English. In addition, knowing the existence of a doctoral thesis published in Spain on the right ventricle in athletes, it was considered appropriate to include the results in the meta-analysis, because it meets the search requirements. The following criteria were taken into account for the selection of the studies to be reviewed:

1º) First criterion: Athletes who practiced disciplines belonging to Categories II and/or III of the classification by Mitchell,[8] independently of the level of the static component.

2º) Second criterion: Measurements recorded by:

- Echocardiography. At least 3 measurements of the right ventricle at rest or before participating in a determined event, according to the guidelines for standardizing echocardiographic measurements of the right ventricle.[3-6]
- Nuclear magnetic resonance. Measurements of the volume of the right ventricle in diastole and systole and the myocardial mass.

3º) Third criterion: The studies had to present the following data and comply with the following criteria:

- Age (mean and SD)
- Anthropometric data: weight, height and body surface area (mean and SD)
- Years of training (mean and SD)
- Absence of pathologies
- Presence of sedentary controls
- Male sex. Given that it has been shown that there are differences in cardiac measurements between the two sexes, this study only considered data on men.
- Age range. Studies were eliminated that focused on populations at the growing stage or ages when the heart begins to deteriorate.

Data collection

The articles were selected by two of the authors (FJC and MB) according to the established criteria. All the data were entered onto a spreadsheet (FJC) and the units of the echocardiographic and nuclear magnetic resonance measurements were reviewed (FJC and MB). In those articles that studied the variations experienced during the competition or the recovery, the values of the analyzed variables were those corresponding to the initial state (Figure 1).

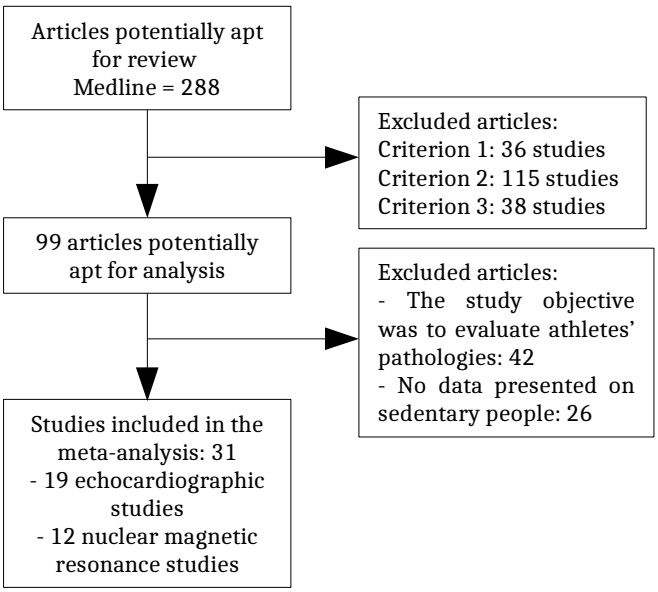

Figure 1. Results of the bibliographic search on the different studies using echocardiography or nuclear magnetic resonance for inclusion in the meta-analysis.

Data synthesis and statistical analysis

Data were analyzed using the Review Manager 5.3 statistical package.[9] A standardized mean difference (SMD); and its corresponding 95% confidence intervals (CIs) were estimated as a measure of effect size. Their interpretation was based on the following criteria: small: ≤ 0.49; moderate: 0.50 – 0.79 and large: ≥ 0.80.[9] Heterogeneity between studies was tested using Chi-square and I^2 statistical tests. A P-value of less than 0.1 indicated a statistically significant heterogeneity for the Chi-square test.[1] The percentage of I^2 represented the degree of heterogeneity: percentages of 25, 50, and 75% indicated a low, moderate, and high degree of heterogeneity, respectively.[10] When significant heterogeneity was found a random-effects model was used to pool the study results; otherwise, a fixed-effects model was adopted. For all analyses, a forest plot was generated to display results.

Although some articles used Foale abbreviations, for a clearer understanding of the text we have used those of Rudski et al.[11]. The variables that were taken into account for the meta-analysis and their nomenclature were as follows:

1º) Dimensions of the right ventricle
- Diameter of the RVOT by parasternal long axis (RVOT-Prox long axis)
- Diameter of the proximal RVOT by parasternal short axis (RVOT-Prox short axis)
- Diameter of the distal RVOT by parasternal short axis (RVOT-Distal short axis)
- Basal diameter of the RV in apical 4 (RVD1)
- Mean diameter of the RV in apical 4C (RVD2)
- Longitudinal diameter of the RV in apical (RVD3)
- Diastolic area of the RV in apical 4C
- Systolic area of the RV in apical 4C

2º) Thickness of the RV in M-mode or 2D, parasternal and subcostal projections

Results

Echocardiographic measures

The characteristics of the included studies, published between 2002 and 2017 are shown in Table 1. Since not all of them included all the measures, we selected those measures that appeared in at least 5 studies.

The forest plots for the 5 studies in which RVD1 was measured in relation to body surface area (Figure 2). One of the studies[8] included 2 samples from endurance athletes and 2 samples from controls. The sample for the meta-analysis involved a total of 939 endurance athletes and 316 controls. The endurance athletes presented significantly higher RVD1 relative scores compared to controls (SMD = 0.98, 95% CI: 0.62-1.35, Z = 5.29, $P < 0.001$) with significant heterogeneity in these estimates (I^2 = 82%, P <0.001).

RVD2 abs (Figure 2) appeared in 12 studies, one of them with 2 samples from endurance athletes and one from controls.[12] These studies included 1477 endurance athletes and 498 controls. Analysis of combined results showed a significant SMD favoring athletes with high heterogeneity in these estimates (SMD = 1.12, 95% CI: 0.78-1.47, Z = 6.32, P <0.001, I^2 = 88%, P < 0.001).

