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Originales

Metodológico

Caso Clínico /Estudio de caso

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Originales

CARACTERIZAÇÃO DO PERFIL TÉRMICO DE JOVENS SEDENTÁRIOS E DE SALONISTAS E FUTEBOLISTAS DE NÍVEL UNIVERSITÁRIO

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RESUMO

Objetivo: Caracterizar o perfil termográfico de membros inferiores de jovens sedentários, bem como de universitários jogadores de futebol e futsal. **Métodos:** A amostra foi composta por 30 universitários homens divididos em três grupos, sendo eles, atletas de futebol, atletas de futsal e sedentários. Analisou-se através do software ThermoHuman® a temperatura da pele (TP) de 14 regiões corporais de interesse (RCI), sendo elas: vasto medial, vasto lateral, reto femoral, coxa posterior interna e externa, femoral, adutores de quadril na visão anterior e posterior, joelhos na visão anterior e posterior, tibial lateral e medial, gastrocnêmio interno e externo (GE). Os valores médios de TP de cada RCI foram utilizados na análise estatística. A anova *two-way e o* post-hoc de Bonferroni foram utilizados para verificar o efeito da dominância podal e do grupo nos valores de TP de cada RCI. Para se estabelecer um referencial de perfil térmico, foi proposta uma curva percentil com os percentis 5, 15, 50, 85 e 95. **Resultados:** Não houve diferença significativa nos valores de TP entre os lados dominante e não dominante em todas as RCIs analisadas. Não foi observada interação significativa entre dominância e grupo. Foi observado efeito do fator grupo apenas para a RCI GE; a análise de post-hoc mostrou que o grupo futsal apresentou valor significativamente maior de TP nesta RCI em comparação ao grupo futebol. **Conclusão:** Atletas de futebol e futsal universitário, bem como jovens sedentários apresentam respostas térmicas similares em repouso. Os níveis de simetria térmica contralateral são <0,4°C. O nível de atividade física, a especificidade do treinamento e a dominância não influenciaram as respostas termográficas.

Palavras-chave: temperatura cutânea; medicina esportiva; atletas universitários; regulação da temperatura corporal; termografia.

CHARACTERIZATION OF THE THERMAL PROFILE OF SEDENTARY YOUNG PEOPLE AND UNIVERSITY LEVEL FUTSAL AND FOOTBALL PLAYERS

ABSTRACT

Objective: To characterize the thermographic profile of the lower limbs of sedentary young people, as well as football players and college salon players. **Methods:** The sample consisted of 30 male college students divided into three groups: soccer athletes, futsal athletes, and sedentary individuals. The skin temperature (TP) of 14 body regions of interest (RCI) was analyzed using the ThermoHuman® software, namely: vastus medialis, vastus lateralis, rectus femoris, internal and external posterior thigh, femoral, hip adductors in view anterior and posterior, knees in anterior and posterior view, lateral and medial tibialis, internal and external gastrocnemius (GE). The mean TP values of each RCI were used in the statistical analysis. Two-way anova and Bonferroni post-hoc were used to verify the effect of foot dominance and group on TP values for each RCI. To establish a thermal profile reference, a percentile curve was proposed with the 5, 15, 50, 85 and 95 percentiles. **Results:** There was no significant difference in TP values between the dominant and non-dominant sides in all RCIs analyzed. No significant interaction was observed between dominance and group. An effect of the group factor was observed only for RCI GE; post-hoc analysis showed that the futsal group presented a significantly higher TP value in this RCI compared to the football group. **Conclusion:** College soccer and futsal athletes, as well as sedentary young individuals, exhibit similar thermal responses at rest. Contralateral thermal symmetry levels are <0.4°C. The level of physical activity, training specificity and dominance did not influence thermographic responses.

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Keywords: skin temperature; sports medicine; college athletes; thermal asymmetry; body temperature regulation; thermography.

CARACTERIZACIÓN DEL PERFIL TÉRMICO DE JÓVENES SEDENTARIOS Y JUGADORES DE FÚTBOL SALA Y FÚTBOL A NIVEL UNIVERSITARIO

RESUMEN

Objetivo: Caracterizar el perfil termográfico de los miembros inferiores de jóvenes sedentarios, así como de futbolistas y jugadores de salón universitarios. **Métodos:** La muestra estuvo compuesta por 30 universitarios hombres, divididos en tres grupos: atletas de fútbol, atletas de fútbol sala y sedentarios. La temperatura de la piel (TP) de 14 regiones corporales de interés (RCI) se analizó utilizando el software ThermoHuman®, a saber: vasto medial, vasto lateral, recto femoral, muslo posterior interno y externo, femoral, aductores de la cadera en vista anterior y posterior, rodillas en vista anterior y posterior, tibial lateral y medial, gastrocnemio interno y externo (GE). En el análisis estadístico se utilizaron los valores medios de TP de cada RCI. Se utilizaron anova bidireccional y Bonferroni post-hoc para verificar el efecto de la dominancia del pie y del grupo sobre los valores de TP para cada RCI. Para establecer una referencia del perfil térmico se propuso una curva percentil con los percentiles 5, 15, 50, 85 y 95. **Resultados:** No hubo diferencia significativa en los valores de TP entre el lado dominante y no dominante en todos los RCI analizados. No se observó interacción significativa entre dominancia y grupo. Se observó un efecto del factor grupo sólo para RCI GE; El análisis post hoc mostró que el grupo de fútbol sala presentó un valor de TP significativamente mayor en este RCI en comparación con el grupo de fútbol. **Conclusión:** Los atletas de fútbol y fútbol sala universitario, así como los jóvenes sedentarios, presentan respuestas térmicas similares en reposo. Los niveles de simetría térmica contralateral son <0,4°C. El nivel de actividad física, la especificidad del entrenamiento y la dominancia no influyeron en las respuestas termográficas.

Palabras clave: temperatura cutánea; medicina deportiva; deportistas universitarios; regulación de la temperatura corporal; termografía.

INTRODUÇÃO

A termografia infravermelha (TI) nos permite monitorar a temperatura da pele (TP) com base no calor irradiado da superfície corporal de forma rápida e não invasiva[1], disponibilizando informações acerca da distribuição de calor das regiões corporais de interesse (RCI), identificando zonas de maior e menor TP, sendo estas associadas a quadros de hiper ou hiporradiação, respectivamente[2]. O controle das alterações térmicas no âmbito esportivo pode auxiliar a prescrição e a prevenção de lesões através da avaliação de diferenças térmicas bilaterais[2-4] ou por meio da criação de faixas de normalidade identificando regiões hipo ou hiper radiadas[5,6], otimizando interpretação dos termogramas.

Visando realizar uma avaliação termográfica mais assertiva, é importante definir um perfil térmico normal para atletas de diferentes modalidades. Rezende et al.[7], por exemplo, verificou que a TP do joelho de atletas de elite varia de acordo com o gênero e a modalidade esportiva. Os resultados apontam para uma diferença de TP contralateral < 0,3°C em atletas de elite de judô, basquete, futsal e vôlei. Além disso, jogadores de basquete apresentaram TP anterior 1,2°C maior que os jogadores de futsal e 0,8°C maior que os judocas. Na visão posterior, os autores observaram que jogadores de basquete também apresentaram um TP 1,1°C maior que os judocas e 0,7°C maior que os jogadores de vôlei. Resultados como estes são importantes, pois permitem avaliar a normalidade de diferentes segmentos corporais, identificando aumentos ou reduções anormais de TP e observando alterações bilaterais clinicamente importantes. Assim como no estudo de Rezende et al., outros estudos estabeleceram o perfil térmico de indivíduos não atletas pertencentes a diferentes grupos populacionais[1,8-10]. No entanto, são poucos os estudos que buscaram traçar o perfil térmico de atletas, como jogadores de futebol e/ou futsal de nível universitário.

Compreender o comportamento térmico normal de um atleta é fundamental para aprimorar o desempenho e prevenir lesões. Assim, este estudo traz à tona uma abordagem inovadora e atualizada na ciência do esporte que pode colaborar com o planejamento e prescrição de treinamento, potencializando o desempenho atlético e prevenindo lesões. Além disso, a comparação entre duas modalidades esportivas oportunizará *insigths* valiosos sobre as demandas específicas de cada uma, contribuindo na busca pela excelência esportiva e pela manutenção da saúde dos atletas.

Visando explorar e entender como diferentes níveis de atividade e a especificidade da prática de exercícios influenciam as respostas de TP, é importante investigar e comparar as respostas térmicas de indivíduos com diferentes níveis de atividade e praticantes de modalidades distintas. No entanto, dos estudos encontrados apenas um realizou essa comparação em estado de repouso[11], não sendo encontrado nenhum estudo com futebolistas e/ou atletas de futsal universitário.

Deste modo, este estudo busca caracterizar o perfil termográfico de membros inferiores de jovens universitários sedentários, bem como de universitários jogadores de futebol e futsal, auxiliando na investigação de como variações do perfil térmico podem estar associadas ou não à prática de atividades esportivas. A hipótese é de que os valores de TP dos indivíduos sedentários será inferior aos dos atletas universitários. Ademais, é esperado que a modalidade esportiva induza respostas térmicas específicas, sendo esperado que os jogadores de futsal apresentem TP inferior aos futebolistas. Com relação às análises de assimetrias térmicas, é esperado que os participantes apresentem simetria térmica contralateral similar entre os grupos.

METODOLOGIA

Amostra

A amostra foi composta por 30 homens divididos em três grupos. O primeiro e o segundo grupo foram formados por universitários futebolistas (G1) e atletas de futsal (G2), respectivamente. O terceiro foi constituído por sedentários (G3). Os voluntários eram atletas e/ou estudantes de uma universidade federal brasileira e foram selecionados por conveniência. A tabela 1 apresenta os dados de caracterização dos participantes.

Todos os voluntários atenderam ao critério de inclusão de ter idade entre 18 e 30 anos. Além deste, foram atendidos os critérios

Tabela 1. Dados de caracterização dos participantes.

Variável	FUTEBOL	FUTSAL	SEDENTÁRIOS	ANOVA
	$\bar{X}$ ± DP	$\bar{X}$ ± DP	$\bar{X}$ ± DP	(F; p)
Idade (anos)	22 ± 1,8	21 ± 2,9	22 ± 2,7	1,078; 0,355
MC (Kg)	76,2 ± 8,7	76,9 ± 7,6	73,7 ± 9,6	0,280; 0,758
Estatura (m)	1,77 ± 0,04	1,75 ± 0,05	1,74 ± 0,04	2,123; 0,139
IMC (kg/m²)	23,7 ± 2,6	24,5 ± 1,6	23,6 ± 3,2	0,755; 0,480
%G	12,3 ± 4,5	13,9 ± 4,3	15,2 ± 6,3	0,894; 0,421

IMC: Índice de Massa Corporal; %G: Percentual de gordura corporal

de inclusão específicos do G1 e do G2, sendo eles: ter participado de um programa de treinamento de uma das modalidades nos últimos 6 meses, com frequência igual ou superior à 3 vezes por semana, atuando em qualquer posição de jogo, exceto como goleiro. Já para o grupo de sedentários, os voluntários foram caracterizados e selecionados conforme os resultados obtidos no questionário internacional de atividade física (IPAQ), cuja confiabilidade e validade foi previamente demonstrada[12].

Não foram incluídos no estudo indivíduos fumantes, com históricos de lesão nos últimos 6 meses, com alergia cutânea, com distúrbio do sono, com quadro febril recente, que realizou tratamento médico/fisioterápico utilizando cremes, pomadas ou loções nas RCIs horas antes da coleta, assim como uso de antitérmicos, diuréticos e/ou suplemento alimentar passível de ocasionar mudanças na homeostase hídrica ou na temperatura corporal nos últimos 15 dias e houvesse consumido medicamentos anti-inflamatórios recentemente[13].

Os voluntários deram o consentimento por escrito para participar do estudo, o qual foi aprovado pelo Comitê de Ética e Pesquisa em Seres Humanos (69887623.9.0000.5153).

Procedimentos

Inicialmente, foram realizadas avaliações antropométricas para caracterização da amostra em que foram mensurados: massa corporal (Kg) (Balança Marte Max® modelo LC200), estatura (cm) (estadiômetro Sanny®), dobras cutâneas do peitoral, abdômen e coxa (mm) (Plicômetro Científico Lange®) empregando a técnica de Jackson e Pollock[14] para calcular a densidade corporal. A equação de Siri[15] foi usada para predizer o percentual de gordura corporal (%G). O IMC (Kg/m²) foi calculado com base nos dados de massa corporal e estatura.

As avaliações termográficas foram padronizadas e atenderam às recomendações propostas por um consenso de experts para obtenção de termogramas na área de atividade física e esportes[16]. Objetivando controlar e minimizar os efeitos circadianos na TP[13], todos os termogramas foram obtidos pela manhã, antes de qualquer exercício físico, e com intervalo mínimo de 24 horas relacionado ao período do treinamento anterior. A temperatura da sala foi mantida em 20,2 ± 0,7°C, e a umidade relativa em 57 ± 5%, ambos mensurados por um termohigrômetro (HT–208, Ligth®). O período de aclimatação dos atletas foi fixado em 12 minutos, superando o período mínimo de 10 minutos recomendado[17]. Antes e durante o procedimento, os avaliados foram orientados a não realizar movimentos repentinos e intensos, ou friccionar, arranhar, cruzar suas pernas e/ou encostar-se a outros objetos ou outros participantes. Foram obtidos dois termogramas, um da vista anterior e outro da vista posterior dos membros inferiores, para análise das RCI.

Os termogramas foram obtidos com um termovisor T420 (Flir Systems®, Estocolmo, Suécia) com faixa de detecção entre -20°C e +120°C, precisão de 2%, sensibilidade de ≤ 0,05°C, banda espectral infravermelho de 7,5µm a 13µm, taxa de atualização de 60Hz, foco automático e resolução de 320 x 240 pixels. A câmera foi posicionada perpendicular às RCI a 2,3m dos avaliados, com altura individualizada objetivando encontrar o melhor enquadramento dos termogramas.

Os termogramas foram analisados no software ThermoHuman®, versão 2.21 (PEMA THERMO GROUP S.L., Madrid, Espanha), que foi previamente validado[18]. Neste estudo foram avaliados a TP da coxa anterior (vastos medial, lateral e reto femoral), coxa posterior (bíceps femoral, semitendinoso e semimembranoso), adutor de quadril (na visão anterior e posterior), joelho (na visão anterior e posterior) perna anterior (tibial lateral e medial) e perna posterior (gastrocnêmio interno e externo). A Figura 1 destaca os termogramas com as RCIs analisadas.

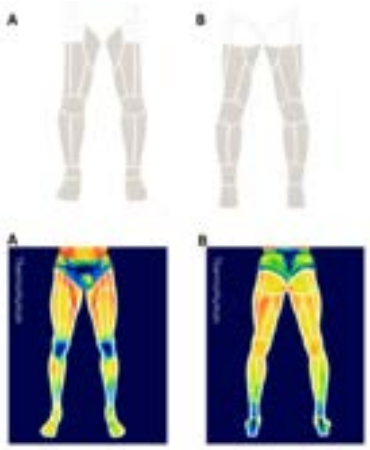

Figura 1. Termogramas dos membros inferiores, vista anterior (A) e posterior (B), destacando as RCI para avaliação da temperatura da pele.

Análise Estatística

Para caracterização da amostra quanto à idade e o perfil antropométrico, foi realizado um tratamento estatístico descritivo com média e desvio padrão. Uma anova *one-way* foi usada para comparar os dados de caracterização dos três grupos participantes do estudo (Tabela 1).

Foi aplicado o teste de Shapiro-Wilk para analisar a normalidade dos dados, e o teste de Levene para analisar a homogeneidade de variância. Como os dados apresentaram normalidade ou homogeneidade de variância, foi utilizada a anova *two-way e o* post-hoc de Bonferroni para verificar o efeito da dominância podal (lado dominante vs. não dominante), do grupo (futebol vs. futsal vs. sedentários) e da interação dominância vs. grupo nos valores de TP de cada RCI. Os resultados foram apresentados como média, desvio padrão (DP) e intervalo de confiança de 95% (IC 95%). O software SPSS, versão 23.0, foi utilizado para análise dos dados, adotando um nível de significância de $p<0,05$.

Para se estabelecer um referencial de perfil térmico, foi proposta uma curva percentil com os percentis 5, 15, 50, 85 e 95 para caracterizar uma área de alto risco hipotérmica (< percentil 5), uma área de risco hipotérmica (> percentil 5 e < percentil 15), uma área

de normalidade térmica (>percentil 15 e < percentil 85), uma área de risco hipertérmica (> percentil 85 e < percentil 95) e uma área de alto risco hipertérmico (> percentil 95).

RESULTADOS

Não houve diferença significativa nos valores de TP entre os lados dominante e não dominante em todas as RCIs analisadas. Também não foi observada interação significativa entre dominância e grupo, o que significa que a simetria térmica observada foi similar entre os grupos. Porém, houve efeito do fator grupo apenas para a RCI GE; a análise de post-hoc mostrou que o grupo futsal apresentou TP significativamente maior em comparação ao grupo futebol (p = 0,029) diferença média 0,67°C (IC 95% 0,05 – 1,3)); não houve diferença significativa entre o grupo futsal vs. controle. Nas demais RCIs, não houve diferença significativa considerando o fator grupo. A tabela 2 apresenta os resultados referentes à análise de variância de dois fatores, bem como os dados referentes as diferenças térmicas bilaterais médias, as quais foram < 0,4 °C.

A figura 2 apresenta os boxplots com os pontos de corte dos percentis 15, 50 e 85 retratados na caixa central pela linha de limite inferior, linha central e linha de limite superior, respectivamente. Ademais, são apresentados os valores de percentil 5 e 95 de TP média para cada RCI, ilustrados pelas extremidades das linhas verticais.

Como foi observado efeito do fator grupo apenas para a RCI GE, foram reportados os valores desta região para cada um dos grupos (Figura 3), destacando que houve diferença significativa apenas na comparação entre futebolistas e atletas de futsal.

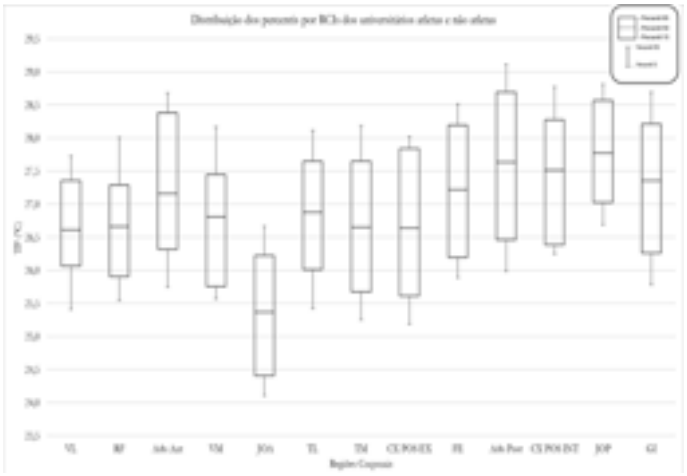

Figura 2. *Bloxplots* para os percentis 5, 15, 50, 85 e 95 de temperatura da pele de universitários atletas e não atletas.

ADU ANT = Adutor Anterior; ADU POST = Adutor Posterior; CX POST EX = Coxa Posterior Externa; CX POST INT = Coxa Posterior Interna; FE = Femoral; GI = Gastrocnêmio interno; JOA = Joelho anterior; JOP = Joelho posterior; RCI = Região corporal de interesse; RF = Reto Femoral; TL = Tibial Lateral; TM = Tibial Medial; VL = Vasto Lateral; VM = Vasto Medial.

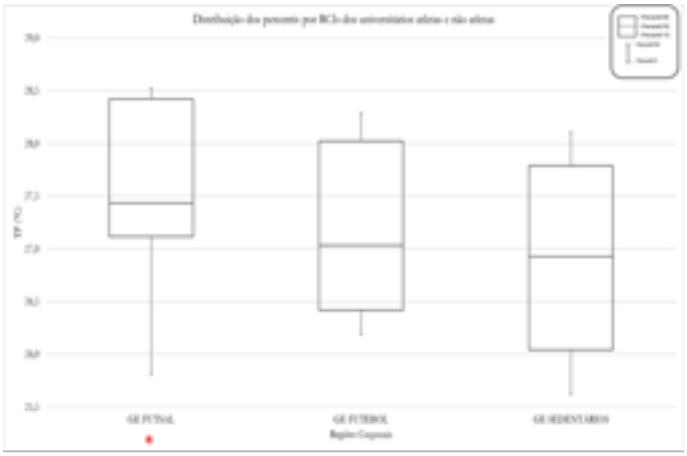

Figura 3. *Bloxplots* para os percentis 5, 15, 50, 85 e 95 de temperatura da pele do gastrocnêmio externo de futebolistas, atletas de futsal e universitários sedentários.

*GE = Gastrocnêmio Externo; * = Diferença estatística significativa Futsal vs Futebol.*

DISCUSSÃO

O presente estudo estabeleceu e comparou o perfil termográfico dos membros inferiores de jovens universitários sedentários, bem como de futebolistas e jogadores de futsal. Inicialmente, era esperado um perfil térmico específico de acordo com a modalidade praticada. No entanto, os resultados sinalizaram essa diferença apenas na RCI GE dos atletas de futsal quando comparado aos futebolistas. Nas demais RCIs, não houve diferenças significativas considerando o fator grupo. Com relação às análises de assimetrias térmicas, nossa hipótese foi confirmada pois a TP dos lados dominante e não dominante foi similar de modo comparável entre os grupos.

O perfil térmico observado em todos os grupos aponta para uma simetria bilateral média com valores < 0,4°C (Tabela 2) em todas as RCIs analisadas. Este é importante resultado pois estudos anteriores sinalizaram baixo risco lesional para diferenças térmicas bilateral ≤ 0,4°C[2]. Assim, existe evidência de que uma normalidade térmica entre os dimídios corporais deverá ser ≤ 0,4°C, para qualquer grupo populacional avaliado. Independentemente dos valores de referência adotados para tolerância de assimetria, os avaliados do presente trabalho apresentaram simetria térmica bilateral. Dado que todos os indivíduos avaliados estavam saudáveis e não lesionados, os resultados obtidos reforçam que, nessas condições, é esperado haver simetria térmica entre os dimídios contralaterais de membros inferiores em jovens sedentários, futebolistas e jogadores de futsal universitários. Com relação à comparação da simetria térmica contralateral entre os grupos, não houve diferenças significativas (Tabela 2), sinalizando que diferentes níveis de atividade/condicionamento e a especificidade da prática desportiva não afetou o comportamento térmico bilateral, sendo este um critério importante a ser considerado e discutido em estudos futuros, com atletas profissionais de ambas as modalidades.

Com relação aos valores absolutos de TP média, os dados obtidos neste estudo estão dentro da faixa normal de flutuação indicada em outros estudos que avaliaram adultos saudáveis[8-10]. Dados normativos podem auxiliar a identificar desequilíbrios térmicos entre áreas contralaterais e possíveis áreas hiper e/ou hiporradiadas, indicando, assim, a necessidade de um processo contínuo e criterioso de investigação para confirmar essa condição e identificar possíveis agentes causadores deste comportamento térmico anormal. Dentro desta perspectiva, as figuras 2 e 3 apresentam as faixas dos percentis 5, 15, 50, 85 e 95 para cada RCI avaliada, que surge como uma possível ferramenta que pode contribuir com essas avaliações, disponibilizando informações que facilitarão o acompanhamento

Tabela 2. Valores médios de temperatura da pele (°C) e assimetrias dos membros inferiores de futebolistas, atletas de futsal e universitários sedentários.

		Temperatura da Pele (°C)			Diferença térmica bilateral (°C)			ANOVA		
		FUTEBOL (n=10)	**FUTSAL (n=10)**	**SEDENTÁRIOS (n=10)**	**FUTEBOL (n=10)**	**FUTSAL (n=10)**	**SEDENTÁRIOS (n=10)**			
RCI	**LADO**	**$\bar{x}$ ± DP**	**$\bar{x}$ ± DP**	**$\bar{x}$ ± DP**	**$\bar{x}$ ± DP**	**$\bar{x}$ ± DP**	**$\bar{x}$ ± DP**	**Dominância (F; p)**	**Grupo (F; p)**	**Dominância x Grupo (F; p)**
VL	**D**	26,64 ± 0,73	26,47 ± 0,90	26,99 ± 0,75	0,10 ± 0,23	-0,05 ± 0,35	0,23 ± 0,28	0,20; 0,66	1,23; 0,30	0,16; 0,86
	ND	26,54 ± 0,78	26,52 ± 0,76	26,76 ± 0,86						
RF	**D**	26,76 ± 0,62	26,50 ± 0,82	26,81 ± 1,02	0,10 ± 0,17	-0,10 ± 0,26	-0,04 ± 0,24	0,00; 0,96	0,58; 0,57	0,09; 0,92
	ND	26,65 ± 0,60	26,61 ± 0,66	26,85 ± 1,00						
ADU ANT	**D**	27,35 ± 0,81	27,18 ± 0,88	27,29 ± 1,25	-0,07 ± 0,10	-0,05 ± 0,25	0,07 ± 0,18	0,01; 0,94	0,18; 0,84	0,03; 0,97
	ND	27,42 ± 0,81	27,24 ± 0,84	27,22 ± 1,25						
VM	**D**	26,75 ± 0,76	26,64 ± 0,71	26,83 ± 1,18	0,14 ± 0,16	-0,04 ± 0,37	-0,08 ± 0,27	0,00; 0,97	0,32; 0,73	0,09; 0,92
	ND	26,61 ± 0,77	26,68 ± 0,68	26,91 ± 1,13						
JOA	**D**	25,24 ± 0,69	25,50 ± 1,01	25,54 ± 0,99	0,17 ± 0,29	0,04 ± 0,33	-0,04 ± 0,43	0,06; 0,81	1,19; 0,31	0,07; 0,93
	ND	25,07 ± 0,73	25,46 ± 0,84	25,57 ± 0,95						
TL	**D**	26,55 ± 0,82	27,13 ± 1,08	27,02 ± 0,78	0,01 ± 0,45	0,04 ± 0,39	0,38 ± 0,38	0,42; 0,52	2,25; 0,12	0,28; 0,76
	ND	26,53 ± 0,78	27,10 ± 0,91	26,65 ± 0,74						
TM	**D**	26,41 ± 0,96	27,06 ± 0,92	26,65 ± 0,74	0,02 ± 0,27	0 ± 0,21	0,11 ± 0,17	0,03; 0,86	2,81; 0,07	0,02; 0,98
	ND	26,39 ± 0,96	27,06 ± 0,96	26,54 ± 0,88						
CX POST EX	**D**	26,60 ± 1,15	26,57 ± 1,10	26,60 ± 1,10	-0,03 ± 0,38	-0,03 ± 0,29	-0,08 ± 0,35	0,03; 0,87	0,01; 0,99	0,00; 1,00
	ND	26,63 ± 1,13	26,60 ± 0,93	26,68 ± 0,90						
FE	**D**	27,08 ± 0,95	27,30 ± 0,97	27,14 ± 0,95	-0,10 ± 0,33	-0,07 ± 0,23	-0,04 ± 0,27	0,09; 0,77	0,30; 0,74	0,01; 0,99
	ND	27,18 ± 0,91	27,37 ± 0,80	27,18 ± 0,93						
ADU POST	**D**	27,42 ± 1,05	27,59 ± 1,02	27,54 ± 1,09	-0,12 ± 0,22	-0,07 ± 0,32	0,02 ± 0,26	0,04; 0,85	0,09; 0,92	0,02; 0,98
	ND	27,54 ± 1,06	27,65 ± 0,96	27,52 ± 1,22						
CX POST INT	**D**	27,40 ± 0,75	27,62 ± 0,85	27,40 ± 0,92	-0,06 ± 0,29	-0,04 ± 0,26	0,05 ± 0,40	0,01; 0,94	0,52; 0,60	0,02; 0,98
	ND	27,45 ± 0,84	27,66 ± 0,79	27,35 ± 0,99						
JOP	**D**	27,75 ± 0,64	27,87 ± 0,69	27,80 ± 0,77	-0,06 ± 0,31	-0,05 ± 0,12	0,05 ± 0,20	0,01;0,91	0,17; 0,84	0,04; 0,96
	ND	27,81 ± 0,76	27,92 ± 0,71	27,75 ± 0,78						
GE	**D**	26,87 ± 0,76	27,60 ± 0,72	27,18 ± 0,80	-0,01 ± 0,41	0,10 ± 0,18	0,05 ± 0,03	0,05; 0,83	3,63;0,03*	0,02; 0,98
	ND	26,86 ± 0,86	27,50 ± 0,80	27,13 ± 0,71						

		Temperatura da Pele (°C)			Diferença térmica bilateral (°C)			ANOVA		
		FUTEBOL (n=10)	**FUTSAL (n=10)**	**SEDENTÁRIOS (n=10)**	**FUTEBOL (n=10)**	**FUTSAL (n=10)**	**SEDENTÁRIOS (n=10)**			
RCI	**LADO**	**$\bar{x}$ ± DP**	**$\bar{x}$ ± DP**	**$\bar{x}$ ± DP**	**$\bar{x}$ ± DP**	**$\bar{x}$ ± DP**	**$\bar{x}$ ± DP**	**Dominância (F; p)**	**Grupo (F; p)**	**Dominância x Grupo (F; p)**
GI	**D**	27,06 ± 0,88	27,71 ± 0,88	27,41 ± 0,89	0,03 ± 0,37	0,04 ± 0,28	0,14 ± 0,22	0,09; 0,77	2,35; 0,11	0,02; 0,98
	ND	27,03 ± 1,10	27,67 ± 0,99	27,27 ± 0,85						

ADU ANT = Adutor Anterior; ADU POST = Adutor Posterior; CX POST EX = Coxa Posterior Externa; CX POST INT = Coxa Posterior Interna; D = Dominante; DP = Desvio-Padrão; FE = Femoral; GE = Gastrocnêmio Externo; GI = Gastrocnêmio interno; JOA = Joelho anterior; JOP = Joelho posterior; ND = Não Dominante; RCI = Região corporal de interesse; RF = Reto Femoral; TL = Tibial Lateral; TM = Tibial Medial; VL = Vasto Lateral; VM = Vasto Medial; ⊿T: Diferença de temperatura.

* *= Diferença significativa Futebol x Futsal.*

longitudinal e a identificação de possíveis quadros de hiper ou hiporradiação local. Na prática, é indicado que as comissões técnicas pré-estabeleçam algumas ações de intervenção e/ou controle para cada um dos percentis. Por exemplo, ao identificar que a TP dos isquiotibiais de um atleta é superior ao percentil 85 (área de risco hipertérmico) poderia se recomendar ações fisioterápicas preventivas, bem como uma redução da carga durante a sessão de treino.

No presente estudo, atletas universitários de futsal e futebol apresentaram valores médios de TP similares aos observados nas RCIs de membros inferiores de universitários sedentários (Tabela 2), com exceção da RCI gastrocnêmio externo dos atletas de futsal quando comparada aos futebolistas (Figura 3). Alguns estudos sinalizaram que indivíduos com maior nível de condicionamento físico possuem maior capacidade de controlar a TP em condição de exercício[11,13,19,20]. Essa diferença ocorre, pois, indivíduos treinados possuem um maior fluxo sanguíneo cutâneo[20]. Além disso, adaptações induzidas pelo exercício, como hipertrofia muscular, aumento da densidade capilar e da velocidade da condução nervosa, também podem justificar essa diferença[19]. No entanto, nossos achados não corroboram com a literatura e uma possível justificativa pode ser a baixa frequência de treinamento, o que de certa forma pode não ocasionar as adaptações termorregulatórias citadas anteriormente nos atletas avaliados em nosso estudo. Apenas um dos estudos encontrados realizou esta comparação em estado de repouso[11], sinalizando que a literatura ainda é escassa sobre a relação entre o nível de condicionamento físico e a TP em repouso, necessitando de investigações mais aprofundadas acerca do tema. Desta forma, por meio das respostas termográficas, não foram identificadas diferenças térmicas no estado de repouso entre sujeitos sedentários quando comparados com jogadores de futebol e/ou futsal de nível universitário.

Outro achado importante diz respeito à comparação das assimetrias bilaterais em função da dominância do membro. Os resultados obtidos (Tabela 2) apontam que a dominância não foi determinante na resposta térmica das 14 RCIs analisadas, corroborando com outros estudos de perfil térmico em que a dominância corporal não impactou as diferenças bilaterais[2,5,6]. Contudo, alguns estudos sinalizaram que pequenas assimetrias podem ser justificadas em função da dominância de um dos membros[13]. Algumas modalidades com padrões de movimentos unilateral repetitivos e predominantes, como o tênis e o judô, podem ocasionar essa assimetria normal[8]. No entanto, esse perfil não é esperado em modalidades como o ciclismo e a natação, pois são modalidades constituídas por um padrão de movimento equilibrado de utilização dos membros contralaterais[8]. Em nosso estudo não foi observada diferença significativa bilateral intra e entre grupos levando em consideração a dominância, sendo este um indicador de que os participantes apresentarem um perfil térmico normal.

Ainda com relação à dominância dos membros, Gómez-Carmona[21] observaram valores mais elevados de TP na perna dominante de atletas profissionais de futebol, possivelmente causadas por uma maior carga física neste membro. No entanto, os atletas universitários no presente estudo não apresentaram diferença significativa quando comparado os resultados bilaterais levando em consideração a dominância, fato este que pode ser explicado pela baixa frequência semanal (máximo de 4 treinos por semana) e menor carga de treinamento/jogos quando comparado aos atletas avaliados por Gómez-Carmona[21]. Além disso, vale ressaltar que o delineamento transversal do nosso estudo não nos permite inferir que o perfil térmico simétrico observado seria mantido ao longo de um período de treinamento.

Além da dominância, outros padrões de assimetria térmica normal ocasionado por aspectos morfológicos e anatômicos podem ser observados, como é o caso da região anterior e posterior dos joelhos[7]. Em condições normais, é esperado que a região patelar apresente TP inferior à obtida na região posterior dos joelhos, pois a patela é uma estrutura rígida que atua como um escudo frio reduzindo a temperatura da região anterior[7]. Esse comportamento fica muito evidente na figura 3 em que a RCI JOA foi a mais fria de todas as 14 RCIs monitoradas. Opostamente, a fossa poplítea é uma região muito vascularizada e, consequentemente, apresenta uma temperatura local maior devido um maior fluxo sanguíneo[1], tornando esta região 1, 2 ou até 3°C mais quente quando comparada à região anterior[5,6]. Estabelecer este referencial de desequilíbrio térmico entre a região anterior e posterior do joelho é primordial para se considerar um estado de normalidade dessa articulação, uma das mais lesionadas no futsal[22] e no futebol[23].

A análise dos termogramas levando em consideração os padrões térmicos individuais e específico da modalidade é extremamente importante e pode evitar intepretações equivocadas. O uso contínuo da TI possibilita a criação de um histórico de avaliações termográficas dos atletas, colaborando para o acompanhamento das respostas térmicas durante toda a temporada, permitindo a identificação precoce de anormalidades na TP com maior precisão, pois cada indivíduo seria comparado consigo mesmo. Assim, as avaliações termográficas tornarão mais eficiente o processo de controle da carga, colaborando para redução da incidência de lesões e, consequentemente, reduzindo gastos financeiros do clube e garantindo a saúde musculoesquelética dos atletas.

Este estudo possui algumas limitações, como o fato dos avaliados serem caracterizados e selecionados conforme os resultados do IPAQ. Embora seja um questionário validado e reconhecido mundialmente, seria interessante avaliar o nível de atividade física e sedentarismo utilizando outras ferramentas em conjunto, como, por exemplo, a pedometria. Além disso, como os participantes são atletas universitários, é esperado que atletas profissionais, em função de uma maior carga de treino, tenham um perfil térmico diferente, com maiores valores de TP. Estudos futuros, com delineamento longitudinal, podem esclarecer se este perfil térmico obtido se mantem constante ao longo de um período de treinamento e se

assemelha ao perfil observado em atletas profissionais ou indivíduos com diferentes níveis de atividade física.

Como implicações práticas têm-se que durante uma avaliação termográfica dos membros inferiores de jovens universitários sedentários e de futebolistas e jogadores de futsal universitários, é esperado observar respostas térmicas similares, com exceção da região do gastrocnêmio. Com relação às respostas bilaterais, são esperadas diferenças térmicas bilaterais inferiores a 0,4°C, independente do grupo e da dominância do avaliado. No que diz respeito aos joelhos, é esperado uma diferença >1°C quando analisadas regiões anteriores e posteriores. Por fim, é destacado que os valores de percentis 5, 15, 50, 85 e 95 para cada uma das regiões avaliadas pode ser utilizado para uma avaliação mais aprofundada, auxiliando a identificar condições de hiporradiação e hiper-radiação e, consequentemente, disponibilizando informações que facilitarão o acompanhamento longitudinal e a tomada de decisão do corpo técnico.

Em conclusão, futebolistas e jogadores de futsal universitários, bem como jovens sedentários apresentam respostas térmicas similares em repouso. Além disso, os níveis de simetria térmica contralateral são <0,4°C, indicando um perfil térmico normal e saudável do ponto de vista musculoesquelético. Por fim, foi observado que o nível de atividade física, a especificidade do treinamento e a dominância não influenciam as respostas termográficas de membros inferiores dos avaliados, com exceção da região dos gastrocnêmios, devendo esta diferença ser investigada em estudos futuros.

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Originales

VARIABLES ASSOCIATED WITH SHOOTING PERFORMANCE AT REST AND AFTER PHYSICAL EFFORT IN POLICE OFFICERS

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ABSTRACT

Objectives: We aimed to evaluate the correlation between anthropometric, cardiovascular, and aerobic fitness variables with shooting performance at rest and after physical exertion in police officers which is important for police preparation.
Methods: The sample consisted of 15 male police officers. In the first session, systolic blood pressure (SBP), resting heart rate (HR_{rest}), peak oxygen consumption (VO_{2peak}), and waist-to-hip ratio (WHR) were evaluated. In the second session, shooting performance was evaluated before (SP_{pre}) and after (SP_{post}) the physical effort by the scored points in five shots at a scored target, and shooting time (ST_{pre} and ST_{post}). Next, officers ran ~300 m on a course designed to simulate a foot chase to make the shortest time possible, while we recorded the elapsed running time (RT) and the heart rate (HR). Pearson's correlation test was used, adopting P<0.05.
Results: At rest, there was a negative correlation between SP_{pre} and age (r=-0,71; P<0.01) and SBP (r=-0.53, P<0.04). The results suggest that age and cardiovascular variables are differently associated with shooting performance in police officers.
Conclusion: Age and SBP may be negatively related to resting shooting performance in police officers. The physical fitness of the sample may have been a factor to be considered for not observing these correlations. In this way, good physical conditioning may have influenced shooting performance, which impacts police preparation, given the importance of acting on all factors that minimize damage when using firearms and increase their effective use.