Eight studies included RVD3 (Figure 2) or RV LAX abs measurements, involving 1357 endurance athletes and 415 controls. Endurance athletes presented significantly higher RVD3 absolutes scores compared to controls (SMD = 0.64, 95% CI: 0.52-0.76, Z = 10.5, $P < 0.001$, I^2 = 6%, P = 0.38)

RVOTprox absolute (Figure 3) was measured in 8 studies involving 859 endurance athletes and 365 controls and the thickness of the right ventricle wall (RVWT) abs (Figure 3) in 7 studies (1232 endurance athletes and 372 controls). Endurance athletes presented significantly higher RVOTprox abs scores (SMD = 0.47, 95% CI: 0.24-0.70, Z = 3.96, P <0.001) and RVWT abs scores (SMD = 0.70, 95% CI: 0.22-1.18, Z = 2.83, P = 0.005) compared to controls, with significant heterogeneity in these estimates (I^2 = 61%, P < 0.01 for RVOTprox abs and I^2 = 92%, P < 0.001 for RVWT abs scores).

Finally, RVFAC abs (%) (Figure 3) was measured in 6 studies (594 endurance athletes and 235 controls). No differences were found between endurance athletes and controls (SMD = 0.31, 95% CI: -0.20-0.83, Z = 1.18, P = 0.240) although a high variability was found in these studies (I^2 = 89%, P < 0.001).

Resonance measures

Table 2 shows the baseline characteristics of the twelve studies included in this review, published between 2010 and 2017. We select those measures that at least appeared in 5 studies.

Table 1. Studies, published between 2002 and 2017

Author	Echocardiographic parameters	Number of athletes and sedentary subjects	Sports from category C	Foale or Rutsky measurement criteria
Baucem et al., 2008	RVD2; RVD3 ; RVOTProx RVFAC abs	40 athletes 40 sedentary	Soccer (28.7 %) Volleyball (10.25) Running (2.5 %)	Foale
Baggish et al., 2010	RVD2; RVFAC abs	20 athletes 20 sedentary	Rowing	Lang
De Luca et al., 2013	RVOTProx	25 athletes 20 sedentary	20 Soccer, 5 Basketball	Rudski
Erol et al., 2002	RVD2	36 athletes 16 sedentary	14 Running	Not mentioned
Esposito et al., 2014	RVD2; RVD3; RVWT abs	40 athletes 43 sedentary	Rowing	Italian Society of cardiology
Gjerdalen et al., 2014	RVD1, RVD2, RVD3, RVWT abs	504 athletes 47 sedentary	Soccer	Lang; Horton, Ruski
Henriksen et al., 1998	RVD2; RVD3; RVOTProx	82 athletes 29 sedentary	Orienteering	Foale
King et al., 2013	RVD2; RVWT abs	42 athletes 17 sedentary	18 Rowing and 24 Soccer	Lang
Pagourelias et al., 2013	RVD2; RVD3; RVOTProx RVFAC abs	80 athletes 26 sedentary	Cycling, Running and Triathlon	Lang
Popovic et al., 2011	RVOTProx	21 athletes 20 sedentary	Waterpolo	Foale
Simsek et al., 2013	RVD2; RVFAC abs	44 athletes 30 sedentary	Long distance running	Rudski
Teske et al., 2009	RVD1	117 athletes 94 sedentary	Long distance running	American Society of Echocardiography
Utomi et al., 2015	RVD1; RVD2; RVD3; RVOTProx; RVWT abs	19 athletes 21 sedentary	Long distance running	Lang
Vitarelli et al., 2013	RVFAC abs; RVWT abs	35 athletes 35 sedentary	Endurance	Lang
Zaidi et al., 2013	RVFAC abs; RVWT abs	375 athletes 84 sedentary	Endurance. Badminton, Basketball, Boxing, Canoeing, Cycling, Hockey, Middle and long distance running, Rowing, Soccer, Skating, Squash, Swimming, Tennis and Triathlon	Lang and Ruski
Heras E., 2016	RVOT-Prox long axis RVOT-Prox short axis RVOT-Distal short axis; RVD1; RVD2; RVD3; VD Thickness	217 athletes 125 athletes CI	Middle and long distance running, Badminton, Orienteering, Soccer, Field hockey, Padel, Basketball, Swimming, Handball	Lang and Ruski

RVD2: Mean diameter of the RV in apical 4C; RVD3: Longitudinal diameter of the RV in apical; RVOT: Right ventricular outflow tract; RVWT: Thickness of the right ventricle wall;RVD1rel: Basal diameter of the RV in apical 4

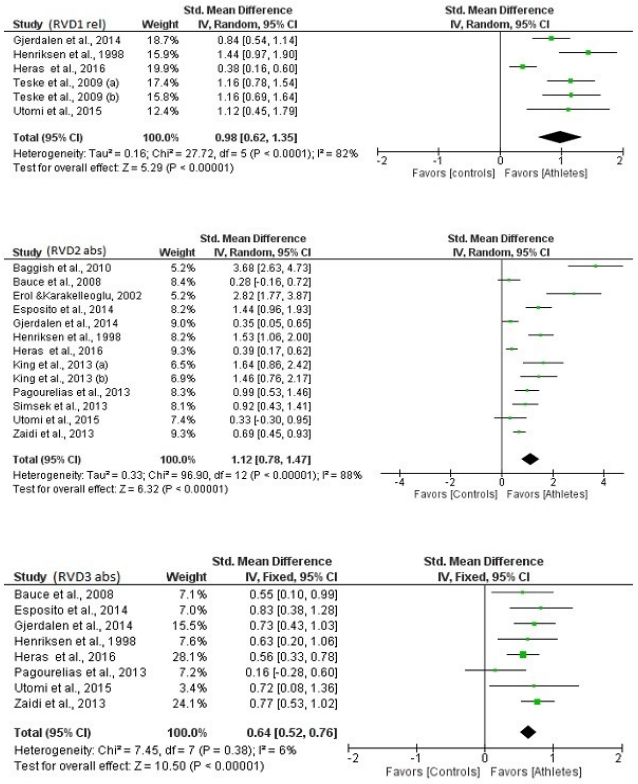

Figure 2. Forest plots corresponding to the following echocardiographic parameters considered in this work: RVD1, RVD2 and RVD3. RVD1rel: Basal diameter of the RV in apical 4 (relative); RVD2abs: Mean diameter of the RV in apical 4C (absolute); RVD3: Longitudinal diameter of the RV in apical (absolute)

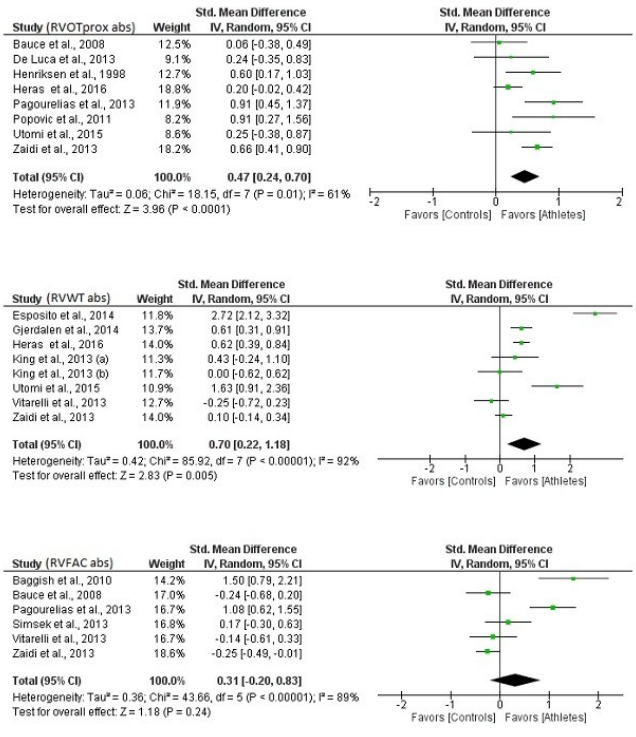

Figure 3. Forest plots corresponding to the following echocardiographic parameters considered in this work: RVOT absolute, RVWT and RVFAC. RVOT: Right ventricular outflow tract; RVWT: Thickness of the right ventricle wall; RVFAC: Right ventricular fractional area change

Table 2. Baseline characteristics of the twelve studies included in this review, published between 2010 and 2017

Author	Nuclear magnetic resonance parameters	Number of athletes and sedentary subjects	Sports from Category C
Dupont et al., 2017	EDV rel CI rel	12 athletes 12 sedentary	Triathlon
Esch et al., 2010	EDV abs; ESV abs	8 athletes 8 sedentary	2 Cycling, 5 Triathlon, 1 Biathlon
La Gerche et al., 2011	EDV abs; ESV abs	39 athletes 14 sedentary	7 Marathon, 9 Cross country skiing, 10 Long-distance runners, 13 Ultra-triathlon
La Gerche et al., 2015	EDV abs; ESV abs	10 athletes 7 sedentary	Triathlon and Cycling
Luijkx et al., 2013	EDV rel; ESV abs; Mass rel	52 athletes 52 sedentary	
Luijkx et al., 2012	EDV rel; ESV abs; Mass rel	93 athletes 56 sedentary	54 III C and 93 III A Mitchell)
Perseghin et al., 2007	EDV abs; EDV rel	9 athletes 10 sedentary	Marathon
Petersen et al., 2006	EDV rel; ESV abs; CI rel	23 athletes 21 sedentary	15 Rowing, 2 Swimming, 6 Triathlon
Prakken et al., 2010	EDV abs; EDV rel; ESV abs; Mass rel	46 athletes 56 sedentary	Rowing, Biathlon, Triathlon, Water polo
Scharf et al., 2010	EDV rel; Mass rel; CI rel	29 athletes 29 sedentary	Soccer
Scharf et al., 2010	EDV rel; Masa rel; CI rel	26 athletes 27 sedentary	Triathlon
Steding-Ehrenborg et al., 2015	EDV abs; ESV abs; CI rel	6 athletes 8 sedentary	Endurance

EDV = End Diastolic volume (absolute and relative); ESV = End systolic volume (absolute); Mass = myocardial mass (absolute and relative); CI = cardiac index

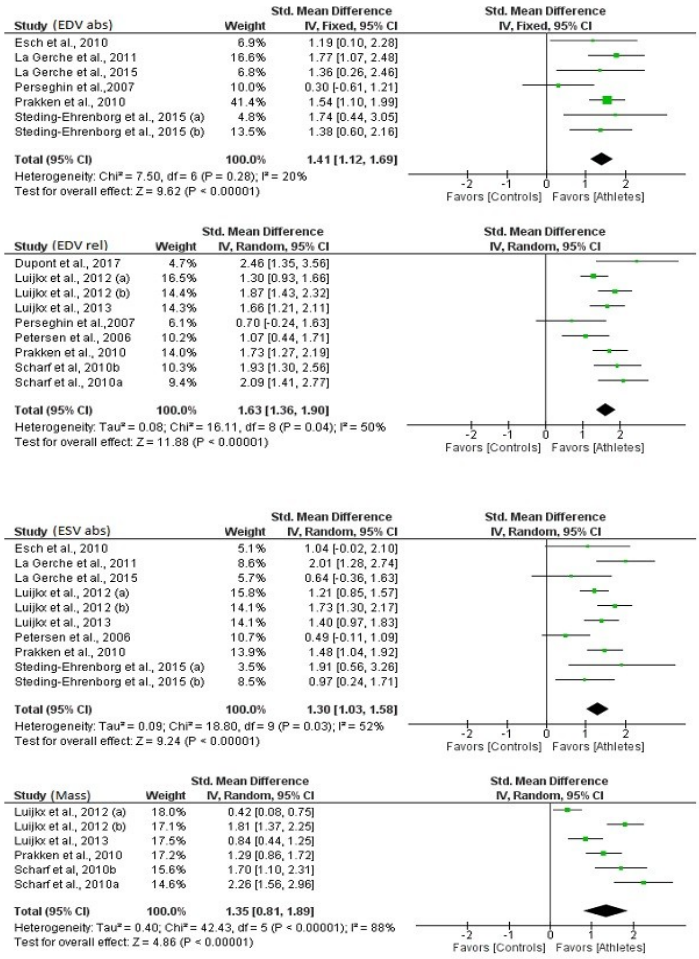

Figure 4. Forest plots corresponding to the following magnetic resonance parameters considered in this work: absolute End Diastolic Volume (EDV abs), relative End Diastolic Volume (EDV rel), absolute End Systolic volume (ESVabs) and myocardial mass (Mass).