Keywords: Physical effort; accuracy; shooting.

VARIABLES ASOCIADAS CON EL RENDIMIENTO DE TIRO EN REPOSO Y DESPUÉS DEL ESFUERZO FÍSICO EN OFICIALES DE POLICÍA

RESUMEN

Objetivos: Nuestro objetivo fue evaluar la correlación entre las variables antropométricas, cardiovasculares y de aptitud aeróbica con el rendimiento de tiro en reposo y después del esfuerzo físico en oficiales de policía, lo cual es importante para la preparación policial.
Métodos: La muestra estuvo compuesta por 15 oficiales de policía varones. En la primera sesión, se evaluaron la presión arterial sistólica (PAS), la frecuencia cardíaca en reposo (FCreposo), el consumo máximo de oxígeno (VO2pico) y la relación cintura-cadera (CCA). En la segunda sesión, se evaluó el rendimiento de tiro antes (SPpre) y después (SPpost) del esfuerzo físico mediante los puntos obtenidos en cinco tiros a un objetivo puntuado y el tiempo de tiro (STpre y STpost). A continuación, los oficiales corrieron ~300 m en un recorrido diseñado para simular una persecución a pie para hacer el menor tiempo posible, mientras registrábamos el tiempo de carrera transcurrido (RT) y la frecuencia cardíaca (FC). Se utilizó la prueba de correlación de Pearson, adoptando P < 0,05.
Resultados: En reposo, se encontró una correlación negativa entre la SPpre y la edad (r=-0,71; P<0,01) y la PAS (r=-0,53, P<0,04). Los resultados sugieren que la edad y las variables cardiovasculares se asocian de forma diferente con el rendimiento de tiro en policías.

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Conclusión: La edad y la PAS pueden estar relacionadas negativamente con el rendimiento de tiro en reposo en policías. La condición física de la muestra puede haber sido un factor a considerar para no observar estas correlaciones. De esta forma, un buen acondicionamiento físico puede haber influido en el rendimiento de tiro, lo que repercute en la preparación policial, dada la importancia de actuar sobre todos los factores que minimicen el daño al utilizar armas de fuego y aumenten su uso efectivo.

Palabras clave: Esfuerzo físico; precisión; tiro.

VARIÁVEIS ASSOCIADAS AO DESEMPENHO DE TIRO EM REPOUSO E APÓS ESFORÇO FÍSICO EM POLICIAIS

RESUMO

Objetivos: Nosso objetivo foi avaliar a correlação entre variáveis antropométricas, cardiovasculares e de aptidão aeróbica com o desempenho de tiro em repouso e após esforço físico em policiais, o que é importante para a preparação policial.

Métodos: A amostra foi composta por 15 policiais do sexo masculino. Na primeira sessão, foram avaliadas a pressão arterial sistólica (PAS), a frequência cardíaca em repouso (FCrepouso), o consumo máximo de oxigênio (VO2pico) e a relação cintura-quadril (RCQ). Na segunda sessão, o desempenho de tiro foi avaliado antes (SPpré) e depois (SPpós) do esforço físico pelos pontos marcados em cinco tiros em um alvo marcado e o tempo de tiro (STpré e STpós). Em seguida, os policiais correram ~300 m em um percurso projetado para simular uma perseguição a pé para fazer o menor tempo possível, enquanto registramos o tempo de corrida decorrido (TR) e a frequência cardíaca (FC). O teste de correlação de Pearson foi usado, adotando P<0,05.

Resultados: Em repouso, houve correlação negativa entre SPpre e idade (r=-0,71; P<0,01) e PAS (r=-0,53, P<0,04). Os resultados sugerem que idade e variáveis cardiovasculares estão diferentemente associadas ao desempenho de tiro em policiais.

Conclusão: Idade e PAS podem estar negativamente relacionadas ao desempenho de tiro em repouso em policiais. A aptidão física da amostra pode ter sido um fator a ser considerado para não observar essas correlações. Dessa forma, um bom condicionamento físico pode ter influenciado o desempenho de tiro, o que impacta no preparo policial, dada a importância de atuar em todos os fatores que minimizem os danos ao usar armas de fogo e aumentem seu uso efetivo.

Palavras-chave: Esforço físico; precisão; tiro.

INTRODUCTION

The primary duty of the police is ensuring public safety through direct contact with criminal actions, involving high risks. Firearm use is allowed in extreme situations to protect life with minimal harm. Muscle fatigue from physical exertion, like foot pursuits, can compromise[1] shooting accuracy by affecting stability and postural balance, which are crucial for performance.

Shooting is a precision task that requires specific physiological adjustments and its performance may be related to the autonomic nervous system modulation since an excessive sympathetic response is harmful to cognitive and psychomotor tasks such as aiming[2] which requires the ability to narrow focus and sustained attention[3]. Cardiac autonomic responses reflect nervous system modulation and distinguish better and worse triggers[4]. In a simulated school shooting, Strahler and Ziegert[5] found an increase in sympathetic activity immediately before the shooting, which tends to be greater in a situation of real danger. Increased sympathetic modulation increases tremors[6], which impairs shooting performance[7,8]. Tremors can be caused by muscle fatigue[9], muscle glycogen depletion[10], increased heart rate (HR)[6], and increased systolic blood pressure (SBP)[11]. Therefore, it becomes important to reduce tremors as much as possible.

Performing physical exertion immediately before shooting can increase tremors due to muscle fatigue[6] and impair performance[8,9]. However, conflicting results have been presented in the literature, with studies showing no negative effect of physical exertion on shooting performance[3,12] or even finding performance improvement after exercise[13]. Gil-Cosano et al.[14] verified that the performance of a shooting test after walking around carrying military equipment worsened shooting performance, attributing to fatigue as the determining factor of the negative impact on accuracy. In this sense, aerobic power is one measure of physical fitness that may be related to shooting performance due to physiological adaptations related to aerobic exercise training, such as greater parasympathetic autonomic modulation, lower HR at rest and during submaximal exercise and greater maximum exercise capacity, which would results in less disturbance in physiological variables in submaximal exercise intensities, compared to untrained individuals[15].

Although previous studies do not present a correlation between aerobic power and shooting performance at rest, immediately after performing a physical effort, individuals with lower aerobic capacity tended to worsen their performance[9,10]. Other studies indicated that aerobic fitness did not correlate with parameters of aiming or shooting efficiency[3]. In a recent systematic review including 23 studies, Simas et al.[16] concluded that physical effort does not decrease shooting performance at distances less than 10m from the target, not even when carrying weights related to their equipment or vests.

Evans et al.[8] verified that although the shooting decreased immediately after the exercise, several variables returned to their initial values after a five-minute recovery, and all the studied parameters were recovered after ten minutes. However, they used a rifle, a long type of firearm, which may have been influenced by causing greater contact with the body in its grip[8]. Sattlecker et al.[17] suggested that the increase in respiratory activity, HR, and muscle fatigue cause oscillation of the armament, and better performance is also linked to shoulder strength. However, none of the previous studies presented a condition of physical exertion that simulated a foot chase inherent to police activity.

Body composition can also influence shooting performance since anthropometric variables linked to the amount of lean mass or obesity are directly related to the activation of the sympathetic autonomic nervous system and increased blood pressure[18]. In this regard, higher abdominal and visceral fat levels may present higher impacts, especially for cardiovascular and autonomic alterations. The waist-to-hip ratio (WHR) is an indicator of body mass distribution, which may indicate the relationship between central (i.e., abdominal)

and peripheral (i.e., hips) accumulation of fat, which can be used as a reference due to its ease of use and low cost[19]. Age is also another factor to be considered since aging can increase cardiovascular sympathetic activity by reducing parasympathetic activity, which can be modified or attenuated by regular exercise since improving or maintaining physical fitness can delay the decline in parasympathetic modulation that occurs with normal aging[20]. However, no studies related shooting performance to age or body composition were found.

Thus we aimed to evaluate the correlation between anthropometric, cardiovascular, and aerobic fitness variables with shooting performance at rest and after physical exertion in police officers which is important for police preparation. We hypothesized that variables related to individual characteristics may be differently associated with shooting performance at rest and after physical exertion. Therefore, we aimed to evaluate the correlation between age, aerobic fitness, anthropometric, and cardiovascular hemodynamic variables with shooting performance before and after physical exertion in police officers.

MATERIALS AND METHODS

Study design

This cross-sectional exploratory study comprised two sessions with a 72-hour interval. In the first, participants underwent anamnesis, anthropometric and cardiovascular hemodynamic evaluation, and familiarization with the air pistol, followed by a maximum incremental test. The second session involved a shooting test before and after running on an obstacle course simulating a foot chase. Participants were instructed to abstain from caffeinated and/or alcoholic beverages and avoid exercise 24 hours before assessments. All sessions occurred between 7 and 9 am. The Institutional Ethics Committee approved the study (CAAE: 31266114.3.0000.5537), and participants provided informed consent before data collection.

Sample

A convenience sample of 15 male military police officers with ≥ 6 years of experience participated in the present study. The inclusion criteria were (a) being part of the urban policing of the Military Police; (2) having a body mass index <30kg/m^2; (3) not having any musculoskeletal condition that would prevent physical exertion and not using medication that would alter the studied variables. The exclusion criteria were injuries during the study that interfered with the outcome variables and not complete any part of the experiment.

Anthropometric assessment

Body mass and height were measured with a digital scale and stadiometer (Welmy®, W110H, São Paulo, Brazil). Body mass index (BMI) was calculated as mass divided by height squared. Waist circumference (WC) at the umbilicus and hip circumference (HC) at the largest gluteal proportion were measured with a flexible metallic tape in centimeters. Waist-to-hip ratio (WHR) was calculated as WC divided by HC.

Cardiovascular hemodynamic evaluation

Systolic blood pressure (SBP) and resting heart rate (HR) were assessed with an Omron® digital blood pressure monitor (742 INT, Kyoto, Japan) following five minutes of rest. Three measurements were conducted at one-minute intervals, and the average was utilized for analysis. Before the measurements, participants were advised to visit the bathroom and empty their bladder if needed.

Assessment of aerobic fitness

Aerobic fitness was assessed with a maximal incremental treadmill test (Inbramed ATL, Porto Alegre, RS, Brazil). Following a 5-minute warm-up at 5 km/h without inclination, the test started at 8 km/h, increasing by 1 km/h/min until voluntary exhaustion, with continuous HR monitoring using a cardiac monitor (RS800cx, Polar Electro OU, Kempele, Finland)[21].

Gas exchange analysis employed a breath-by-breath gas analyzer (Cosmed, Quark CPET, Rome, Italy). Calibration, following the manufacturer's recommendations, used standard gases and a 3L syringe. Post-test, 20-second averages were analyzed, and the highest average during the incremental test represented peak oxygen uptake (VO_{2peak}).

Evaluation of shooting performance

The shooting test was performed before and immediately after the physical effort. Five shots were fired at the target positioned 8 meters away and 1.65 m high. The shots were aimed at punctuated shooting targets, with the circle in the center of the target with a 1 cm diameter corresponding to 10 points. The circles increased by one centimeter in diameter from the center to the outside, and the score decreased by one point (Figure 1). To perform the shots, participants had to be in the initial position with the weapon next to the thigh on the dominant side, as if it were in a holster. At the "go" command, the policemen should draw the gun, take aim and shoot. The officers were instructed to shoot as accurately (i.e., achieving the highest score) and as fast as possible. The time elapsed between the verbal command and the execution of each shot was recorded with a digital stopwatch by a single, previously trained evaluator. To perform the shooting test, initially, the volunteers became familiar with the air pistol (Beeman® 2004, caliber 4.5 mm, 0.77 kg) by performing three shots. The score and time for each shot were recorded.

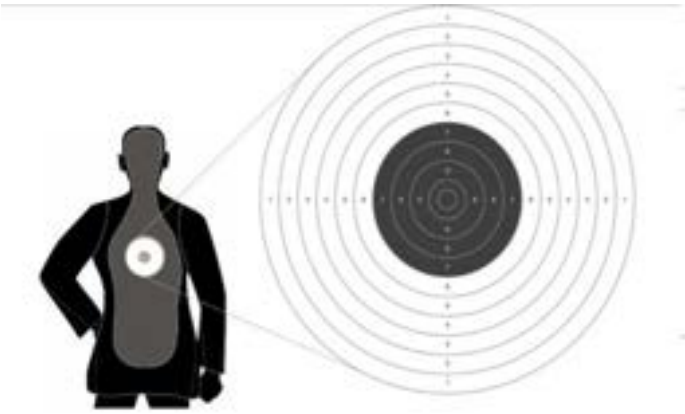

Figure 1. A humanoid figure used for evaluation of shooting performance (left) with the punctuated shooting target, enlarged on the right.

Running task

The physical effort was performed by having participants run on a course with obstacles that aimed to resemble a real chase that police officers could face in the "real world" (Figure 2). The total course of the track comprised a distance of 297 m with five obstacles: 1) going up and down a slope with sandy soil of approximately 30 meters (15 m uphill and 15 m downhill), similar to a dune; 2) after running in a straight line, enter through a narrow door opening in a one-room building and exit over a wall approximately 1.00 m high; 3) perform a sinuous race (zigzag) between three flagpoles positioned one meter apart from each other; 4) perform the kneeling shooting

Table 1. Characterization of the sample of 15 male police officers participating in the study (n = 15).

Variable	Mean (standard deviation)
Age (years)	34.1 (5.4)
Experience time	9.7 (6.9)
Body Mass (Kg)	81.5 (8.8)
Body mass index (kg/m^2)	27.7 (2.3)
Waist-to-hip ratio	0.89 (0.04)
Systolic blood pressure (mm/Hg)	117.2 (12.4)
Diastolic blood pressure (mm/Hg)	75.0 (4.0)
Resting Heart Rate (bpm)	63.9 (7.5)
Aerobic power (ml·kg-1·min-1)	44.9 (4.0)

position (one of the knees on the ground and the other bent forward to provide support) in four locations demarcated by cones two meters apart, in an approximate Z shape; 5) cross the first obstacle of the circuit in the opposite direction again, ending the race at the starting point. Volunteers were instructed to complete the circuit as quickly as possible, and strong verbal encouragement was given throughout the performance. The time to complete the course was registered using a digital stopwatch, and HR was continuously recorded. The police officers wore light clothing and shoes suitable for physical exercise.

Figure 2. Satellite image, obtained through Google Maps, of the place where the physical effort was carried out and edited with the indication of obstacles on the track. Zero (0) indicates the starting and ending point near which the shooting tests were carried out. The arrows indicate the direction of running. The numbers correspond to the type of obstacle: (1) up/down a sandy soil; (2) entering a room and jumping over a 1-meter-high wall; (3) zigzag running using flagpoles; (4) four repetitions of kneeling shooting aiming; (5) up/down a sandy soil.

Statistical analysis

The normality of the data distribution was confirmed by the Shapiro-Wilk test. Data were presented as mean and standard deviation. Pearson's correlation coefficient (r) was used to analyze the correlation between anthropometric variables (WHR), cardiovascular hemodynamic variables (SBP), aerobic fitness (VO_{2peak}), and shooting performance before and after physical exertion. The magnitude of the correlation was interpreted as weak (0.3<|r|<0.5), moderate (0.5<|r|<0.7), strong (0.7<|r|<0.9), and very strong (|r|>0.9) correlation[22]. An additional linear regression analysis was included when the variables presented significative correlation. P < 0.05 was adopted. SPSS 28.0 software was used for all analyses.

RESULTS

Participants' characteristics are described in Table 1. Moreover, participants completed the running course in 75.3 ± 4.4 seconds with ~85% of the maximum HR achieved in the maximum incremental test. Age and SBP were not correlated (r=0.225; p=0.421).

Shooting performance at rest showed a strong negative correlation with Age (Figure 3A) and a moderate negative correlation with SBP (Figure 3B). Linear regression was significant between the score in the shooting test before physical exertion and age (R^2=0,51; $F_{(1, 13)}$=13.5; p=0.003), SBP (R^2=0,289; $F_{(1, 13)}$=5.27; p=0.039), and experience time (R^2=0,65; $F_{(1, 13)}$=9.55; p=0.009); regression between the score in the shooting test after physical exertion and experience time was significant (R^2=0,7; $F_{(1, 13)}$=12.6; p=0.004).

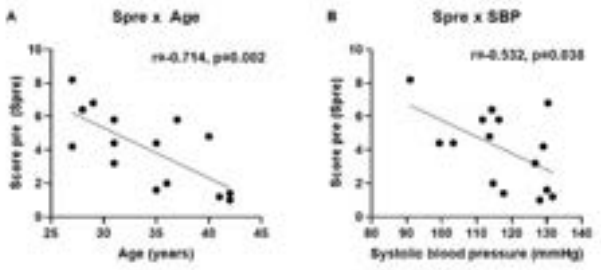

Figure 3. Significant correlations between the variables studied and shooting performance. (A) strong negative correlation between the score in the shooting test before physical exertion (Spre) and Age; (B) moderate negative correlation between Spre and systolic blood pressure (SBP) measured at rest; "r" represents Pearson's correlation coefficient and "p" represents statistical significance.

VO_{2peak} showed a strong negative correlation with the time taken to go through the circuit (r = -0.64; p = 0.01). No other significant correlations were found (Table 2).

DISCUSSION

The study explored correlations between age, aerobic capacity, anthropometric, and cardiovascular hemodynamic variables with police officers' shooting performance at rest and after a simulated foot chase. Our main finding revealed negative correlations between age, SBP, and experience time with shooting performance at rest, and experience time and score after physical exertion. No other variables correlated with shooting performance pre- or post-exertion. Aerobic capacity is negatively correlated with circuit completion time. This supports our hypothesis that individual characteristics, anthropometrics, cardiovascular hemodynamics, and cardiorespiratory fitness may be differently associated with shooting performance at rest, with no observed influence after physical exertion.

The negative correlation between age and shooting performance agrees with the increased sympathetic activity and reduced parasympathetic activity caused by age[20]. However, this change in modulation with aging seems more linked to increased blood pressure than age itself[20]. Moreover, caution should be taken when considering the relationship between age and shooting performance because the shooter's experience time is a relevant variable since, through the practice of the specific shooting activity, they can attenuate the amount of psychological stress[16], improve the accuracy of fine motor movements and reduce possible decreases in accuracy that may occur due to increasing age[23]. Indeed, our data shows that the experience

Table 2. Analysis of the correlation between different anthropometric and hemodynamic variables, aerobic fitness, and shooting performance before and after exertion in police officers (n = 15).

Variables	Shooting performance			
	At rest		After physical exertion	
	Score	Shooting time	Score	Shooting time
Age	**r=-0.714***	r=-0.216	r=-0.455	r=-0.330
Experience time	**r=-0.651***	r=0.349	**r=-0.702***	r=0.321
Waist-to-hip ratio	r=-0.328	r=-0.102	r=0.295	r=0.151
Systolic blood pressure	**r=-0.532***	r=-0.437	r=-0.102	r=-0.051
Resting Heart Rate	r=-0.321	r=0.121	r=-0.163	r=-0.046
Peak oxygen uptake	r=0.044	r=-0.285	r=-0.464	r=-0.257
Running completion time			r=0.276	r=0.373
Maximum heart rate in the circuit			r=0.409	r=-0.034

Note: * *p<0.05;*
r= correlation coeficiente.

time seems to explain the results better than age itself, independently of physical exertion.