The EDV abs (Figure 4) was measured in 6 studies; one of them[13] included 2 samples from endurance athletes and 2 samples from controls. These studies involved 134 endurance athletes and 119 controls. EDV rel (Figure 4) was measured in 7 studies (347 endurance athletes and 263 controls), one of them (8) including 2 samples from endurance athletes and 1 sample from controls. Endurance athletes presented significantly higher EDV abs scores (SMD = 1.41, 95% CI: 1.12-1.69, Z = 9.62, P < 0.001, I^2 = 20%, P = 0.28) and EDV rel scores (SMD = 1.63, 95% CI: 1.36-1.90, Z = 11.88, P < 0.001) compared to controls. In SMD estimates for EDV rel scores moderate heterogeneity was found (I^2 = 50%, P = 0.04).

ESVabs (Figure 4) was measured in 8 studies, one of them with 2 samples from endurance athletes and one from controls[14] and another one[13] included 2 samples from endurance athletes and 2

samples from controls. These studies included 350 endurance athletes and 294 controls. The analysis of combined results showed a significant SMD favoring athletes with a moderate heterogeneity in these estimations (SMD = 1.30, 95% CI: 1.03-1.58, Z = 9.24, P < 0.001, I2 = 52%, P = 0.03).

Five studies included Mass rel measures (Figure 4), one of them with 2 samples from endurance athletes and one from controls.[14] These studies included 330 endurance athletes and 220 controls. Endurance athletes presented significantly higher Mass rel scores compared to controls with a high heterogeneity in these estimations (SMD = 1.35, 95% CI: 0.81-1.89, Z = 4.86, P < 0.001, I^2 = 88%, P < 0.001). Finally, five studies included IC rel measures, one of them[15] included 2 samples from endurance athletes and 2 samples from controls, involving 112 endurance athletes and 113 controls. Endurance athletes presented significantly higher IC rel scores compared to controls with a moderate heterogeneity in these estimations (SMD = 0.47, 95% CI: 0.20-0.74, Z = 3.42, P < 0.001, I^2 = 46%, P = 0.10).

Discussion

The aim of this review was to characterize the limit of physiological adaptation of the right ventricle in endurance athletes by means of echocardiography and magnetic resonance imaging. As Morganroth[16] rightly surmised more than a century ago, the adaptation of the right ventricle had to "symmetrically match" that of the left ventricle. In fact, the balance of the right/left adaptation was demonstrated later by,[14,17,18] although La Gerche[19] obtained higher values in the left ventricle/right ventricle ratio suggesting a different physiological adaptation mechanism to training, as the right ventricle is more sensitive to the volume overload resulting from greater venous return during exercise.

1) Discussion of the echocardiographic results. This study showed that the mean values for the different measurements of the right ventricle in athletes are significantly greater than that of sedentary controls. However, the differences found in some studies may be due to 1) problems arising from the echocardiographic technique and 2) the way the different authors defined endurance athletes and sedentary controls.

The technical echocardiographic problems include: 1) the placement of the transducer to obtain the best image, 2) the unequivocal delimitation of the axes of the right ventricle (short and long axis), 3) the inclusion or not of certain structures in the different measurements of the right ventricle, which has made it difficult in many cases to standardize them, and 4) the delimitation of the endocardial borders, given the considerable trabeculation of this chamber.

Regarding the selection of the population of athletes and controls, it is necessary to bear in mind the characteristics of endurance athletes. For example, the population studied by Gjerdalen et al.[20] includes soccer players whose static component is notably lower than rowers, cyclists and long-distance runners. Soccer is characterized by high-intensity intermittent activity and although aerobic energy contributes significantly to performance in this sport, a high anaerobic capacity is also required.[11,21-24] The maximum oxygen consumption reached by soccer players on average is lower than that obtained by endurance athletes.[25]

Oxygen consumption ($\dot{V}O_2$) is a parameter that integrates the functions of uptake (respiratory system), pumping, transport and distribution (cardiorespiratory system) and use (mainly muscle tissue). Therefore, the athletes with a greater $\dot{V}O_2$ develop a greater ventricular function which translates into a higher degree of adaptation. Moreover, the selection of the controls is also of utmost importance.

The study by Heras[26] did not include a sedentary population, but it was decided to use the "opposite extreme" IA of Mitchell's classification (golf, Olympic shooting) that is, sports with low dynamic and static components. Although it may in fact be questionable to choose these athletes as controls, the values of the different echocardiographic measurements are within normal limits for the sedentary population.[3-6] It is also exceptional for the different studies included in this review to adequately describe the characteristics of the control population. In our understanding it is not enough to indicate that the control population did not suffer from any cardiac pathology and that it was physically inactive. To really understand the possibilities of physiological adaptation the control population should have revealed conditions of "cardiac atrophy" as happens to people on bed-rest or those who have been in space for a long time. In this type of study, the mean loss of heart muscle mass measured by resonance is 14%.[14]

RVD1. In several studies [8,15,18,19,27] which measured this variable the endurance athletes had higher values than the sedentary controls. In this echocardiographic measurement Heras showed a difference of means of 0.38. As indicated above this value may be due to the consideration of athletes from category IA as the control population. Mitchell's classification[8] may have a clear cardiological indication but not from the viewpoint of the athletes' cardiac overload. Currently, golfers, for example, have very comprehensive training including dynamic and static overload, so that they may experience a certain degree of adaptation.