WHR is an indirect measure used to estimate the distribution and accumulation of body fat in the central part of the body. Adipose cells produce a variety of adipokines and cytokines that can influence the local vascular tonus[24] that, when unbalanced, can be inflammatory agents and cause vasoconstriction[25]. Although a greater portion of fat is suggested to be correlated with increased cardiac sympathetic modulation[26], in the present study, there was no relationship between WHR and shooting performance either at rest or after exercise. In addition, the absent correlation can be explained by the good level of fitness and experience of the participants since, in addition to fat mass, lean mass can also influence blood pressure levels[24]. Goossens[27] points out that different body fat distributions in the body have different effects on metabolism. More accurate body fat measurements such as dual x-ray absorptiometry or magnetic resonance would be better to analyze the possible relationship between body fat and shooting performance, since the WHR, despite its low cost and ease of use, does not consider the whole-body composition.

SBP was the only hemodynamic variable significantly correlated with shooting performance at rest. The negative correlation indicated that a higher SBP was associated with a lower shoot score. According to Lakie[6] force impulses generated by the pulsatile momentum of each heartbeat produced by the transitory oscillation of the blood through the limb cause a physiological tremor. Thus, a greater SBP would cause greater limb oscillation, impairing shooting performance[6]. It has also been suggested that an increase in HR, or a delay in returning to resting levels after physical exertion, increases tremor, which would lead to impaired shooting, which was not found in this study. The resting HR did not correlate with any shooting performance variable, which can be explained by the low values presented by the sample (64 ± 7.45 bpm). It should be noted that HR and SBP were measured at rest the day before the running test, which may explain why blood pressure was associated with shooting performance before the effort, but not after it.

Significant physiological adjustments are required to control the stress response during the time elapsed between the end of the running task and the post-physical effort shooting. Thompson et al.[2] verified that heart rate recovery (i.e., the difference between HR at the end of the physical effort and HR at the moment of the first shot; HRR) is significantly related to shooting performance and is even associated with cognitive control. Ortega et al.[28] also verified that HRR predicts shooting performance since the heartbeat intervals are longer by lowering the heart rate, and shooters have a larger window to shoot. They also suggested that at the beginner level, this longer interval may impact effectiveness, but over time the shooters adjust the speed of their shot, performing it more efficiently before ventricular systole. As the participants in the present study had at least six years of experience, this may have been a factor that justified the non-correlation of shooting performance with HR, even after exercise.

Shooting performance after physical exertion was not correlated to SBP, resting HR, and maximum HR achieved during the running task. Although it was observed that the participants reached a high $\%HR_{max}$ during physical exertion, this did not influence their performance when shooting immediately afterward. Similarly, Brown et al.[3] also did not find in HR a predictor of shooting performance before or after physical exertion. HRR can also provide relevant information about the control of the autonomic nervous system[29]. In this regard, shooters who recover faster (i.e., a greater decrease in HR after exercise) would present better shooting performance. Unfortunately, HRR was not evaluated in this study, and future studies should consider this variable in their assessment.

Cardiorespiratory fitness (VO_{2peak}) objectively measured was not correlated with shooting performance at rest or after the physical effort. At rest, a higher VO_{2peak} could be associated with greater parasympathetic cardiac autonomic control and could have reduced heart-related tremors after exertion[30]. Moreover, higher VO_{2peak} results in a lower physiological disturbance during the physical effort[31], resulting in easier shooting stabilization afterward. However, this association was not confirmed. On the other hand, we verified a strong negative correlation between VO_{2peak} and the time to complete the running task, indicating that more fit police officers ran faster than their less-fit peers. Dias et al.[9] showed that physical exertion would cause a reduction in shooting efficiency and suggested physiological alterations as the main reasons for that. The differences in results could be attributed to the type of gun used because while the current study used an air pistol, Dias et al.[9] used an air rifle, which has more contact points with the body due to its size/length, making it more susceptible to the influence of body sway and tremor. This may indicate that the influence of physiological stress caused by physical effort on shooting performance depends on the type of weapon used.

Limitations and future directions

A potential study limitation is that police officers performed the running task in light clothing and running shoes, excluding the impact of carrying their usual equipment. In real-world scenarios, carrying a gun, bulletproof vests, and other gear may affect physical performance, induce muscle fatigue, and alter physiological distress levels. Additionally, the use of a compressed air pistol, due to its size, weight, and lack of recoil, may have influenced the absence of correlations between study variables and shooting performance. Unlike long-barreled weapons, pistols require stable upper limb

positioning, and the absence of recoil minimizes body/aiming adjustments.

Future studies should consider participants' experience duration in the specific activity and how the HRR may correlate with tremor reduction and improved post-exertion shooting results. Factors such as using realistic recoil-producing weapons during running tasks might influence the results. Also, other physiological variables should be included, such as heart rate variability, since the autonomic system might be important to shooting performance. Also, this study's sample size is very small, limiting the generalization of the results. Lastly, firearm decision-making involves complex task control and requires good executive function performance, including attention, emotional control, and the ability to ignore irrelevant. Research is needed to explore not only physical characteristics and correlations but also cognitive abilities.

CONCLUSION

The results of the present study suggest that age and SBP may be negatively related to resting shooting performance in police officers. It was also found that the other variables studied did not correlate with shooting performance. However, the physical fitness of the sample may have been a factor to be considered for not observing these correlations. In this way, good physical conditioning may have influenced shooting performance, which impacts police preparation, given the importance of acting on all factors that minimize damage when using firearms and increase their effective use.

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CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

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Originales

ARE RELATIVELY OLDER SOCCER PLAYERS MORE FREQUENT AND VALUABLE THAN THEIR RELATIVELY YOUNGER PEERS? A STUDY OF THE MAJOR AMERICAN LEAGUES

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ABSTRACT

Aim: The purpose was to analyze the Relative Age Effect (RAE) on players' representativeness in Top American soccer leagues, and analyze the RAE on players' market value in the above-mentioned leagues.
Methods: The date of birth and perceived market value from 3494 male elite soccer athletes who participated in the 2022 season of the Argentinian (Superliga), Brazilian (Série A), Colombian (Liga Dimayor I), Mexican (Liga MX), and US American (MLS) soccer leagues were collected. The occurrence of the RAE among players was assessed in each of the leagues through a comparison of the incidence of athletes born in each quarter and the frequency expected for each quarter.
Results: The examinations of the players' birth quarters revealed a disparity in birth distribution across all leagues when compared to the expected values.
Conclusion: Results also indicated that market values did not differ based on the players' quarter of birth in Argentina, Brazil, Colombia, Mexico and USA.

Keywords: Relative age effect; Sports performance; Sports management; Sports development.

¿SON LOS FUTBOLISTAS RELATIVAMENTE MAYORES MÁS FRECUENTES Y VALIOSOS QUE SUS PARES RELATIVAMENTE MÁS JÓVENES? UN ESTUDIO DE LAS PRINCIPALES LIGAS AMERICANAS

RESUMEN

Objetivo: El objetivo fue analizar el Efecto de la Edad Relativa (EER) sobre la representatividad de los jugadores en las principales ligas americanas de fútbol, y analizar el EER sobre el valor de mercado de los jugadores en estas ligas.
Métodos: La fecha de nacimiento y el valor de mercado percibido de 3494 deportistas masculinos de fútbol de élite que participaron en la temporada 2022 de las ligas Argentina (Superliga), Brasileña (Série A), Colombiana (Liga Dimayor I), Mexicana (Liga MX) y estadounidense

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(MLS) de fútbol. Se evaluó la aparición del EER entre los jugadores de cada una de las ligas mediante la comparación de la incidencia de deportistas nacidos en cada trimestre y la frecuencia esperada para cada trimestre.
Resultados: La evaluación de los cuartos de nacimiento de los jugadores revelaron una disparidad en la distribución de los nacimientos en todas las ligas en comparación con los valores esperados.
Conclusión: Los resultados también indicaron que los valores de Mercado no diferían según el trimestre de nacimiento de los jugadores en Argentina, Brasil, Colombia, México y Estados Unidos.

Palabras clave: Efecto de la Edad Relativa; Rendimiento Deportivo; Gestión deportiva; Desarrollo deportivo.

JOGADORES DE FUTEBOL RELATIVAMENTE MAIS VELHOS SÃO MAIS FREQUENTES E VALIOSOS DO QUE SEUS COLEGAS RELATIVAMENTE MAIS JOVENS? UM ESTUDO DAS PRINCIPAIS LIGAS AMERICANAS

RESUMO

Objetivo: O objetivo foi analisar o Efeito da Idade Relativa (EIR) na representatividade dos jogadores nas principais ligas de futebol dos Estados Unidos e analisar o EIR no valor de mercado dos jogadores nessas ligas.
Métodos: Foram coletadas a data de nascimento e o valor de mercado percebido de 3.494 atletas de futebol masculino de elite que participaram da temporada de 2022 das ligas de futebol da Argentina (Superliga), Brasil (Série A), Colômbia (Liga Dimayor I), México (Liga MX) e Estados Unidos (MLS). A ocorrência do EIR entre os jogadores foi avaliada em cada uma das ligas por meio de uma comparação da incidência de atletas nascidos em cada trimestre e a frequência esperada para cada trimestre.
Resultados: As análises dos trimestres de nascimento dos jogadores revelaram uma disparidade na distribuição dos nascimentos em todas as ligas quando comparadas aos valores esperados.
Conclusão: Os resultados também indicaram que os valores de mercado não diferiram com base no trimestre de nascimento dos jogadores na Argentina, Brasil, Colômbia, México e EUA.

Palavras-chave: Efeito da idade relativa; Desempenho esportivo; Gestão esportiva; Desenvolvimento esportivo.

INTRODUCTION

Youth athletes are usually organized into annual age groups using specific cut-off dates[1]. Grouping by age could lead to a bias in the selection of athletes since being relatively older is more likely to provide a performance and selection advantage when assessed or evaluated (by coaches) against annual age-group peers[1]. In other words, those born earlier in the year are more likely to be bigger, stronger, and more physically mature than those born later in the same year[2,3]. As a result, they are often identified as better athletes and receive more attention and opportunities to develop their skills. This phenomenon is called the relative age effect (RAE) and refers to the tendency for individuals who are born early in a selection year (usually the first few months) to have an advantage over those born later in the same year, in certain areas such as sports. This effect has been observed in many different sports, including soccer[4-6], ice hockey[7], basketball[8], tennis[9,10], and athletics[11].

The RAE is closely related to biological maturation, as children who are born earlier in the selection year are often more physically mature than those born later in the same year. This can give them a performance advantage in sports and other competitive activities, as they are stronger, faster, and more coordinated than their less-mature peers[1]. They may also be more likely to be identified as talented athletes and receive opportunities for training and development[12]. Studies have found that RAE is present in soccer at both the amateur and professional levels[13,14]. For instance, a study revealed that amongst the 100 most valuable soccer players 60% were born in the first half of the year[15]. Also, a big sample comprising 202.951 players competing in Brazilian soccer showed that RAE is present and influenced the players' selection[4]. In fact, this has been found to be true across many different soccer leagues and countries, including the English Premier League, Spanish La Liga, and Italian Serie A.

With a particular emphasis on the Americas, a study testing 1.344 male and female youth soccer players found that while male players showed a strong relative age effect, there was only a marginal effect for female players, suggesting gender differences in the effect may be due to a complex interaction of biological, maturational, and socialization factors[16]. In a South American country (Argentina) it was found a significant correlation between the player's relative age and their likelihood of becoming a professional player, but this effect disappears when professional players are compared with one another, highlighting the potential biases in institutional policies[17]. In a competition that implies different American countries (under-10 Libertadores CUP), it was found significant differences in birth quartiles and playing positions, indicating a tendency towards selecting players born in the early months of the year[18].

Some studies have been trying to include different countries aiming to analyze the RAE effect on soccer across different cultures. One of the examples was performed in ten European countries[13]. The results showed that the RAE has remained consistent, with no change observed over the 10-year period in the ten countries[13]. However, as far as we may know, no study included different American competitions in an RAE study, which may offer an opportunity to confirm if RAE effects are present among different contexts and may also help to provide some information to identify possible strategies to adjust to these contexts. Moreover, the prevalence of studies focusing on the influence on market values is reduced, and, as far as we know, absent in the Americas, thus research focusing on that can also bring some value to the overall discussion on the topic.

Thus, the purpose of this study was to: (i) analyze the RAE effect on players' representativeness in Argentinian (Superliga), Brazilian (Série A), Colombian (Liga Dimayor I), Mexican (Liga MX), and US American (MLS) soccer leagues; and (ii) analyze the RAE effect on players' market value on the above-mentioned leagues.

Table 1. Number of teams, players, players' average age, and total estimated market values for selected soccer leagues.

	Argentina	Brazil	Colombia	Mexico	USA
Nº of teams	28	20	20	18	29
Nº of players	703	838	593	472	888
Market value (T€)	512.039	584.979	216.734	446.074	523.450

Note *T€ – thousands of euros.*

METHODS

Participants

Data from 3494 male elite soccer athletes who participated in the 2022 season of the Argentinian (Superliga), Brazilian (Série A), Colombian (Liga Dimayor I), Mexican (Liga MX), and US American (MLS) soccer leagues were collected. These leagues represent the five most valuable soccer leagues in the American continent in terms of players' market values. General information on the selected leagues is available in Table 1.

Data collection and procedures

The complete names of players, along with their dates of birth and assessed market values, were acquired as publicly available information from the "Transfermarkt" database (www.transfermarkt.com.br), similar to previous studies[19,20]. Data was collected on January 10th 2023, which was one day before the transfer window opened. The selection of this particular date aimed to mitigate fluctuations in market values, as it was presumed that values had stabilized by this juncture. Athletes with incomplete information were excluded from the research. Whenever an athlete appeared in more than one roster in the same country, duplicate data was removed and only the higher market value was considered for analyses. All data used in this study were reported anonymously.

The examined variables comprised the estimated market values of players (in thousands of euros) and the birth quarters of the players: Q1 (from January to March); Q2 (from April to June); Q3 (from July to September); and Q4 (from October to December).

All data was collected from public documents available online, so this research does not require an ethics committee's approval.

Statistical analysis

The absolute values were used to display the occurrences of players' birth quarters. To evaluate the RAE among players in each league, an analysis was conducted by contrasting the incidence of athletes born in each quarter with the expected frequency for each respective quarter. The frequencies of players' quarters of birth were presented in absolute values. Given the relevant presence of foreign players in each league (over 10% in all cases), it was not recommendable to base our analyses on specific population births databases. Therefore, we followed the indications by Edgar and O'Donoghue[10], considering the days encompassed within each quarter, we adopted the subsequent anticipated birth distribution for each quarter: Q1 = 24.71%, Q2 = 24.91%, Q3 = 25.19% and Q4 = 25.19%.

Chi-square tests (χ^2) were employed to compare the distribution of athletes' birthdates within each of the scrutinized leagues. The effect size (w) for the chi-square tests was computed for all analyses, adhering to Cohen's[21] guidelines. According to this author's framework, 0.1 denoted a small effect, 0.3 a medium effect, and 0.5 a large effect. The significance level was established at 0.05, except in instances where multiple comparisons between quarters were requisite, leading to the implementation of Bonferroni's corrections. In such cases, the significance level was adjusted to 0.0083.

The data concerning estimated market values underwent scrutiny for normality, and both the Kolmogorov-Smirnov test and quantile-quantile plots indicated a deviation from normal distribution. Consequently, the comparison of players' market values across the quarters of the year in each league employed the Kruskal-Wallis test. The effect size (η^2) for the Kruskal-Wallis tests was computed for all analyses, with 0.01 indicating a small effect, 0.06 denoting a moderate effect, and 0.14 representing a large effect, according to Cohen's[21] criteria. The significance level was established at 0.05. The Statistical Package for the Social Sciences (SPSS), version 20.0 (Chicago, USA), was utilized for all analyses.

RESULTS

Relative Age Effects

The analyses of the players' quarters of birth indicated that the distribution of births was different from expected for all of the leagues analyzed (Figure 1).

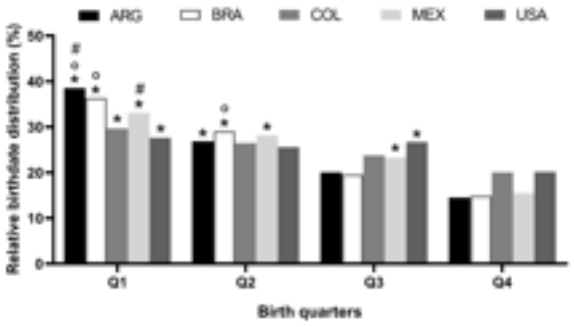

Figure 1. Analyses of the players' quarters of birth for all of the leagues analyzed.

In the case of the Argentinian league [χ^2 = 94.778; p < 0.001; w = 0.367], post hoc analyses indicated a higher frequency of players born in Q1 [p < 0.001] and Q2 [p < 0.001] compared to those born in Q4. Furthermore, players born in Q1 exhibited a higher frequency compared to those born in Q2 [p < 0.001] and Q3 [p < 0.001]. In the case of the Brazilian league [χ^2 = 97.886; p < 0.001; w = 0.342], post hoc analyses revealed a higher frequency of players born in Q1 and Q2 compared to those born in Q3 [p < 0.001] and Q4 [p < 0.001]. In the case of the Colombian league [χ^2 = 13.157; p = 0.004; w = 0.149], post hoc analyses indicated that players born in Q1 [p < 0.001] were more frequent than players born in Q4. In the case of the Mexican league [χ^2 = 33.695; p < 0.001; w = 0.267], post hoc analyses indicated that players born in Q1 [p < 0.001], Q2 [p < 0.001], and Q3 [p = 0.008] were more frequent than players born in Q4 and that players born in Q1 [p = 0.006] were more frequent than players born in Q3. Finally, in the case of the US American league [χ^2 = 12.853; p = 0.005; w = 0.12], post

hoc analyses indicated that players born in Q1 [p = 0.002] and Q3 [p = 0.006] were more frequent than players born in Q4.

Market Value Analysis

The comparison of players' market values was conducted considering birth quarters for each of the leagues (Figure 2). Findings suggested that there were no variations in market values based on the players' birth quarters in Argentina [H(3) = 2.507; p = 0.474; η^2 = -0.001], Brazil [H(3) 0.517; p = 0.915; η^2 = -0.006], Colombia [H(3) = 2.125; p = 0.547; η^2 = -0.002], Mexico [H(3) = 5.236; p = 0.155; η^2 = 0.005], and United States of America [H(3) = 3.983; p = 0.263; η^2 = 0.002].

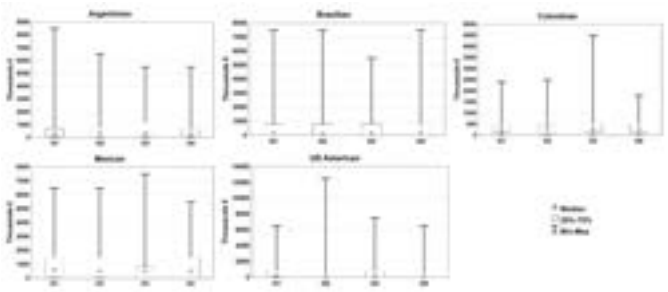

Figure 2. Comparison of players' market values considering birth quarters for each of the leagues.