RVD2. This echocardiographic measurement also shows a great amount of heterogeneity among the different studies[12,15,18-20,23,24,26-30] due both to the small differences found between athletes and sedentary controls[15,19,27,30] and also to the higher values of the athletes compared to sedentary controls.[20,23] Bauce and Gjerdalen[20,31] include in the athlete population soccer players and volleyball players who are clearly not classified at the maximum limit of adaptation (Mitchell's category IIIC).[2]

RVD3. In contrast to the previous measurements, the degree of homogeneity in this variable was very high in all the studies that analyzed it.[15,18,19,24,27-30] Only Pagourelias et al.[32] observed similar values in the studied athlete population and the sedentary controls. This homogeneity probably suggests that this measurement was not affected by the echocardiographic technique or the choice of the athletes. The results of this author attract attention as the athlete population is clearly made up of endurance athletes and also a consensus method was used.[6]

RVOTProx. Although moderately heterogeneous, the values found by Bauce et al., De Luca et al., Heras and Popovic et al.[26,31,33,34] are similar between the athlete population and the sedentary controls. With regard to the results of Heras,[26] it seems reasonable to think that the population chosen to compare with the endurance athletes was not suitable, as indicated above.

RVFAC abs (%). The high degree of heterogeneity in this echocardiographic measurement observed in the studies that analyzed it[20,26,28-30,35] is due, in our opinion, to the echocardiographic methodology used. As the measurement is taken during the two phases of the cardiac cycle (systole and diastole) it is highly conditioned. The phases of the cardiac cycle considered for the left ventricle cannot be extrapolated. The pressure/volume ratio in the right ventricle has been defined as a trapezium or triangle, with a poor definition of the periods of isovolumetric contraction and relaxation that are observed in the left ventricle.[31,36] The pressure exerted by the right ventricle is lower and has a different form, as it reaches an initial peak very quickly in contrast to the form and magnitude of pressure in the left ventricle.

RVWT abs. Again, the high degree of heterogeneity in this measurement is due to the inherent errors that can be made when measuring the thickness of the myocardium of the right ventricle. Thus, while Espósito et al. and Utomi et al.[37,38] found considerable differences for this measurement between endurance athletes and sedentary controls, other authors that measured this variable[12,15,27,29,35] did not observe significant differences.

2) Discussion of the results of the magnetic resonance. In contrast to the echocardiographic measurements, the homogeneity found between the different volumetric values

presented in the different studies that measured them using magnetic resonance is worthy of note. The differences in effect size between the resonance and the echocardiograph are due to the greater accuracy of the former in quantification, as the structural limits are determined more precisely. In fact, magnetic resonance constitutes the gold standard for determining volumes, for this reason we think that the differences observed in the volumetric measurements taken by magnetic resonance may be due more to the selection of the sample of athletes and sedentary controls than the technique itself. However, other parameters measured using magnetic resonance, the relative myocardial mass (Mass rel) and the relative cardiac index (CI rel) showed a great deal of heterogeneity. In these two measurements the differences are due both to the technique itself and to the selection of the study subjects.

EDV abs. Only the study by Perseghin et al.[39] failed to demonstrate differences in this measurement, while in the rest of the studies[7,8,13,32,40] the ventricular volume was greater in the endurance athlete population studied. It is curious that although the athlete population studied by Perseghin et al.[39] was clearly made up of endurance athletes, no differences were found compared to the control group.

EDV rel. The evaluation of the right ventricular volume relative to body surface area showed significant differences between the two populations. Of note are the extreme values: no differences in the study by Perseghin et al.[39] and considerable differences in that by Dupont et al.[41].

Mass rel. The heterogeneity in this measurement is due both to the selection of the endurance athletes as to the errors that can be made in the valuation of the right myocardial mass. With regard to the former problem, all the resonance studies consulted were carried out with endurance athletes that could be included in Mitchell's group IIIC,[8] with the exception of the study by Scharf,[42] who carried it out with soccer players.

CI rel. The heterogeneity of this variable seems coherent as the heart output depends on the size of the body and although it is relativized by body surface area, the values are very similar among individuals from the same type.

In conclusion, this review study shows that the right ventricle experiences an adaptation to endurance training, but without reaching values that are considered pathological. This adaptation is a consequence of the high heart output that the athletes develop during training and competition. In spite of the statistical differences found in this meta-analysis, it can be stated that the effect size measures in this review are within the moderate to high range.[9] This means that the percentage of control subjects with values lower than those of the endurance athletes in some measurements of the right ventricle reached more than 70%. Finally, the differences found between the two techniques used (echocardiography and resonance) should be underlined.

Limitations of the study. We consider that to be able to compare the degree of adaptation of the two cardiac pumps it would have been advisable to analyze the structural variables using echocardiography and magnetic resonance. Because in spite of the studies that present a similar degree of adaptation of the two ventricles, there are also others that indicate the opposite.