DISCUSSION

The present study aimed two-fold: (i) analyze the RAE effect on players' representativeness in Argentinian (Superliga), Brazilian (Série A), Colombian (Liga Dimayor I), Mexican (Liga MX), and US American (MLS) soccer leagues, and (ii) analyze the RAE effect on players' market value on the above-mentioned leagues. Our findings showed that birth date was preponderant in participation in the major American leagues, corroborating the literature. In fact, the present study is in line with previous research developed in the top five European soccer leagues: La Liga (Spain), Premier League (England), Serie A (Italy), Bundesliga (Germany), and Ligue 1 (France), where the RAE was also noticed[5,13]. Nevertheless, being born earlier did not influence the market value of those soccer players.

The present study clearly showed a higher frequency of soccer players born in the first months of the year at high levels in the major American leagues. In fact, all leagues presented differences between the number of players born in the first months of the year and the last quartile. For instance, in the Argentinian league, it is clear that being born in Q1 increases the probability of reaching the highest levels of this league since Q1 was statistically different from the other quartiles. Within the Brazilian league, there was a higher prevalence of athletes born in Q1 and Q2 compared to those born in Q3 and Q4. This suggests that athletes born before July are more prone to achieve the professional level in this league. In Colombia, the influence of RAE seems to be softer, with more differences between extremes (Q1 and Q4). In the Mexican and US leagues, although there was also a higher frequency of players from Q1 compared to Q4, players from Q2 and Q3 are also overrepresented, indicating a more even distribution of birthdates compared to the other leagues analyzed. These results are in line with previous investigations that reported the RAE phenomenon in soccer[4,14,18], especially in male players[17]. Indeed, soccer is a competitive sport with a high number of practitioners and a well-developed youth competition system[5,18]. This suggests that maturation plays an important role in the selection of the most suitable athletes to play in youth categories, affecting the chances of reaching elite tiers. In other words, relatively older players usually benefit from demonstrating better results in physical fitness and anthropometric characteristics, compared to their relatively younger peers[4,20], favoring the prevalence of such a deep RAE that it may persist along the athletes' developmental pathway up to the senior categories in some cases[19].

Recently, the idea of implementing bio-banding has emerged to overcome RAE[3]. It refers to the grouping of players based on their maturation, i.e. grouping youth athletes within a chronological age range (between 11 to 15 years), into 'bands' or groups based on characteristic(s) other than chronological age for specific competitions and training[3]. This strategy is potentially useful for both identifying and developing talent, as athletes will be grouped based on the same "biological advantages". This strategy eliminates the impact of maturation-related variability by creating a suitable environment and challenges, equalizing competition, increasing the chances of success, avoiding injury due to mismatches in size, customizing training, and fostering talent development[3]. Nevertheless, it has been also highlighted that a process of education should be conducted on coaches, teachers, and all agents who make decisions in youth sports[15].

Although maturation is indicated as one of the main triggers for developing RAE[11,17], that phenomenon seems to persist in senior teams, where maturation is not expected to play a major role[1]. However, it has been shown that the RAE likelihood decreases in these contexts compared to younger categories[1]. One explanation could be related to the overload in adolescent years because of greater demands, leading to withdrawal from competitive levels of participation preceding or during their senior years due to injury, overtraining, burnout, or boredom[1]. This could be the reason why a relationship between RAE and market value has not been observed in the present study. Moreover, after reaching senior professional soccer categories, the market value of players is primarily determined by their sports performance, which is not expected to be influenced by maturational aspects at this point, leading to a leveling out of values among relatively younger and older players. As a result, market value is no longer influenced by age or birth month/semester[19]. The majority of the studies on this topic did not find that relationship[20], as in the present study. Nevertheless, it seems relevant to point out that the discrepancy in the players' market value seems to be very high, as represented in Figure 2, and the average of the values could be "hiding" this effect. Among this study's limitations is the fact that was only considered the market value of athletes based on a single season, only with male athletes, as well as players from only the top leagues. Considering that the RAE is modulated by individual, environmental, and task constraints[22], is likely that the level of competitiveness has an impact on this effect, potentially yielding different results when considering other levels of competition. Future investigations should focus on longitudinal analysis, as well as female categories, and other levels of competition.

CONCLUSION

In summary, the results of the study showed that the distribution of births was different from expected for all of the leagues analyzed, with a predominance of athletes born in the first months of the year, suggesting the existence of RAE in the top American soccer leagues. This finding confirms that relatively older players are more likely to achieve high levels of competition than relatively younger ones.

Conversely, the findings suggested that there were no disparities in market values associated with the players' quarter of birth, irrespective of the leagues under examination. Since the market value of players is primarily determined by their sports performance, this finding reinforces the notion that, in elite senior soccer categories, the athlete's month of birth does not affect performance indicators. Coaches, stakeholders, and other professionals involved in the sport in the American top soccer leagues must be aware of the RAE phenomenon, considering that it affects the development and selection processes for elite male soccer players. Evidence indicates

that choices made based on physical characteristics or performance indicators without considering the differences related to age and maturational stages in youth categories will have an impact that lasts to the senior categories, leading to a loss of potential talents.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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Originales

ASSOCIATIONS BETWEEN PHYSICAL ACTIVITY, SPORTS PARTICIPATION AND WELL-BEING IN ADOLESCENTS FROM LOW-DENSITY COMMUNITIES

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ABSTRACT

INTRODUCTION: Regular physical activity (PA) and sports participation in youth are usually associated with improved physical and psychological health. However, this evidence is scarce among adolescents living in low-density communities. Therefore, this study aimed to investigate the associations between PA, organized sports participation and well-being in adolescents living in low-density areas of the Portuguese midlands.

METHODS: The sample comprised 245 adolescents (114 girls), aged between 12 and 17 years (*M*= 14.20, *SD*= 1.09), recruited from public schools located in low-density communities. Participants completed self-report measures of sociodemographic data, moderate-to-vigorous physical activity (MVPA) levels (PACE+), sports participation, and well-being (MHC-SF and the physical well-being subscale of the KIDSCREEN-27). A tri-axial accelerometer was used to assess intensity levels of PA during week and weekend days separately. ANCOVAs and partial correlations were used controlling for potential confounders.

RESULTS: After controlling for sex, chronological age and school's context, findings indicated that adolescents meeting the MVPA guidelines reported higher levels of social and psychological well-being. In addition, physical well-being was positively associated with team sport participation, volume of sports training, self-reported MVPA levels (on weekdays and at the weekend) and MVPA assessed by accelerometry on weekdays. Sports participation revealed no significant effect on emotional, social and psychological well-being dimensions.

CONCLUSIONS: The findings revealed small to moderate effects of MVPA and sports participation on physical well-being. Conversely, the adolescents' social and psychological well-being was positively associated only with higher levels of self-reported MVPA.

Keywords: Physical activity; youth sports; well-being; adolescence.

ASOCIACIONES ENTRE ACTIVIDAD FÍSICA, PARTICIPACIÓN DEPORTIVA Y BIENESTAR EN ADOLESCENTES DE COMUNIDADES DE BAJA DENSIDAD POBLACIONAL

RESUMEN

INTRODUCCIÓN: La actividad física (AF) regular y la participación deportiva en la juventud suelen asociarse a una mejora de la salud física y psicológica. Sin embargo, esta evidencia es escasa entre los adolescentes que viven en comunidades de baja densidad. Por lo tanto, este estudio tuvo como objetivo investigar las asociaciones entre AF, participación en deportes organizados y bienestar en adolescentes que viven en áreas de baja densidad de la región central de Portugal.

MÉTODO: La muestra comprendió 245 adolescentes (114 chicas), con edades comprendidas entre los 12 y los 17 años (M= 14,20, SD= 1,09), reclutados en escuelas públicas situadas en comunidades de baja densidad. Los participantes completaron medidas de autoinforme sobre datos sociodemográficos, niveles de actividad física moderada a vigorosa (AFMV) (PACE+), participación en deportes y bienestar (MHC-SF y

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la subescala de bienestar físico del KIDSCREEN-27). Se utilizó un acelerómetro triaxial para evaluar los niveles de intensidad de AF durante los días laborables y los fines de semana por separado. Se utilizaron ANCOVA y correlaciones parciales para controlar los posibles factores de confusión.

RESULTADOS: Después de controlar el sexo, la edad cronológica y el contexto de la escuela, los resultados indicaron que los adolescentes que cumplían las directrices de AFMV informaron niveles más altos de bienestar social y psicológico. Además, el bienestar físico se asoció positivamente con la participación en deportes de equipo, el volumen de entrenamiento deportivo, los niveles de AFMV auto informados (en días laborables y durante el fin de semana) y la AFMV evaluada objetivamente en días laborables. La participación deportiva no reveló ningún efecto significativo sobre las dimensiones de bienestar emocional, social y psicológico.

CONCLUSIONES: Los resultados revelaron efectos entre pequeños y moderados de la AFMV y la participación en deportes sobre el bienestar físico. Por el contrario, el bienestar social y psicológico de los adolescentes se asoció positivamente sólo con niveles más altos de AFMV autodeclarada.

Palabras clave: Actividad física; deportes juveniles; bienestar; adolescencia.

ASSOCIAÇÕES ENTRE ATIVIDADE FÍSICA, PARTICIPAÇÃO DESPORTIVA E BEM-ESTAR EM ADOLESCENTES DE COMUNIDADES DE BAIXA DENSIDADE POPULACIONAL

RESUMO

INTRODUÇÃO: A atividade física (AF) regular e a participação desportiva na juventude estão geralmente associadas a uma melhor saúde física e psicológica. No entanto, esta evidência é escassa entre os adolescentes que vivem em comunidades de baixa densidade populacional. Assim, este estudo teve como objetivo investigar as associações entre AF, participação em desportos organizados e bem-estar em adolescentes que vivem em zonas de baixa densidade populacional do centro de Portugal.

MÉTODO: A amostra foi constituída por 245 adolescentes (114 raparigas), com idades compreendidas entre os 12 e os 17 anos (M= 14,20, DP= 1,09), recrutados em escolas públicas localizadas em comunidades de baixa densidade populacional. Os participantes completaram medidas de autorrelato de dados sociodemográficos, níveis de atividade física moderada a vigorosa (AFMV) (PACE+), participação desportiva e bem-estar (MHC-SF e a subescala de bem-estar físico do KIDSCREEN-27). Foi utilizado um acelerómetro triaxial para avaliar os níveis de intensidade da AF durante os dias de semana e de fim de semana, separadamente. Foram utilizadas ANCOVAs e correlações parciais para controlar o efeito de variáveis sociodemográficas.

RESULTADOS: Após controlar o efeito das variável sexo, idade cronológica e contexto escolar, os resultados indicaram que os adolescentes que cumpriam as recomendações relativas à AFMV reportaram níveis mais elevados de bem-estar social e psicológico. Além disso, verificaram-se associações positivos entre bem-estar físico, a participação em desportos coletivos, o volume de treino desportivo, os níveis autorreportados de AFMV (durante a semana e ao fim de semana) e a AFMV avaliada por acelerometria durante a semana. A participação desportiva não revelou efeitos significativos nas dimensões de bem-estar emocional, social e psicológico.

CONCLUSÕES: Os resultados revelaram efeitos pequenos a moderados da AFMV e da participação desportiva no bem-estar físico. Por outro lado, os níveis de bem-estar social e psicológico dos adolescentes associaram-se positivamente com os níveis de AFMV autorreportada.

Palavras-chave: Atividade física; desporto juvenil; bem-estar; adolescência.

1. INTRODUCTION

Physical activity (PA) is commonly defined as a multidimensional concept which includes a wide range of movements within its different dimensions, such as recreational activities, active commuting, school activities, and organized sports. This last dimension has long been acknowledged as an essential element of both physical health and social development. In fact, participation in organized sports promotes increasing physical fitness levels, particularly its cardiorespiratory component,[1] and concomitantly develops crucial life skills such as teamwork, respect for others, and social interaction/integration, among others.[2,3] Among the several advantages associated with organized sports, one of the most remarkable, yet under-studied, is its effect on different dimensions of mental well-being (emotional, social and psychological), particularly in adolescents residing in suburban and/or low-density communities.

Recent research indicates that the well-being and mental health of adolescents are considerably influenced by their engagement in organized sports, with benefits extending beyond physical health. Indeed, youth who participate in organized sports often exhibit higher levels of self-esteem, reduced levels of anxiety, and fewer depressive symptoms.[4–7] On the other hand, the sports activities available in the geographic settings where youth are living, as well as the specific nature of these activities, tend to have a crucial impact on their school activities, and familial and community satisfaction in their daily life.[8,9] For example, the social interactions inherent in individual and team sports training and competition foster a sense of belonging and community, which are essential components of positive mental health. Developing pleasant activities with teammates can provide emotional support and positively contribute to an individual's mental state.[4,10] Previous research has also shown that adolescents who regularly engage in organized sports tend to perceive their satisfaction with life more favorably than those who do not participate in such activities.[6]

The literature commonly reports that participation in team sports compared to non-sport participation is associated with 10% lower anxious/depressed scores, 19% lower withdrawn/depressed scores, 17% lower social problems scores, 17% lower thought problems scores, and 12% lower attention problems scores.[10] In addition, this same study conducted with a broadly representative sample of 11,235 US children and adolescents aged 9 to 13 years, revealed that team sport participation was associated with fewer mental health difficulties, whereas individual sport participation was associated with greater mental health difficulties compared

with team sport. Other research had already indicated that child and adolescent participation in team sports appeared to be associated with improved psychosocial health compared to individual activities.[4,7,9] In general, engagement in sports can enhance the mental well-being of adolescents by providing valuable opportunities to develop social connections and friendships, contributing to a sense of belonging within the sporting environment. The aforementioned relationships have been influenced not only by the analytical approaches used in previous studies, but also by the geographic communities and the socioeconomic features where data are collected.

Encouraging greater involvement in sports among children and adolescents is also a goal outlined in the Healthy People 2030 physical activity objectives.[11] However, in some countries, the existing pay-to-play structure of the youth sports system has created significant barriers to participation, disproportionately affecting adolescents from minority backgrounds or from different neighborhood environments. Indeed, youth from families with higher income levels have significantly higher levels of participation in organized activities.[12] In addition, youth from rural or suburban settings may have less access to structured forms of PA and sports participation due to higher unavailability or distance to sports facilities and infrastructures, less pedestrian infrastructures for walking and cycling, and more transportation barriers.[13–15] Research evidence suggests that children and adolescents of less densely populated communities are less likely to participate in organized sports, especially in more diverse activities, than their urban counterparts,[16] whereas other studies have found no significant association between youth's PA and neighborhood characteristics.[17] Therefore, there is a need for more comprehensive studies to investigate these influences in suburban and low-density communities, as these settings may present unique challenges and opportunities for well-being and mental health promotion in young people.[15]

Furthermore, a lack of comprehension also exists regarding the impact of certain moderating factors on youth participation in sports and how these elements interact to affect the well-being of adolescents.[18] As society continues to recognize the importance of active lifestyles for maintaining health across all age groups, particularly at earlier stages of life, understanding these associations becomes increasingly important for public health initiatives aimed at encouraging greater involvement of youth in organized sports activities. Therefore, the present study aimed to investigate the associations between PA, organized sports participation, and the perception of well-being in a sample of adolescents living in suburban and low-density communities, controlling for potential confounders (i.e., sex, age and schools' geographic context). It was hypothesised that: i) adolescents involved in organized sports would be more physically active; and ii) more physically active adolescents and sports participants would report higher levels of well-being.

2. METHODS

2.1. *Participants and study design*

Participants were recruited under the scope of the project PMBH-2024 "Portuguese Midlands Behavioral Health", which aims to assess the behavioral lifestyle and health markers of Portuguese youth, and their association with pediatric obesity. The sampling design for this cross-sectional study, conducted in 2024, is similar to previous scientific projects.[19] The current study sample included 245 adolescents (114 girls and 131 boys), aged between 12 and 17 years (M= 14.20; SD= 1.09), recruited from two public schools located in Coimbra (n= 101) and Viseu (n= 144) districts. These schools were located in non-urban, low-density communities, classified as areas of residence with fewer than 500 inhabitants/km^2 or less than 50,000 inhabitants.[20] For the accelerometer analysis, data were collected from a subsample of 78 adolescents. However, nine of these youths (11.5%) failed to provide adequate accelerometry data (≥ 10 hours of registered time on the measured days). Therefore, the final accelerometer subsample included 69 adolescents (34 girls and 35 boys) with a mean age of 13.86 years (SD= 0.96).

This study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Institutional Ethics Committee (CE/FCDEF-UC/00092024) and the Portuguese Directorate-General for Education (Study Registration No 1472300001/MIME) before data collection. Additionally, approval was provided by the head of each school, and informed written consent was obtained from parents or guardians.

2.2. *Instruments*

2.2.1. *Physical activity*

The PA assessment included a multi-method approach, utilizing a self-report questionnaire and accelerometry, which objectively measured the adolescents' activity for 7 consecutive days using a w*GT3X-BT Actigraph* accelerometer (ActiGraph LLC, Pensacola, FL, USA).

Self-report instruments

The PA levels were assessed through the PACE+ two-item questionnaire.[21] Adolescents reported the number of days they were physically active at a moderate to vigorous intensity level, in the last week and a typical week. An average value of the two items represented the number of days per week that adolescents accumulated 60 or more minutes of moderate to vigorous physical activity. Compliance with MVPA recommendations was determined by creating a binary variable for those adolescents who met (≥ 5 days) or not (< 5 days) the physical activity guidelines for health.[22] In this study, a moderate correlation was observed between the PACE+ score and the MVPA levels measured through accelerometery (r= 0.36, p< 0.01). Adolescents were also asked to indicate their average time (in minutes) spent in moderate to vigorous physical activity, during a typical weekday and a weekend day.

wGT3X-BT Actigraph accelerometer

Adolescents were instructed to use the tri-axial accelerometer over the hip with an elastic belt above the right anterior superior iliac spine. The filtered acceleration signal was digitized, and the magnitude was summed over a user-specified period (an epoch interval), set at 5 seconds, as in other studies of children, which has been shown to be more accurate for the assessment of the spontaneous and intermittent activities of young people. Accelerometer data were electronically downloaded using ActiLife 6 software. Non-wear time was defined as periods of at least 20 consecutive minutes of zero counts. After removing sequences of 20 or more consecutive zero counts, interruptions up to 2 minutes were allowed. Days in which participants did not complete a minimum of 600 minutes of accelerometer data were excluded from subsequent analyses. Data processing and inclusion criteria were the same as in a previous study.[1] For pediatric individuals, accelerometer output was interpreted using intensity-based cut-points, which categorizes activity counts as sedentary, light, moderate, or vigorous PA. In this study, only light and MVPA levels were considered and analyzed.

Table 1. Descriptive statistics for the self-reported and accelerometer-measured physical activity levels, for the total sample and separately for boys and girls

Variables	Total sample *M* ± *SD*	Boys *M* ± *SD*	Girls *M* ± *SD*
Self-report			
MVPA levels (days/week)	3.48 ± 1.69	4.08 ± 1.68	2.79 ± 1.42
MVPA on weekdays (min/day)	94.72 ± 100.22	110.57 ± 106.09	76.33 ± 89.94
MVPA on weekend days (min/day)	67.81 ± 77.68	85.49 ± 91.29	47.09 ± 50.90
Accelerometry			
Light PA on weekdays (min/day)	166.96 ± 44.80	174.46 ± 45.71	159.25 ± 43.15
Light PA on weekend days (min/day)	144.56 ± 48.37	154.77 ± 46.32	134.05 ± 48.38
MVPA on weekdays (min/day)	54.09 ± 23.14	59.67 ± 26.20	48.36 ± 18.15
MVPA on weekend days (min/day)	42.24 ± 26.98	45.37 ± 28.14	39.02 ± 25.75

Table 2. Descriptive statistics for the well-being dimensions, according to the MVPA compliance.

Variables	Meeting the MVPA guidelines *M* ± *SD*	Not meeting the MVPA guidelines *M* ± *SD*
Emotional well-being (MHC-SF)	12.03 ± 2.33	11.03 ± 3.02
Social well-being (MHC-SF)	16.33 ± 5.43	13.25 ± 5.69
Psychological well-being (MHC-SF)	21.50 ± 5.03	18.24 ± 6.27
Total well-being (MHC-SF)	49.61 ± 11.49	42.70 ± 13.31
Physical well-being (KIDSCREEN)	20.42 ± 3.12	16.72 ± 3.84

2.2.2.

Sports participation

Adolescents responded to three questions that measured organized sports participation (yes or no), type of sport (individual or team) and volume of practice (number of training hours per week).

2.2.3.

Mental well-being

A validated Portuguese version of the Mental Health Continuum-Short Form (MHC-SF) was used to assess adolescents' well-being.[23] The MHC-SF includes 14 items that measure emotional (3 items), social (5 items), and psychological well-being (6 items). A total score of well-being was computed by summing all 14 items. These items were rated on a six-point Likert scale, ranging from 0 (never) to 5 (every day), depending on the frequency of well-being symptoms in the last month. The scores for each dimension were calculated by summing all items in each dimension. Omega reliability values indicated good internal consistency for all dimensions, namely, emotional well-being (ω= 0.83), social well-being (ω= 0.84), psychological well-being (ω= 0.81) and total well-being (ω= 0.92).

Physical well-being was measured using the Portuguese version of the KIDSCREEN-27 questionnaire.[24] This dimension includes five items rated on a five-point Likert scale, summed to provide a total score. Higher scores indicate better physical well-being. Internal consistency analysis revealed good reliability (ω= 0.87).

2.3.

Statistical Analyses

The data set was initially inspected for input errors or outliers. Descriptive statistics included means, standard deviations (SD), frequencies and percentages (%). The subscales' internal consistency (reliability) was estimated using McDonald's omega coefficients.

The chi-square test was employed to compare proportions between variables. The analysis of covariance (ANCOVA) was used to examine the differences between groups (sex, MVPA compliance and sports participation) on physical activity and well-being levels, while controlling for certain factors (sex, chronological age and school of origin). Estimates of effect size (partial eta squared: η^2) were used to interpret the magnitude of the differences between groups, according to the following cutoffs: small (η^2 > 0.01), medium (η^2 > 0.06) or large (η^2 > 0.14). Pearson's correlations were used to examine the relationships between sports, MVPA and well-being variables.

McDonald's omega coefficients were calculated using JASP software (JASP Team 2024, version 0.19). The remaining analyses were conducted using IBM SPSS Statistics for Windows, version 27 (IBM Corp., Armonk, NY, USA). The level of statistical significance was set at 5%.

3.

RESULTS

Table 1 presents the mean and *SD* for self-reported and accelerometer-measured physical activity levels for the total sample, as well as separately for boys and girls. The accelerometer subsample included 69 adolescents (34 girls and 35 boys).

ANCOVA analysis, controlling for chronological age and schools' context, indicated that boys reported significantly higher MVPA levels (p< 0.001, η^2= 0.15) than girls, as well as MVPA on weekdays (p= 0.009, η^2= 0.03) and MVPA at the weekend (p< 0.001, η^2= 0.06). Additionally, results showed that boys were more active than girls (p< 0.023, η^2= 0.08), in terms of MVPA during weekdays. No other significant differences were observed between boys and girls for the remaining physical activity categories.

About 32% of the adolescents of the present study (62 boys and 16 girls) achieved the minimum recommended MVPA guidelines ≥ 5 days per week. The descriptive statistics (means and *SD*) for the well-being dimensions according to compliance (or not) with the MVPA recommendations are presented in Table 2.

ANCOVA analysis, controlling for sex, chronological age and schools, indicated that MVPA compliance had significant small to

Table 3. Descriptive statistics for sports participation variables, for the total sample and separately for boys and girls.

Variables	Total sample	Boys	Girls
Sports participation			
Yes (%)	89 (36.3%)	55 (42.0%)	34 (29.8%)
No (%)	156 (63.7%)	76 (58.0%)	80 (70.2%)
Type of sports			
Team (%)	62 (69.7%)	40 (72.7%)	22 (64.7%)
Individual (%)	27 (30.3%)	15 (27.3%)	12 (35.3%)
Weekly volume of practice (min)	286.85 ± 152.46	272.00 ± 135.05	310.88 ± 176.56

Note Continuous values presented as mean ± SD and frequency data in percentage values

Table 4. Descriptive statistics for the self-reported and accelerometer-measured physical activity levels, according to the types of sports participation.

Variables	Participation in team sports *M* ± *SD*	Participation in individual sports *M* ± *SD*	Non-sport participation *M* ± *SD*
Self-report			
MVPA levels (days/week)	4.37 ± 1.36	4.06 ± 1.46	3.02 ± 1.68
MVPA on weekdays (min/day)	136.08 ± 108.22	112.59 ± 112.16	74.81 ± 88.98
MVPA on weekend days (min/day)	91.13 ± 75.02	65.44 ± 50.55	58.71 ± 81.06
Accelerometry			
Light PA on weekdays (min/day)	162.61 ± 46.39	175.69 ± 48.55	166.76 ± 44.29
Light PA on weekend days (min/day)	160.06 ± 54.15	128.62 ± 44.01	142.19 ± 46.56
MVPA on weekdays (min/day)	46.79 ± 24.05	67.73 ± 29.74	53.96 ± 20.54
MVPA on weekend days (min/day)	49.85 ± 38.03	33.63 ± 25.17	41.23 ± 22.15

moderate effects on social (p= 0.006, η^2= 0.03), psychological (p= 0.005, η^2= 0.03), total (p= 0.012, η^2= 0.03) and physical well-being (p< 0.001, η^2= 0.11), with more physically active adolescents reporting higher levels in these well-being dimensions.

Regarding sports participation, about 36% of the sample (89 adolescents) reported being engaged in organized sports (62 in team sports and 27 in individual sports). The descriptive statistics (frequencies, means and *SD*) of the sports participation variables for the total sample and separately for boys and girls are presented in Table 3.

Chi-square analysis indicated that significantly more boys than girls reported involvement in organized sports participation ($\chi^2_{(1)}$= 3.90, p= 0.048). However, no significant differences were observed for the different types of sports (p= 0.424) and the weekly volume of practice (p= 0.259), when compared by sex.

The mean scores (and *SD*) of the self-reported and accelerometer-measured PA levels are presented in Table 4, according to the types of organized sports participation. Of note, the accelerometer subsample included 69 adolescents (44 non-sport, 16 team, and 9 individual participants).

ANCOVA analysis, controlling for sex, chronological age and schools, indicated that the sports participation variable had large to moderate effects on MVPA levels (p< 0.001, η^2= 0.12) and MVPA during weekdays (p< 0.001, η^2= 0.06). Bonferroni pairwise comparisons showed that team sport participants reported significantly higher MVPA levels (p< 0.001) and MVPA during weekdays (p< 0.001) than their non-sport participant counterparts, who reported lower levels of MVPA during weekdays than their individual sport participation peers (p= 0.006). No other significant differences were observed between sports and non-sports participants for the remaining physical activity categories.

Table 5 presents the descriptive statistics (means and *SD*) for the well-being dimensions according to the different types of sports.

After controlling for sex, chronological age and schools, results indicated that the sports participation variable had a significant moderate effect on physical well-being (p< 0.001, η^2= 0.06). Specifically, Bonferroni pairwise comparisons showed that team sport participants reported significantly higher levels of physical well-being (p< 0.001) than non-sport participants. No other significant effects were observed on well-being dimensions.

Table 6 presents the partial correlation coefficients between sports/physical activity levels and the well-being dimensions, controlling for sex, chronological age and schools.

Findings revealed that the physical well-being dimension was positively associated with all self-reported sports/physical activity levels and with MVPA during the weekdays, as measured by accelerometry. Moreover, self-reported MVPA levels were also positively associated with the social, psychological and total well-being dimensions, although the correlation coefficients were somewhat smaller.

4.

DISCUSSION

Despite the health benefits of PA and sports participation during adolescence, there is limited evidence about these associations and effects in adolescents living in suburban and low-density communities, which may restrict access and opportunities for some types of spontaneous PA and organized sports. The main findings of

Table 5. Descriptive statistics for the well-being dimensions, according to the types of sports participation.

Variables	Participation in team sports *M* ± *SD*	Participation in individual sports *M* ± *SD*	Non-sport participation *M* ± *SD*
Emotional well-being (MHC-SF)	11.66 ± 2.50	11.30 ± 2.55	11.23 ± 3.03
Social well-being (MHC-SF)	15.40 ± 5.60	14.82 ± 4.81	13.68 ± 5.95
Psychological well-being (MHC-SF)	19.60 ± 6.00	19.48 ± 5.34	19.14 ± 6.27
Total well-being (MHC-SF)	46.81 ± 12.74	45.59 ± 11.10	44.05 ± 13.61
Physical well-being (KIDSCREEN)	19.74 ± 3.41	18.59 ± 3.63	17.05 ± 4.05

Table 6. Correlation coefficients between sports/physical activity levels and well-being dimensions.

Variables	EWB	SWB	PWB	TWB	PhWB
Self-report					
Weekly volume of SP (min)	0.01	0.10	0.01	0.05	0.31**
MVPA levels (days/week)	0.11	0.19**	0.20**	0.20**	0.41**
MVPA on weekdays (min)	0.10	0.17*	0.11	0.15*	0.23**
MVPA on weekend days (min)	0.09	0.16*	0.17*	0.17*	0.19**
Accelerometry					
Light PA on weekdays (min)	0.03	0.16	−0.01	0.09	0.19
Light PA on weekend days (min)	0.08	0.04	−0.13	−0.02	0.06
MVPA on weekdays (min)	0.00	0.15	0.18	0.13	0.29*
MVPA on weekend days (min)	0.14	0.05	0.02	0.08	0.22

Note SP = Sports participation; EWB = emotional well-being, SWB = social well-being, PWB = psychological well-being, TWB = total well-being and PhWB = physical well-being.

* $p < 0.05$

** $p < 0.01$

this study showed that self-reported MVPA and sports participation were positively associated with some well-being dimensions, particularly with physical well-being. Moreover, physical well-being was also positively associated with MVPA levels during weekdays, as measured by accelerometry. These results add to the growing evidence on the effects of MVPA and sports participation on well-being,[4,7,9,15] by providing context-specific findings for adolescents residing in suburban and low-density communities.

Regarding the influence of PA on well-being, the results of the present study suggest that compliance with MVPA recommendations during adolescence contributes to better physical and psychosocial well-being, which is in line with previous studies.[4–6] Notably, both self-reported and accelerometer-measured MVPA showed the most substantial effects on physical well-being, which translates into a better general state of physical health and fitness. This evidence supports previous research findings based on self-report,[25] accelerometer data,[26] or both,[27] suggesting that the direct positive outcomes from PA are primarily achieved through better physical fitness and health perceptions, rather than on emotional or psychosocial outcomes. This finding is particularly significant in this sample of adolescents, as youth populations living in suburban and low-density communities are known to face more emotional and mental health difficulties[28] and they have less availability of sports facilities and accessibility to parks, sidewalks, recreational facilities, and organized sport,[13–16] although this evidence is somewhat not consensual.[29] Previous studies have also suggested the need for a more in-depth understanding and identification of potential mediators and moderators of the relationship between PA and mental health,[30,31] which may vary according to different social and neighborhood contexts.[32] Therefore, future studies are needed to examine the complex interplay between urbanization, urbanicity and socioeconomic status on physical activity and sports participation in youth, and consequently, its effects on distinct dimensions of well-being.

A finding of particular interest of this study was that team sports participation only had a moderate effect on adolescents' levels of physical well-being, compared to non-sport participants. On one hand, previous research has suggested that the effects of youth sports and PA on well-being and mental health dimensions are better explained by physical or body-related mediating factors, such as body image satisfaction, physical health, or physical self-worth,[6,31] which lead to more positive feedback and evaluation by peers and significant others, as well as lower social-appearance anxiety.[30] On the other hand, and contrary to previous research,[3,4,10] youth's participation in team (and individual) sports showed no positive association with social well-being. This suggests that the social opportunities, experiences and interactions perceived by these adolescents during sports activities are not fostering a sense of belonging, connection and community, as hypothesized. Therefore, more studies are also needed to further examine the associations between youth sports participation and psychosocial well-being, considering potential mediators (social support, social connections and sense of belonging) and moderators (urbanization, urbanicity and socioeconomic status) of this relationship.

The present study has several strengths and limitations that should be acknowledged. The major strengths of this study are

the multi-method approach used for PA assessment of adolescents and particularly the sociodemographic features of those participants who are from less studied geographic communities such as the low-density people areas of the Portuguese midlands. Second, the integrated examination of the potential factors of diverse nature (i.e. biological, behavioral, and emotional) and their different etiology related to youth sport participation should be clearly highlighted. Third, the analysis of the associations between the study variables, while controlling for sociodemographic variables (sex, chronological age and schools' context) related to PA, sports participation and well-being. One of the study's limitations is its cross-sectional design which restricts the ability to draw conclusions about causal relationships. Second, the moderate and unrepresentative sample size of this study, that may compromise the generalizability of the results to adolescents who practice sports; in fact, the external validity of a study is often affected by the size and diversity of the sample. Moreover, since adolescents come from suburban communities it is natural the concept of sport participants is somewhat reduced to the usual low diversity of activities available in those geographic settings.
5.

CONCLUSIONS

Findings of the present study revealed that adolescents who meet the MVPA recommendations reported higher levels of social and psychological well-being, after adjusting for sociodemographic variables. In addition, physical well-being was positively associated with team sport participation, volume of sports training, self-reported MVPA levels (on weekdays and at the weekend) and objectively measured MVPA on weekdays.

Specific strategies are needed to implement and promote diversity of available PA and sports opportunities for youth living in suburban and low-density communities, to avoid unhealthy lifestyles that may last into adulthood. Future scientific investigations ought to broaden the scope of their design to encompass larger samples of adolescents living in different neighborhood social and built environments, while continuing to use objective measures of PA to validate the findings of the current study.

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AUTHORSHIP

A.M. Machado-Rodrigues and H.M. Fernandes have given substantial contributions to the conception or the design of the manuscript; A.M. Machado-Rodrigues, F. Sobral, N. Borges and H.M. Fernandes have given substantial contributions to acquisition, analysis and interpretation of the data. All authors have participated in drafting the manuscript and revised it critically. All authors read and approved the final version of the manuscript.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

ETHICAL RESPONSABILITIES

Protection of individuals and animals: The authors declare that the conducted procedures met the ethical standards of the responsible committee on human experimentation of the World Medical Association and the Declaration of Helsinki.

Confidentiality: The authors are responsible for following the protocol established by their respective healthcare centres for accessing data from medical records for performing this type of publication in order to conduct research/dissemination for the community.

Privacy: The authors declare no patient data appear in this article.

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Metodológico

A EUROPEAN INITIATIVE PROMOTING A HEALTHY LIFESTYLE AMONG YOUNG PEOPLE AGED 10-17: THE ROCK YOUR HEALTH PROJECT (RYHEALTH)

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ABSTRACT

Background: The RYHEALTH project is a European initiative aimed at promoting a healthy lifestyle among young people aged 10-17.9 years. The project focuses on four key pillars: physical activity, nutrition, mental health, and sustainability, recognizing their interconnected impact on adolescent well-being.

Objective: The project aims to assess the lifestyle behaviors of European adolescents, examining the interrelationships between physical activity, nutrition and mental health. Additionally, the project seeks to develop a digital intervention platform (RYHEALTH HUB) to provide accessible, evidence-based resources for promoting healthy behaviors among youth, parents, and educators.

Methods: This cross-sectional study will collect data from adolescents in Germany, Portugal, Spain, and Sweden using the *RYHEALTH e-Questionnaire*, a validated, multilingual digital survey. The questionnaire assesses sociodemographic factors, physical activity, dietary patterns, and mental well-being. Statistical analyses will explore associations between lifestyle behaviors and key health indicators, adjusting for sociodemographic factors.

Expected Results: It is anticipated that a significant proportion of adolescents will not meet recommended guidelines for physical activity, diet, and mental well-being. Positive associations are expected between regular physical activity, Mediterranean diet adherence, and improved mental health outcomes. In contrast, sedentary behavior and poor dietary habits could correlate with increased stress, anxiety, and depressive symptoms. Additionally, exposure to nature is hypothesized to have protective effects on psychological well-being.

Conclusion: The findings will provide a comprehensive understanding of youth lifestyle behaviors across Europe, facilitating the development of evidence-based interventions. RYHEALTH HUB, an innovative digital platform, will serve as a resource to support adolescents, parents, and educators in adopting and maintaining healthy lifestyle habits.

Keywords: Physical Activity; Nutrition; Mental Health; Adolescents; Youth.

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UNA INICIATIVA EUROPEA PARA PROMOVER UN ESTILO DE VIDA SALUDABLE ENTRE JÓVENES DE 10 A 17 AÑOS: EL PROYECTO ROCK YOUR HEALTH (RYHEALTH)

RESUMEN

Antecedentes: El proyecto RYHEALTH es una iniciativa europea destinada a promover un estilo de vida saludable entre jóvenes de 10 a 17,9 años. El proyecto se centra en cuatro pilares clave: actividad física, nutrición, salud mental y sostenibilidad, reconociendo su impacto interconectado en el bienestar de los adolescentes.

Objetivo: El proyecto tiene como objetivo evaluar los comportamientos relacionados con el estilo de vida de los adolescentes europeos, examinando las interrelaciones entre la actividad física, la nutrición y la salud mental. Además, busca desarrollar una plataforma de intervención digital (RYHEALTH HUB) para proporcionar recursos accesibles y basados en evidencia que promuevan hábitos saludables entre los jóvenes, sus padres y educadores.

Métodos: Este estudio transversal recopilará datos de adolescentes en Alemania, Portugal, España y Suecia mediante el e-Cuestionario RYHEALTH, una encuesta digital validada y multilingüe. El cuestionario evalúa factores sociodemográficos, actividad física, patrones dietéticos y bienestar mental. Los análisis estadísticos explorarán las asociaciones entre los comportamientos de estilo de vida y los principales indicadores de salud, ajustando por factores sociodemográficos.

Resultados esperados: Se anticipa que una proporción significativa de adolescentes no cumplirá con las recomendaciones establecidas para la actividad física, la alimentación y el bienestar mental. Se esperan asociaciones positivas entre la práctica regular de actividad física, la adherencia a la dieta mediterránea y mejores resultados en salud mental. En contraste, el comportamiento sedentario y los hábitos alimentarios inadecuados podrían correlacionarse con un aumento del estrés, la ansiedad y los síntomas depresivos. Además, se plantea la hipótesis de que la exposición a la naturaleza tendrá efectos protectores sobre el bienestar psicológico.

Conclusión: Los hallazgos proporcionarán una comprensión integral de los comportamientos de estilo de vida juvenil en Europa, facilitando el desarrollo de intervenciones basadas en evidencia. RYHEALTH HUB, una innovadora plataforma digital, servirá como un recurso para apoyar a adolescentes, padres y educadores en la adopción y mantenimiento de hábitos de vida saludables.

Palabras clave: Actividad Física; Nutrición; Salud Mental; Adolescentes; Jóvenes.