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References

1. Cohn PF. From cardiac catheterization data to hemodynamic parameters, third edition, Edited by S. S. Yang, L. G. Bentivoglio, V. Maranhao, and H. Goldberg, Philadelphia: F. A. Davis Company; 1988. Clin Cardiol. 1988 Aug;11(8):586.
2. Haddad F, Hunt SA, Rosenthal DN, Murphy DJ. Right Ventricular Function in Cardiovascular Disease, Part I. Circulation. 2008 Mar 18;117(11):1436–48.
3. Vitarelli A, Terzano C. Do we have two hearts? New insights in right ventricular function supported by myocardial imaging echocardiography. Heart Fail Rev. 2010 Jan 29;15(1):39–61.
4. Sheriff DD, Zhou XP, Scher AM, Rowell LB. Dependence of cardiac filling pressure on cardiac output during rest and dynamic exercise in dogs. Am J Physiol Circ Physiol. 1993 Jul 1;265(1):H316–22.
5. Henschen S. Skidlauf und skidwettlauf: eine medizinische sportstudie. Mitt Med Klin Upsala. 1899; 2.
6. Maron BJ. Structural features of the athlete heart as defined by echocardiography. J Am Coll Cardiol. 1986 Jan;7(1):190–203.
7. Arias T, Chen J, Fayad ZA, Fuster V, Hajjar RJ, Chemaly ER. Comparison of Echocardiographic Measurements of Left Ventricular Volumes to Full Volume Magnetic Resonance Imaging in Normal and Diseased Rats. J Am Soc Echocardiogr. 2013 Aug;26(8):910–8.
8. Mitchell JH, Haskell W, Snell P, Van Camp SP. Task Force 8: Classification of sports. J Am Coll Cardiol. 2005 Apr 19;45(8):1364–7.
9. Cohen J. Statistical Power Analysis. Curr Dir Psychol Sci. 1992 Jun 24;1(3):98–101.
10. Higgins JPT. Measuring inconsistency in meta-analyses. BMJ. 2003 Sep 6;327(7414):557–60.
11. Rudski LG, Lai WW, Afilalo J, Hua L, Handschumacher MD, Chandrasekaran K, et al. Guidelines for the Echocardiographic Assessment of the Right Heart in Adults: A Report from the American Society of Echocardiography. J Am Soc Echocardiogr. 2010 Jul;23(7):68.
12. Forteza-Albertí JF, Sanchis-Gomar F, Lippi G, Cervellin G, Lucia A, Calderón-Montero FJ. Limits of ventricular function: from athlete's heart to a failing heart. Clin Physiol Funct Imaging. 2017 Nov 1;37(6):549–57.
13. Pelliccia A, Maron BJ, Spataro A, Proschan MA, Spirito P. The Upper Limit of Physiologic Cardiac Hypertrophy in Highly Trained Elite Athletes. N Engl J Med. 1991 Jan 31;324(5):295–301.
14. Luijkx T, Cramer MJ, Prakken NHJ, Buckens CF, Mosterd A, Rienks R, et al. Sport category is an important determinant of cardiac adaptation: an MRI study. Br J Sports Med. 2012 Dec;46(16):1119–24.
15. Steding-Ehrenborg K, Boushel RC, Calbet JA, Åkeson P, Mortensen SP. Left ventricular atrioventricular plane displacement is preserved with lifelong endurance training and is the main determinant of maximal cardiac output. J Physiol. 2015 Dec 1;593(23):515
16. Morganroth J, Maron BJ, Henry WL, Epstein SE. Comparative left ventricular dimensions in trained athletes. Ann Intern Med. 1975 Apr;82(4):521-4.
17. Scharhag J, Schneider G, Urhausen A, Rochette V, Kramann B, Kindermann W. Athlete's heart. J Am Coll Cardiol. 2002 Nov 20;40(10):1856–63.
18. Prakken NH, Velthuis BK, Teske AJ, Mosterd A, Mali WP, Cramer MJ. Cardiac MRI reference values for athletes and nonathletes corrected for body surface area, training hours/week and sex. Eur J Cardiovasc Prev Rehabil. 2010 Apr;17(2):198–203.
19. La Gerche A, Heidbüchel H, Burns AT, Mooney DJ, Taylor AJ, Pfluger HB, Inder WJ, Macisaac AI, Prior DL. Disproportionate exercise load and remodeling of the athlete's right ventricle. Med Sci Sports Exerc. 2011 Jun;43(6):974-81.