UMA INICIATIVA EUROPEIA PARA PROMOVER UM ESTILO DE VIDA SAUDÁVEL ENTRE JOVENS DE 10 A 17 ANOS: O PROJETO ROCK YOUR HEALTH (RYHEALTH)

RESUMO

Antecedentes: O projeto RYHEALTH é uma iniciativa europeia destinada a promover um estilo de vida saudável entre jovens de 10 a 17,9 anos. O projeto foca em quatro pilares fundamentais: atividade física, nutrição, saúde mental e sustentabilidade, reconhecendo seu impacto interconectado no bem-estar dos adolescentes.

Objetivo: O projeto tem como objetivo avaliar os comportamentos relacionados ao estilo de vida dos adolescentes europeus, examinando as inter-relações entre atividade física, nutrição e saúde mental. Além disso, busca desenvolver uma plataforma de intervenção digital (RYHEALTH HUB) para fornecer recursos acessíveis e baseados em evidências que promovam hábitos saudáveis entre os jovens, seus pais e educadores.

Métodos: Este estudo transversal coletará dados de adolescentes na Alemanha, Portugal, Espanha e Suécia por meio do e-Questionário RYHEALTH, uma pesquisa digital validada e multilíngue. O questionário avalia fatores sociodemográficos, atividade física, padrões alimentares e bem-estar mental. As análises estatísticas explorarão as associações entre comportamentos de estilo de vida e principais indicadores de saúde, ajustando-se para fatores sociodemográficos.

Resultados esperados: Espera-se que uma proporção significativa de adolescentes não cumpra as recomendações estabelecidas para atividade física, alimentação e bem-estar mental. São esperadas associações positivas entre a prática regular de atividade física, a adesão à dieta mediterrânea e melhores resultados em saúde mental. Em contraste, o comportamento sedentário e hábitos alimentares inadequados podem estar correlacionados com aumento do estresse, ansiedade e sintomas depressivos. Além disso, levanta-se a hipótese de que a exposição à natureza terá efeitos protetores sobre o bem-estar psicológico.

Conclusão: Os resultados fornecerão uma compreensão abrangente dos comportamentos de estilo de vida dos jovens na Europa, facilitando o desenvolvimento de intervenções baseadas em evidências. O RYHEALTH HUB, uma plataforma digital inovadora, servirá como um recurso para apoiar adolescentes, pais e educadores na adoção e manutenção de hábitos de vida saudáveis.

Palavras-chave: Atividade Física; Nutrição; Saúde Mental; Adolescentes; Jovens.

INTRODUCTION

Physical activity, mental health, and nutrition are critical components of overall health and well-being, particularly in children and adolescents. The World Health Organization (WHO) emphasizes the importance of these three factors in promoting good health and preventing chronic diseases later in life[1]. However, despite the well-established benefits of physical activity, healthy eating, and positive mental health, many children and adolescents fail to meet recommended guidelines in these areas[2].

Regular physical activity helps children and adolescents develop strong bones, muscles, and cardiovascular systems, improves overall physical health, and reduces the risk of chronic diseases such as obesity, diabetes, and heart disease[3,4]. In addition to its physical benefits, physical activity has been linked to better mental health

outcomes, including reduced symptoms of depression and anxiety, improved self-esteem, and enhanced academic performance[5,6].

Healthy eating habits are also essential for promoting overall health and well-being in children and adolescents. Proper nutrition supports body and brain development and can reduce the risk of chronic diseases later in life[7]. However, many children and adolescents consume diets high in unhealthy fats, sugars, and processed foods while lacking nutrient-rich foods such as fruits, vegetables, and whole grains[8].

Mental health is equally important for overall well-being. Poor mental health can negatively affect physical health, academic performance, and social relationships[9]. Mental health issues, such as anxiety and depression, are common among children and adolescents and can be exacerbated by factors such as stress, lack of physical activity, and poor nutrition[10,11].

In summary, physical activity, healthy eating, and positive mental health are crucial for the overall health and well-being of children and adolescents. Encouraging these behaviours early in life can provide long-term benefits for physical and mental health and help reduce the risk of chronic diseases later in life.

Therefore, the primary objectives of this project are to characterize youth lifestyle behaviours and analyze the interactions among healthy and unhealthy lifestyle factors. As a secondary objective, the project aims to develop and provide a comprehensive suite of digital tools for young people, parents, and teachers to facilitate easier access to a healthy lifestyle.

METHODS

Participants and selection criteria

The present cross-sectional project involves study research conducted in the partner countries participating in the RYHEALTH project consortium (https://ryhealth.net/), namely Spain, Portugal, Germany, and Sweden. RYHEALTH aims to increase the impact of European actions for health promotion and disease prevention, focusing on health-enhancing physical activity, a healthy environment, healthy eating, and mental health and well-being among young individuals.

Eligible participants are youth from European countries. Inclusion criteria include: i) being between 10 and 17.9 years old, ii) having parental or guardian consent to participate in the questionnaire, and iii) having sufficient comprehension of one of the available languages for the questionnaire (i.e., German, Spanish, Portuguese, Swedish, or English). Participants who do not meet these criteria will be excluded from the study.

Data Collection

To gain insight into the lifestyles of children and adolescents and their perspectives on health-related behaviors, the RYHEALTH consortium has established four fundamental pillars, which correspond to subprojects: *The Happiness Project*, *The Activity Project*, and *The Food Project*. These pillars guide the measurements, focusing on three evaluation blocks: i) sociodemographic aspects, ii) mental health, and iii) lifestyle behaviors. Participants will complete a multidisciplinary, digital, and online questionnaire called the "RYHEALTH e-Questionnaire" (https://hub.ryhealth.net/survey). The questionnaire has been developed in English and subsequently translated into German, Spanish, Portuguese, and Swedish. It will be available online through the RYHEALTH platform. To engage the target group and collect data anonymously, the RYHEALTH consortium employs various strategies. These include dissemination through the social media channels of the project and its partners, outreach to traditional media outlets, and direct contact with educational centers to promote participation among students. Additionally, project staff distribute the questionnaire directly at RYHEALTH and externally organized events.

Outcomes measures

The RYHEALTH e-Questionnaire includes participants' history along with validated questionnaires focusing on the main 4 subprojects of a healthy lifestyle promoted by the project. Therefore, the final RYHEALTH e-Questionnaire consists of 4 sections; the first includes questions on anthropometric, sociodemographic information, and relevant covariates such as socioeconomic level. The remaining 3 sections are based on behavioral and lifestyle factors related to 3 RYHEALTH subprojects:

Section 1: RYHEALTH-specific section

This section comprises information on sociodemographic aspects, socioeconomic status, as well as self-reported anthropometric information such as height and weight. Precisely, The Family Affluence Scale (FAS)[12] will measure the socioeconomic level of families. The FAS consists of four items that ask about the family's material possessions and experiences, such as owning a car, having their own bedroom, going on vacations, and the number of computers. The children are asked to indicate whether each item applies to their family. The responses are then combined to create a composite score that provides an estimate of the family's level of material affluence. The FAS has shown a high internal consistency, good test-retest reliability, and validity.

Section 2: Mental health – The happiness project

Stress will be evaluated by The Perceived Stress Scale (PeSS)[13], a widely used questionnaire designed to measure the degree to which individuals perceive their lives as stressful. The PeSS consists of 10 items, each asking about feelings and thoughts related to stress in the past month. Participants rate each item on a 5-point scale ranging from 0 (never) to 4 (very often). Examples of items on the PeSS include "In the last month, how often have you felt that you were unable to control the important things in your life?" and "In the last month, how often have you felt nervous and 'stressed'?". The PeSS has been used to assess stress in a wide range of populations, including college students, medical patients, and community samples. It has also been translated into many languages and has been used in cross-cultural research. The PeSS has shown a high internal consistency, good test-retest reliability, and validity.

Health-related quality of life (HRQoL) will be assessed by the KIDSCREEN-27[14], a self-reported questionnaire applied in children and adolescents aged 8-18 years old. The KIDSCREEN-27 consists of 27 items that are grouped into five dimensions: physical well-being, psychological well-being, autonomy and parent relations, social support and peers, and school environment. Each item is scored on a 5-point Likert scale. The KIDSCREEN-27 has shown high internal consistency, good test-retest reliability, and validity.

Section 3. Lifestyle behaviours – The activity and food projects

In this section, physical activity, self-reported physical fitness, sedentary behaviour, sleep, eating behaviour and adherence to the Mediterranean diet will be assessed by using the following questionnaires, respectively.

The International Physical Activity Questionnaire (IPAQ) for Children and Adolescents[15] is a questionnaire designed to assess physical activity levels in young people aged 5-17 years. The IPAQ for Children and Adolescents consists of seven items that ask about the amount of time spent doing different types of physical activity, such as walking, running, cycling, and playing sports, over the past

seven days. Participants are asked to indicate the frequency, duration, and intensity of each type of physical activity they engaged in during the past week. The IPAQ has shown a high internal consistency, good test-retest reliability, and validity.

The International Fitness Scale (IFIS)[16] is a self-reported questionnaire designed to measure physical fitness (cardiorespiratory fitness, muscular strength, speed-agility, and flexibility) in children and adolescents. The IFIS consists of 5 items asking about how the participant thinks that is his/her physical fitness level compared to their friends. Each item is scored on a 5-point Likert scale. The IFIS has shown good test-retest reliability and validity.

The Youth Leisure-time Sedentary Behavior Questionnaire (YLSBQ)[17] is a self-report questionnaire designed to assess sedentary behavior in children and adolescents aged 10-18 years. The YLSBQ consists of 12 items that ask about the amount of time spent engaged in different sedentary behaviors, such as watching TV, playing video games, and using the computer, during leisure time on a typical weekday and weekend day. Participants will be asked to indicate the amount of time they spend engaged in each activity in hours and minutes. The YLSBQ has shown a high internal consistency, good test-retest reliability, and validity.

Sleep quantity will be measured by asking the wake-up and fall asleep either for weekdays and weekends. In addition, we will measure sleep quality by the Epworth Sleepiness Scale (ESS) for children and adolescents[18] is a self-report questionnaire designed to assess daytime sleepiness in children and adolescents aged 6-18 years. The ESS for children and adolescents consists of eight items that ask about the likelihood of falling asleep during different activities, such as sitting and reading, watching TV, and sitting and riding in a car, on a scale of 0-3. The ESS has shown a high internal consistency, good test-retest reliability, and validity.

The 21-item Three-Factor Eating Questionnaire (TFEQ-R21)[19] is a self-report questionnaire designed to assess three factors related to eating behavior: cognitive restraint, disinhibition, and hunger. The TFEQ-R21 is a modified version of the original TFEQ, which consisted of 51 items. The TFEQ-R21 consists of 21 items that ask about various aspects of eating behavior, such as how often the participant thinks about food, how much they enjoy eating, and how often they eat when feeling anxious or stressed. The TFEQ-R21 has shown a high internal consistency, good test-retest reliability, and validity.

The KIDMED questionnaire[20] is a tool that was developed to assess the quality of the Mediterranean diet in children and adolescents aged 2-24 years old. The KIDMED questionnaire consists of 16 items that assess various aspects of the Mediterranean diet, such as the consumption of fruits, vegetables, fish, nuts, and olive oil, as well as the intake of foods that are high in sugar and saturated fat. Each item is assigned a score of +1 or -1 based on the “yes” or “no” responses. The KIDMED has shown a high internal consistency, good test-retest reliability, and validity. The estimate duration will be 2 minutes.

Sample size

It is expected to obtain a minimum of 200 and up to 500 completed questionnaires from each of the four countries, which makes a total of expected responses ranging from 800 to 2,000. This estimation will provide a comprehensive understanding of children and adolescents that accurately reflects the general population and their characteristics. It will enable statistical analysis of cohorts, including potential sensitivity analyses based on factors such as age, gender, demographics, lifestyle behaviors, mental health outcomes, or any other unique group relevant to research interest.

Digital HUB for Youth

The RYHEALTH project aims to create and deliver a comprehensive set of digital tools for parents, teachers, and students to facilitate access to a healthy lifestyle and promote a network among them, called the "RYHEALTH HUB". This platform will host resources based on updated scientific evidence, adapted for easy understanding and applicability. It will include learning and empowerment tools in each of the four RYHEALTH subprojects: **Activity** (Physical Activity), **Food** (Healthy Eating), **Happiness** (Mental Well-being), and **Sustainability**.

The HUB will feature various tools such as podcasts, videos, infographics, interactive guides, online challenges, games on healthy lifestyles on interactive platforms, and resources for educational sessions, among others.

Ethical considerations

All participants will require parental or guardian consent, provided by confirming online, to allow the data collected in the questionnaire to be used for research purposes within the framework of the European RYHEALTH project. Parents or guardians will be informed that the data are completely anonymous, do not personally identify their children, and will only be used for the purposes established in the research project. They will also confirm their understanding that the questionnaire complies with the General Data Protection Regulation (GDPR) for the processing of personal data in the European Union, published on 17 April 2016, repealing the former Directive 95/46/EC.

Statistical analyses

Descriptive analyses will be performed for continuous and categorical variables. The mean, standard deviation, minimum, maximum and quartiles or percentages will be calculated for continuous and categorical variables, respectively. Covariates will be identified through examining associations between specific questions in each questionnaire and demographic or other variables. Multiple linear regression analyses will be used to examine the association of Linear regression models, logistic regression, and ANCOVA will be conducted to study the associations and interactions between the variables across different dimensions, with a particular focus on analyzing the relationship between healthy and unhealthy patterns and characteristics. All analyses will be performed using the STATA software for Windows version 14.0. The level of significance was set at $p<0.05$ in the statistical model.

EXPECTED RESULTS

The RYHEALTH project is expected to provide a comprehensive understanding of the lifestyle behaviors of European youth aged 10-17.9, offering valuable insights into the interconnections between physical activity, nutrition, mental well-being, and environmental factors.

First, we anticipate that a substantial proportion of participants will probably fail to meet the recommended guidelines for physical activity, dietary habits, and mental health, aligning with previous literature indicating low adherence to health-promoting behaviors in adolescents. Furthermore, significant differences may emerge based on sociodemographic factors such as age, gender, and socioeconomic status, providing an opportunity to identify high-risk subgroups requiring targeted interventions.

Regarding **physical activity**, we expect to observe an association between higher levels of engagement in structured and unstructured exercise with improved self-perceived fitness, better mental health outcomes, and/or lower sedentary time. Conversely, excessive screen time and sedentary behavior are likely to correlate

with poorer self-rated health, lower adherence to a balanced diet, and higher levels of stress and anxiety.

For **nutrition**, it is hypothesized that a considerable percentage of adolescents will demonstrate suboptimal adherence to a Mediterranean diet, with a higher prevalence of processed food consumption and low fruit and vegetable intake. This dietary pattern may be negatively associated with mental well-being indicators such as stress levels and self-reported health status.

In the **mental health domain**, we anticipate that higher engagement in physical activity, better sleep quality, and frequent exposure to nature will be protective factors against anxiety and depressive symptoms. Additionally, perceived stress is expected to be inversely correlated with quality of life and overall well-being, reinforcing the importance of integrated health promotion strategies.

Finally, the **RYHEALTH HUB**, the digital intervention platform, is expected to enhance accessibility to evidence-based health education resources for adolescents, parents, and educators, ultimately facilitating behavior change and long-term adherence to a healthier lifestyle. The project outcomes will contribute to developing innovative policies and interventions aimed at improving adolescent health across multiple European contexts.

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DISCLOSURE STATEMENT

The authors declare that they have no competing interests.

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Casos Clínicos

ENTRENAMIENTO ACENTUADO EXCÉNTRICO COMO PROCESO DE REHABILITACIÓN LUEGO DE CIRUGÍA DE LIGAMENTO CRUZADO ANTERIOR. UN ESTUDIO DE CASO

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RESUMEN

Objetivo: Determinar los efectos del entrenamiento acentuado excéntrico (EAE) como protocolo de rehabilitación en un paciente con doble intervención quirúrgica por ruptura de Ligamento Cruzado Anterior (LCA).

Método: Se llevó a cabo un programa de entrenamiento acentuado excéntrico (dos meses post operación) durante 10 semanas, de las cuales, la primera y la décima fueron de evaluaciones, las ocho restantes, protocolo de intervención. Este estudio de caso fue llevado a cabo con la participación de un hombre joven, físicamente activo (22 años; 184cm de altura; 93 kg de peso). Se aplicaron pruebas para determinar la profundidad de la sentadilla y el ángulo de flexión de la rodilla, capacidad de salto mediante el Broad Jump (BJ) y el Triple Hop Test (THT), así como, la escala Lysholm-Tegner para la funcionalidad de la rodilla.

Resultados: Hubo mejora en el BJ en un 10%, por su parte, se mostraron aumentos en el THT en un 36% (rodilla no operada) y 14% (rodilla operada). El índice de simetría mejoró un 26%, mientras que la flexión de rodilla incrementó un 8%. Por su parte, la escala Lysholm-Tegner mejoró 30 puntos luego de la intervención.

Conclusión: Luego de diez semanas de intervención se concluye que el entrenamiento de fuerza acentuado excéntrico es efectivo para la rehabilitación y funcionalidad de rodilla luego de cirugía de ligamento cruzado anterior.

Palabras clave: Entrenamiento acentuado excéntrico; Lesiones deportivas; Ligamento cruzado anterior; Rehabilitación.

ACCENTUATED ECCENTRIC TRAINING AS A PROCESS OF REHABILITATION AFTER ANTERIOR CRUCIATE LIGAMENT SURGERY. A CASE STUDY

ABSTRACT

Objective: Determine the effects of accentuated eccentric training (AET) as a protocol for rehabilitation in a patient with double surgical intervention for Anterior Cruciate Ligament (ACL).

Method: An accentuated eccentric training program was carried out for ten weeks, of which, the first and the last were of the evaluation, the remaining eight, of intervention protocol. This case study was carried out with the participation of a young, physically active man (22 years old; height 184cm; weight 93kg). Tests were applied to determine the depth of the squat and the angle of knee flexion, jumping capacity through the Broad Jump (BJ) and the Triple Hop Test (THT), as well as the Lysholm-Tegner scale for knee functionality.

Results: There was an improvement in the BJ by 10%, on the other hand, increases in the THT were shown by 36% (unoperated knee) and 14% (operated knee). The symmetry index improved by 26%, while knee flexion increased by 8%. For its part, the Lysholm-Tegner scale improved 30 points after the intervention.

Conclusion: After ten weeks of intervention, it is concluded that accentuated eccentric strength training is effective for rehabilitation and functionality of knee after cruciate ligament anterior surgery.

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Keywords: Accentuated eccentric training; Anterior cruciate ligament; Rehabilitation; Sports injuries.

TREINAMENTO EXCÊNTRICO ACENTUADO COMO PROCESSO DE REABILITAÇÃO APÓS CIRURGIA DO LIGAMENTO CRUZADO ANTERIOR. UM ESTUDO DE CASO

RESUMO

Objetivo: Determinar os efeitos do treinamento acentuado excêntrico acentuado (TAE) como protocolo de reabilitação em paciente com dupla cirurgia para ruptura do Ligamento Cruzado Anterior (LCA).

Método: Foi realizado um programa de treinamento excêntrico acentuado durante 10 semanas, sendo a primeira e a décima avaliações, as oito restantes foram protocolo de intervenção. Este estudo de caso foi realizado com a participação de um homem jovem, fisicamente ativo (22 anos; altura 184cm; peso 93kg). Foram aplicados testes para determinar a profundidade do agachamento e o ângulo de flexão do joelho, capacidade de salto através do Broad Jump (BJ) e do Triple Hop Test (THT), além da escala Lysholm-Tegner para funcionalidade do joelho.