20. Gjerdalen GF, Hisdal J, Solberg EE, Andersen TE, Radunovic Z, Steine K. The Scandinavian athlete's heart; echocardiographic characteristics of male professional football players. Scand J Med Sci Sports. 2014 Oct 1;24(5):e372–80.
21. Lang RM, Badano LP, Mor-Avi V, Afilalo J, Armstrong A, Ernande L, et al. Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. Eur Hear J - Cardiovasc Imaging. 2015 Mar 1;16(3):233-71.
22. Teske AJ, Prakken NH, De Boeck BW, Velthuis BK, Martens EP, Doevendans PA, et al. Echocardiographic tissue deformation imaging of right ventricular systolic function in endurance athletes. Eur Heart J. 2008 Sep 26;30(8):969–77.
23. Bangsbo J. The physiology of soccer--with special reference to intense intermittent exercise. Acta Physiol Scand Suppl. 1994 Jan 1;619:1–155.
24. Wragg CB, Maxwell NS, Doust JH. Evaluation of the reliability and validity of a soccer-specific field test of repeated sprint ability. Eur J Appl Physiol. 2000 Sep 15;83(1):77–83.
25. King G, Almuntaser I, Murphy RT, La Gerche A, Mahoney N, Bennet K, et al. Reduced Right Ventricular Myocardial Strain in the Elite Athlete May Not Be a Consequence of Myocardial Damage. "Cream Masquerades as Skimmed Milk." Echocardiography. 2013 Sep;30(8):929-35.
26. Heras Gómez ME. Valoración ecocardiográfica del ventrículo derecho en deportistas de élite: estudio comparado sobre el ventrículo derecho en deportistas con diferente componente dinámico y estático. Facultad de Medicina. Universidad Autónoma. Madrid, 2016. Tesis Doctoral.
27. Foale R, Nihoyannopoulos P, McKenna W, Kleinebenne A, Nadazdin A, Rowland E, et al. Echocardiographic measurement of the normal adult right ventricle. Heart. 1986 Jul 1;56(1):33–44.
28. Ramos-Álvarez JJ, Maffulli N, Bragazzi NL, Ardigò LP, Jiménez-Herranz E, Naranjo-Ortiz C, et al. Cardio-respiratory values during recovery from exercise in soccer Spanish leagues. Physiol Meas. 2018 Oct 11;39(10):105003.
29. Perhonen MA, Franco F, Lane LD, Buckey JC, Blomqvist CG, Zerwekh JE, et al. Cardiac atrophy after bed rest and spaceflight. J Appl Physiol. 2001 Aug 1;91(2):645–53.
30. Jemni M, Prince MS, Baker JS. Retracted Note: Assessing Cardiorespiratory Fitness of Soccer Players: Is Test Specificity the Issue?–A Review. Sport Med - Open. 2018 Dec 19;4(1):28.
31. Bauce B, Frigo G, Benini G, Michieli P, Basso C, Folino AF, et al. Differences and similarities between arrhythmogenic right ventricular cardiomyopathy and athlete's heart adaptations. Br J Sports Med. 2010 Feb 1;44(2):148–54.
32. Pagourelias ED, Kouidi E, Efthimiadis GK, Deligiannis A, Geleris P, Vassilikos V. Right Atrial and Ventricular Adaptations to Training in Male Caucasian Athletes: An Echocardiographic Study. J Am Soc Echocardiogr. 2013 Nov;26(11):1344–52.
33. De Luca A, Stefani L, Galanti G. Right Ventricle Chamber of Young Trained Athletes: Morphology and Function. Asian J Sports Med. 2013 Jul 25;4(4):281–8.
34. Popovic D, Ostojic MC, Petrovic M, Vujisic-Tesic B, Popovic B, Nedeljkovic I, et al. Assessment of the Left Ventricular Chamber Stiffness in Athletes. Echocardiography. 2011 Mar;28(3):276–87.
35. Baggish AL, Yared K, Weiner RB, Wang F, Demes R, Picard MH, Hagerman F, Wood MJ. Differences in cardiac parameters among elite rowers and subelite rowers. Med Sci Sports Exerc. 2010 Jun;42(6):1215-20.
36. Erol MK, Karakelleoglu S. Assessment of right heart function in the athlete's heart. Heart Vessels. 2002 Jul 1;16(5):175–80.
37. Esposito R, Galderisi M, Schiano-Lomoriello V, Santoro A, De Palma D, Ippolito R, et al. Nonsymmetric Myocardial Contribution to Supranormal Right Ventricular Function in the Athlete's Heart: Combined Assessment by Speckle Tracking and Real Time Three-Dimensional Echocardiography. Echocardiography. 2014 Sep;31(8):996-1004.
38. Utomi V, Oxborough D, Ashley E, Lord R, Fletcher S, Stembridge M, et al. The impact of chronic endurance and resistance training upon the right ventricular phenotype in male athletes. Eur J Appl Physiol. 2015 Aug 17;115(8):1673–82.
39. Perseghin G, De Cobelli F, Esposito A, Lattuada G, Terruzzi I, La Torre A, et al. Effect of the sporting discipline on the right and left ventricular morphology and function of elite male track runners: A magnetic resonance imaging and phosphorus 31 spectroscopy study. Am Heart J. 2007 Nov;154(5):937-42.
40. Simsek Z, Tas MH, Gunay E, Degirmenci H. Speckle-tracking echocardiographic imaging of the right ventricular systolic and diastolic parameters in chronic exercise. Int J Cardiovasc Imaging. 2013 Aug 12;29(6):1265–71.
41. Dupont A-C, Poussel M, Hossu G, Marie P-Y, Chenuel B, Felblinger J, et al. Aortic compliance variation in long male distance triathletes: A new insight into the athlete's artery? J Sci Med Sport. 2017 Jun 1;20(6):539–42.
42. Scharf M, Brem MH, Wilhelm M, Schoepf UJ, Uder M, Lell MM. Cardiac magnetic resonance assessment of left and right ventricular morphologic and functional adaptations in professional soccer players. Am Heart J. 2010 May;159(5):911–8.

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Artículo Especial

Conclusiones de las XI Jornadas del Grupo Avilés sobre Medicina del Deporte 3 y 4 de Octubre de 2022 (Barcelona)

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RESUMEN

El Grupo de Trabajo Avilés fue impulsado por el Consejo Superior de Deportes en 2009 y está formado por representantes de los Centros de Medicina de la Educación Física y el Deporte de todas las comunidades autónomas que cuentan con estas infraestructuras y representantes de centros de medicina del deporte de centros de tecnificación, centros municipales de medicina del deporte y la Agencia Española de Protección de la Salud en el Deporte. Como objetivos de este grupo de trabajo figuran la coordinación entre estas estructuras autonómicas de la medicina del deporte, el planteamiento de soluciones comunes a las diferentes problemáticas que sufren cada uno de los centros y el ser un grupo de asesoramiento, en los diferentes ámbitos de la medicina de la educación física y el deporte, para el Consejo Superior de Deportes.
Este grupo de trabajo se reúne periódicamente; en su última reunión, celebrada en Barcelona el 3 y 4 de octubre de 2022, se acordaron una serie de conclusiones, en relación a la muerte súbita y las arritmias en el deporte, el SARS Cov-2, la prevención, la salud mental, la diversidad sexual y la especialidad MIR.

Palabras clave: Muerte Súbita; Arritmias; Deporte; Salud Mental; SARS-CoV-2; Prevención; Diversidad Sexual; Especialidad MIR.

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Conclusions of the XI Conference of the Aviles Group on Sports Medicine, October 3 and 4, 2022 (Barcelona)

ABSTRACT

The Avilés Working Group was promoted by the National Sports Council in 2009 and is made up of representatives of Physical Education and Sports Medicine Centers of all the autonomous communities that have these infrastructures, Sports Technification Centers, municipal Sports Medicine Centers and the Spanish Agency for Health Protection in Sport. The objectives of this working group include the coordination between these autonomous structures of Sports Medicine, the proposal of common solutions to the different problems suffered by each of the centers and to be an advisory group in the different areas of the Physical Education and Sports Medicine, for the National Sports Council.
This working group meets periodically; at its last online meeting, held in Barcelona on October 3-4, 2022, a series of conclusions were agreed in relation to sudden death and arrytmias in sport, SARS Cov-2, prevention, mental health, sexual diversity and the MIR specialty.

Keywords: Sudden Death; Arrhythmias; Sports; Mental Health; SARS-CoV-2; Prevention; Mental Health; Sexual Diversity; MIR Specialty.

Conclusões da XI Conferência do Grupo Aviles de Medicina Esportiva, 3 e 4 de outubro de 2022 (Barcelona)

RESUMO

O grupo de Trabalho Avilés foi incentivado pelo Conselho Superior de Esportes em 2009. É composto por representantes dos Centros de Medicina da Educação Física e Esporte de todas as comunidades autônomas que contam com estas infraestruturas, bem como representantes dos centros de medicina do esporte de centros técnicos, centros municipais de medicina do esporte e da Agencia Espanhola de Proteção da saúde no Esporte. Como objetivos de trabalho desde grupo, figuram a coordenação entre estas estruturas autonômicas da medicina do esporte, a criação de soluções comuns as diferentes problemáticas que sofrem cada um dos centros, além de ser um grupo de assessoramento, nos diferentes âmbitos da medicina da educação física e do esporte, para o Conselho Superior de Esportes.
Este grupo de trabalho se reúne periodicamente; Em sua última reunião, realizada em Barcelona de 3 e 4 de outubro de 2022, foi acordada uma série de conclusões em relação à morte súbita e arritmias no esporte, SARS Cov-2, prevenção, saúde mental, diversidade sexual e especialidade MIR.

Palavras-chave: Morte Súbita; Arritmias; Esporte; SARS Cov-2; Prevenção; Saúde Mental; Diversidade Sexual; Especialidade MIR.

Introducción

El "Grupo de Trabajo Avilés" está integrado por representantes médicos de los centros públicos de Medicina del Deporte de Comunidades Autónomas, de Centros de Alto Rendimiento y de Tecnificación Deportiva y de entidades locales, y sus objetivos son:

- Armonizar el trabajo técnico y profesional de los Centros de Medicina del Deporte que dependen de las entidades públicas.
- Buscar soluciones a problemas de funcionamiento comunes. Compartir y mejorar el conocimiento técnico y científico.
- Mejorar la formación de los profesionales que prestan servicio en esos Centros.
- Disponer de un foro de intercambio de ideas, inquietudes e iniciativas en el ámbito profesional.

A tal efecto, el Grupo establece reuniones anuales de contenido científico y técnico que sirven de intercambio de experiencias en el ámbito de la Medicina del Deporte y cuyas conclusiones puedan servir a los responsables públicos para poner en marcha las políticas más eficientes. A su vez, ejerce de vía de distribución de conocimientos y de relación de los responsables de los centros de Medicina del Deporte de la administración pública del país.

Conclusiones de las XI Jornadas del Grupo de Trabajo "Avilés" de Medicina del Deporte (Barcelona, octubre 2022)

- Se insiste en la importancia de los reconocimientos médicos previos a la práctica deportiva para la prevención de la muerte súbita. Una exploración médico-deportiva que incluya anamnesis, exploración física y ECG, es esencial como punto de partida. La realización de pruebas más específicas como ecocardiograma o prueba de esfuerzo, estarían indicadas como complementarias para los deportistas a partir de los 14 o 15 años o en el caso de sospecha de patología cardiaca.
- El ejercicio de resistencia "extremo" continuado durante muchos años puede provocar alteraciones en la estructura y función cardíaca y crear un sustrato para padecer arritmias. Por este motivo, y especialmente en las personas que practican este tipo de deportes, es importante y necesaria la realización de valoraciones cardiacas periódicas.
- La incidencia de miocarditis por SARS Cov-2 es baja y en general leve. Esta incidencia tras la vacunación es todavía más baja, afectando en este caso a la franja de edad de 18-25 años. Se aconseja no practicar deporte durante la infección. Si bien la prescripción y práctica deportiva es de gran ayuda en el proceso de recuperación de pacientes post COVID.
- En relación con la infección por SARS Cov-2, no se ha observado un aumento de muerte súbita en el deporte.
- Se ha de normalizar la realización de pruebas de esfuerzo según el criterio del especialista en medicina del deporte si bien es importante mantener en todo caso la utilización de mascarilla por parte del personal sanitario, y realizarse en espacios con abundante ventilación y renovación del aire. En el caso de un deportista sintomático se debe realizar un test diagnóstico previo.
- Se recuerda la importancia de la prevención en el deporte en general y especialmente en el deporte de alto nivel. Es de destacar que no se llega al alto rendimiento si no hay salud.
- Hay que avanzar en la prescripción de ejercicio físico para la salud mental.
- La actividad física modula la neuroplasticidad y estimula la adherencia terapéutica por lo que es recomendable su uso para el tratamiento de las enfermedades en salud mental, con una prescripción individualizada para cada paciente.
- Es importante tener en cuenta los estudios y aportaciones que sobre la diversidad sexual y de género, el deporte y sus implicaciones se vienen realizando en nuestra sociedad.
- Las unidades de medicina deportiva deberían estar vinculadas a los departamentos hospitalarios junto al resto de especialidades médicas por el valor añadido que suponen para cuidar la salud de nuestros deportistas, sea cual sea su nivel, y practicantes de actividad física así como por su utilidad como herramienta preventiva y terapéutica para las distintas patologías.
- La actual falta de formación en España de médicos especialistas en medicina del deporte ha originado una grave carencia de estos y que continuará agravándose en los próximos

años si no se aprueba próximamente el sistema de formación MIR en esta especialidad.

- Este déficit afecta de forma importante a todo el sistema deportivo, a la salud de los deportistas en general y especialmente en los de alto nivel. Un país con importantes resultados deportivos internacionales no puede desprenderse de unos profesionales que vienen contribuyendo sustancialmente al cuidado de la salud y mejora del rendimiento de nuestros deportistas. Del mismo modo la formación de Médicos del Deporte es la referencia especializada para una sociedad activa y saludable que práctica deporte de forma segura.
- Una vez más este Grupo de trabajo "Avilés" insta al Ministerio de Sanidad a la aprobación prioritaria y urgente de la formación de Médicos Especialistas en Medicina del Deporte.

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