Resultados: Houve uma melhora no JB de 10%, enquanto aumentos no THT foram mostrados em 36% (joelho não operado) e 14% (joelho operado). O índice de simetria melhorou 26%, enquanto a flexão do joelho aumentou 8%. Por sua vez, a escala Lysholm-Tegner melhorou 30 pontos após a intervenção.

Conclusão: Após dez semanas de intervenção, conclui-se que o treinamento de força excêntrico acentuado é eficaz para reabilitação e funcionalidade do joelho após cirurgia do ligamento cruzado anterior.

Palavras-chave: Treinamento acentuado excêntrico; lesões esportivas; ligamento cruzado anterior; Reabilitação.

INTRODUCCIÓN

Las lesiones de rodilla, particularmente las que afectan y comprometen al ligamento cruzado anterior (LCA) son de las que más predominancia presentan en el ámbito deportivo[1].

El LCA juega un papel importante en la estabilidad del complejo articular de la rodilla debido a su función anatómica, la cual, se encarga de evitar el desplazamiento anterior de la tibia, además, limita la rotación lateral y medial de la rótula[2].

Las lesiones por la ruptura del LCA son más comunes en adultos jóvenes, principalmente en aquellos que son atletas a nivel profesional, amateur o simplemente que realizan deporte de manera recreacional. El LCA está íntimamente relacionado con gestos de aceleración, desaceleración, cambios de dirección, saltos y aterrizajes, lo que lo hace más propenso a sufrir una lesión[2,3].

La distancia de los saltos, como el triple hop test es una variable fundamental para el proceso de rehabilitación y readaptación deportiva, esto debido a que permite conocer parámetros de funcionalidad del complejo articular de la rodilla, a nivel neuromuscular, de fuerza y potencia aplicada[4]. De la misma manera, las variables biomecánicas se deben atender en pacientes con lesión de LCA, ya que, se ha demostrado que los ángulos de movimiento de rodilla y cadera pueden verse afectados, y con ello, desviaciones en planos de movimiento sagital, frontal y transversal[5].

Otro factor importante, además de los descritos previamente es el déficit de fuerza que se presenta luego de una lesión de LCA. Este déficit se manifiesta hasta en un 30% menos producción de fuerza, y no solo eso, se ha encontrado una atrofia en la musculatura implicada hasta en un 20% lo que puede ser un indicador de la necesidad de un estímulo de sobrecarga para el desarrollo de la fuerza[6].

Debido a lo anterior, se han estudiado diversas metodologías como protocolo de rehabilitación en lesiones de tipo muscular y esquelético, entre esas, sobresale el entrenamiento excéntrico, ya que al estimular los componentes elásticos de la fibra muscular habrá un mayor daño muscular (Del inglés: Delayed Onset Muscle Soreness) y, con ello, se activa un proceso de proliferación de células satélite para comenzar la regeneración y recuperación de las fibras musculares. Además, el ejercicio de carácter excéntrico estimula la sobreexpresión proteínas integrinas, específicamente la α7BX2 que ofrece un efecto protector contra el daño muscular inducido por el ejercicio (EIMD por sus siglas en inglés: Exercise Induced Muscle Damage) y ante dolor muscular tardío[7].

Otra de las bondades del entrenamiento excéntrico es el bajo coste energético, por ello, es una metodología viable debido a que, la activación muscular es menor, lo que conlleva menos gasto energético, además, se obtienen mayores ganancias de fuerza a nivel muscular y tendinoso, lo que es fundamental en el proceso de rehabilitación[8]. Sumado a lo anterior, el tiempo de recuperación es un indicador que se atribuye a la capacidad funcional de la producción de fuerza, en ese sentido, el protocolo excéntrico ofrece efectos residuales en la producción de fuerza máxima hasta por seis meses post intervención[9], lo que favorece en el proceso de recuperación y, además, ayudar a prevenir la reincidencia en la lesión. Por su parte, el nivel de estímulo dado mediante el ejercicio de índole excéntrico en los ligamentos, tendones y músculos beneficia cuantitativamente y cualitativamente las propiedades morfológicas y funcionales en comparación a otras modalidades de entrenamiento de fuerza[10].

Diversas investigaciones[3,4,5,6,17,19] se han enfocado en aplicar un protocolo de intervención mediante el ejercicio excéntrico en pacientes con lesión de LCA como protocolo de rehabilitación y mejora de la funcionalidad del complejo articular de la rodilla. Sin embargo, para el conocimiento de los autores dichos estudios han estimulado la acción muscular excéntrica de manera aislada, y al parecer, este es el primer estudio que estimula las diferentes acciones musculares con énfasis en la fase excéntrica en paciente con intervención quirúrgica de LCA.

A su vez, los autores presentan una hipótesis en la que, el EAE es efectivo para mejorar la capacidad de salto, ángulo de profundidad y flexión, así como, la funcionalidad del complejo articular de la rodilla. Por ello, el objetivo del presente estudio es determinar los efectos del Entrenamiento Acentuado Excéntrico (EAE) como protocolo de rehabilitación en un paciente con doble intervención quirúrgica por ruptura de LCA.

MÉTODO

Participantes

Este estudio de caso fue llevado a cabo con la participación de un hombre joven, físicamente activo (22 años; 184cm de altura;

93 kg de peso). Con diagnóstico médico que hacía referencia a tres artroscopias de rodilla y dos intervenciones más, una por ruptura de LCA y la segunda por reincidencia en ruptura de LCA.

Se entregó el consentimiento informado al participante y se le explicó a detalle los beneficios y posibles riesgos del estudio. Además, se le manifestó que estaba en su derecho de abandonar la intervención cuando él quisiese. El estudio se llevó a cabo bajo los lineamientos de la declaración de Helsinki[11], además, de ser aprobado por la unidad de investigación de la FCCF UACH.

Diseño del estudio

La intervención fue un estudio de caso con diseño pre experimental de tipo *pre post*. La duración fue de 10 semanas, de las cuales la primera y la décima fueron de evaluaciones, mientras que, ocho de ellas fueron de intervención. Las evaluaciones fueron las mismas tanto en el *pre* como en el *post*, además, se mantuvieron las mismas condiciones de evaluación.

Evaluaciones

Análisis de la profundidad de sentadilla y ángulo de flexión de rodilla

Se dio la instrucción al participante de bajar lo más profundo posible en el ejercicio de sentadilla, después de ello, se realizó la medición del ángulo de flexión de la rodilla. Para ello, se utilizó un goniómetro, el cual se colocaba en la parte lateral de la rodilla y se marcaba la región que servía como punto de referencia. La medición se realizó tres veces, tomando en cuenta el máximo grado de flexión como valor de la prueba.

Determinación de la capacidad de salto y asimetría

Se determinó mediante la longitud máxima alcanzada mediante un salto horizontal de manera bilateral (BJ: *broad jump*, del inglés), así como, con la prueba del triple salto de manera unilateral (THT: *triple hop test*, por sus siglas en inglés).

El THT consiste en saltar tres veces con una sola pierna. Este se realiza con ambas piernas (lesionada LCA y no lesionada), y con ello, se determina el índice de asimetría y el déficit de fuerza de manera unilateral entre la pierna sana y la que presenta alguna lesión.

Para llevarse a cabo se le dio la indicación al participante de saltar lo más amplio posible en línea recta. Se le pidió que tratara de mantener la estabilidad en el último salto con el fin de realizar la medición desde el punto de inicio hasta el punto máximo que se alcanzó al finalizar el tercer y último salto.

Por su parte, el BJ consiste en realizar un salto de manera horizontal con ambas piernas. Para su realización se le indicó al participante que tenía que saltar lo más lejos posible y al final se le pidió que no se moviera para realizar la medición de la longitud, la cual se mide desde el punto de inicio (punta del pie) hasta el punto de máxima distancia (talón).

Se eligió la capacidad de salto horizontal, ya que, la distancia alcanzada por los saltos es un parámetro fundamental en los procesos de rehabilitación en pacientes con ruptura de LCA[4].

Evaluación de la escala Lysholm-Tegner

Se aplicó la escala al participante pidiéndole que la llenara, tanto en la etapa pre como en la post intervención. Esta escala es de las más utilizadas para la evaluación personal y cualitativa de pacientes que se han sometido a cirugía de LCA.

La escala presenta rangos de valoración que van desde malo (<65 puntos), regular (65-83 puntos) y bueno-muy bueno (84-100 puntos). Estos valores permiten conocer el progreso en actividades de la vida cotidiana, así como en disciplinas deportivas.

Plan de entrenamiento

Se llevó a cabo un plan de ejercicio con énfasis en la acción muscular excéntrica mediante sobrecarga (acentuando el tiempo bajo tensión en la fase excéntrica con dos segundos), con el objetivo de fortalecer las unidades musculares y tendinosas, así como el complejo articular de la rodilla. La duración del programa fue de ocho semanas con una frecuencia de tres sesiones por semana (Lunes-Miércoles-Viernes). Los ejercicios se realizaban por patrones de flexión y extensión, así como, dominante de rodilla y dominante de cadera, además, se realizaron ejercicios de carácter isométrico y de propiocepción para coadyuvar a la estabilidad rotuliana. De la misma manera, se trabajó de manera bilateral y unilateral.

Una parte fundamental fue lo que el primer autor de este estudio denomina “contraste de fases y acoplamiento neuromuscular”, en el cual, a pesar de hacer énfasis en la acción excéntrica, esta se estimulaba en conjunto con las acciones concéntricas e isométricas mediante diferentes estímulos, desde el tiempo bajo tensión hasta gestos más complejos como acelerar, desacelerar, cambiar de dirección e incluso pliometría en la fase final. Lo anterior, con el objetivo de mejorar los patrones de movimiento y estímulos funcionales del complejo articular rotuliano.

La distribución del trabajo (Figura 1) fue de la siguiente manera: semana 1 y 10 fueron para evaluar las variables pre y post intervención respectivamente. Posteriormente, la semana 2 y 3 se trabajó con un volumen de 3 series de 8 repeticiones con el 30% del peso corporal del participante; la semana 4 y 5 se aumentó el volumen de trabajo a 4 series de 10 repeticiones manteniendo el porcentaje de la carga; la semana 6 y 7 hubo un aumento en la carga de trabajo, 4 series de 10 repeticiones con el 50% del peso corporal. Finalmente, en la semana 8 se volvió a incrementar la carga al 70% con 4 series de 10 repeticiones, mientras que, la semana 9 se bajó la carga al volumen inicial, esto con el fin de tener un periodo de descarga y aprovechar el efecto potenciador de las semanas anteriores, lo que mejora los mecanismos de señalización muscular y neural, ya que, beneficia al complejo articular de la rodilla.

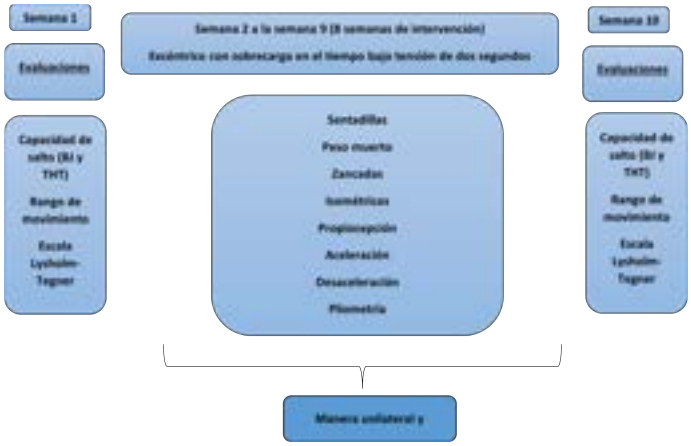

Figura 1. Esquema de las etapas de la intervención.

Análisis estadístico

Debido a que se trató de un estudio de caso el análisis estadístico no se llevó a cabo, en su lugar, se determinaron los resultados mediante la delta (diferencia) de cambio entre las evaluaciones *pre* y *post* intervención.

RESULTADOS

El objetivo del presente estudio fue determinar los efectos del entrenamiento acentuado excéntrico (EAE) como protocolo de rehabilitación en un paciente con doble intervención quirúrgica por

Tabla 1. Principales resultados del estudio.

Variables	Pre	Post	Diferencia
BJ (m)	1.57	1.72	↑ 10%
THTo (m)	2.38	3.25	↑ 36%
THTno (m)	3.97	4.56	↑ 14%
Índice simetría (%)	66	40	↑ 26%
AFR (°)	120	130	↑ 8%

BJ= *broad jump*, THTa= *triple hop test* rodilla operada, THTno= *triple hop test* rodilla no operada, AFR= ángulo de flexión de rodilla en sentadilla, ↑= aumento, %= porcentaje

ruptura de LCA. Luego de ocho semanas de intervención hubo mejora en el BJ en un 10%, por su parte, se mostraron aumentos en el THT en un 36% (rodilla no operada) y 14% (rodilla operada). El índice de simetría mejoró un 26%, mientras que la flexión de rodilla incrementó un 8%. Por su parte, la escala Lysholm-Tegner presentó mejoras en relación a su valor inicial el cual fue de 66 puntos lo que indica un resultado global regular, mientras que, después de la intervención fue de 96, valor que se sitúa en un resultado muy bueno. Los resultados se muestran en la Tabla 1.

DISCUSIÓN

Uno de los factores más importantes durante el proceso de rehabilitación es la capacidad de producir fuerza en el mínimo tiempo posible, esto debido a que, los procesos de estabilización a nivel articular y tendinoso, se llevan a cabo en lapsos de 50 a 100 milisegundos. A lo anterior se le denomina RFD (Rate of Force Development)[12]. Debido a ello, en este estudio se evaluó la capacidad de salto, tanto de manera bilateral como unilateral, ya que, la producción de fuerza no es igual en miembros pélvicos inferiores cuando se evalúan de manera agrupada que independiente, ya que, la sumatoria de fuerzas es mayor cuando se aplica de manera unilateral en comparación con los valores de manera bilateral[13]. Por ello, conocer los niveles de fuerza y potencia de manera unilateral ayuda a los procesos de rehabilitación, ya que, permite analizar los valores de simetría que se tienen que lograr antes de dar de alta al paciente.

El desarrollo de la fuerza se relaciona con los radios de producción de esta entre músculos agonistas y antagonistas, por ello, en esta intervención la planificación del entrenamiento se centraba tanto en ejercicios que estimularan la cadena anterior como posterior con el objetivo de fortalecer todo el complejo articular rotuliano lo que es fundamental en procesos de rehabilitación[2]. Este estudio, mejoró la distancia de salto lo que sugiere un aumento en el desarrollo de fuerza tanto en cuádriceps como en bíceps femoral, ya que son grupos musculares que se activan durante las fases de despegue y aterrizaje de los saltos, lo que está de acuerdo con los hallazgos de Ong et al.[14], quienes encontraron mejoras en los radios de fuerza en cuádriceps y bíceps femoral luego de 6 semanas de ejercicio excéntrico, lo que se relaciona con un mejor control motor y producción de fuerza aplicada en gestos como los saltos, no obstante, una diferencia entre el estudio de Ong et al.[14] y este estudio fue la metodología utilizada, ya que Ong et al.[14] llevaron a cabo su intervención con tecnología isocinética, mientras que en este estudio se aplicó el ejercicio excéntrico con el uso de pesos libres.

En esta investigación hubo mejoras en el nivel de simetría entre la rodilla afectada y la que no presentaba lesión, los valores aumentaron en un 26% luego de la intervención, estos resultados pueden deberse a las adaptaciones a nivel neuromuscular que se estimulan durante el entrenamiento excéntrico favoreciendo la recuperación de lesiones, ya que coadyuva en regenerar las propiedades mecánicas de los miembros afectados[15]. Además, el uso de pesos libres aplicando un protocolo excéntrico basado en el tiempo bajo tensión de la fase excéntrica beneficia el desarrollo de fuerza debido al reclutamiento de unidades motoras tipo IIx, además, la trasferencia a la potencia muscular será mayor, por ello, la mejora en la capacidad de salto se le puede atribuir, además, a las adaptaciones nerviosas que la sobrecarga excéntrica ejerce sobre la función muscular[16].

Por otro lado, una variable de suma importancia es la contribución del trabajo ejercido a nivel articular, ya que en los saltos se involucra el tobillo, la rodilla y cadera, lo que proporciona picos de fuerza aplicada de diferente manera, los cuales pueden variar en los resultados obtenidos en test de salto como el THT. Si bien, en este estudio hubo mejoras en el nivel de simetría, lo que concuerda con lo encontrado por Kotsifaki et al.[17], no se puede asegurar el trabajo articular realizado ya que, en nuestra intervención no utilizamos plataforma de salto ni análisis de video como en la investigación de Kotsifaki et al.[17].

De la misma manera, Milandri y Sivarasu[5] encontraron ganancias de fuerza en un 15.4% luego de un protocolo excéntrico en cicloergómetro isocinético, además, se evidenció un aumento en los ángulos de flexión de rodilla y cadera en un 2.1% para ambos, lo que concuerda con lo encontrado en esta investigación en la que el ángulo de flexión de rodilla mejoró un 8%. Sin embargo, el protocolo de Milandri y Sivarasu[5] por su naturaleza mantenía los ángulos de flexión de manera estable. Aun así, nuestro estudio superó el 3% de aumento en el ángulo de flexión lo que sobrepasa la diferencia mínima clínica importante y estipula los beneficios del entrenamiento con sobrecarga excéntrica de manera acentuada.

No obstante, las mejoras en la simetría pueden deberse al fortalecimiento de las unidades musculotendinosas. Harris-Love et al.[18] manifiestan que el ejercicio excéntrico tiene mejoras a nivel de patrones de movimiento de flexión y extensión de rodilla luego de dos semanas de familiarización, lo que está acorde con este estudio. En cambio, Harris-Love et al.[18] evidencian que lo anterior es en dispositivos isocinéticos, por lo que, la velocidad se mantiene constante, así como los rangos de movimiento, los cuales son más controlados y exactos en comparación al uso de pesos libres que se utilizaron en nuestra intervención. De la misma manera, los resultados coinciden con lo encontrado por Vidmar et al.[3] quienes muestran que el entrenamiento excéntrico es efectivo para recuperar los niveles de fuerza aplicada en lesiones de LCA. Sin embargo, al igual que Harris-Love et al.[18] el protocolo de Vidmar et al.[3] fue realizado en dispositivos isocinéticos a diferencia del presente estudio que se llevó a cabo con la utilización de pesos libres.

A pesar de que hubo mejoras en la simetría luego de esta intervención, se deben tomar en cuenta los vectores de fuerza aplicada en las pruebas realizadas. Si bien, el BJ y el THT son parámetros que demuestran el nivel de fuerza y la capacidad de producirla en el mínimo tiempo posible, algunos autores expresan que no solo se debe evaluar el vector horizontal, sino también el vector vertical como lo indica Kotsifaki et al.[19]. Esto se debe a que se han encontrado discrepancias entre el nivel de simetría cuando se evalúa mediante el SLDJ (*Single Leg Drop Jump*, del inglés) y el SLJ (*Single Leg Jump*, por sus siglas en inglés), en los cuales, se aplica un vector de fuerza vertical. En comparación al THT y el BJ que

evalúan el vector horizontal, dichas fluctuaciones en la simetría son de un 97% (THT), un 83% (SLJ) y un 77% (SLDJ) lo que indica que la biomecánica aplicada es otro factor importante al momento de dar de alta al paciente con lesión de LCA. Además, no hay criterios de unificación entre los valores obtenidos en los diversos tipos de saltos, por lo que, la elección de las pruebas será a discreción de los profesionales del deporte.

Los resultados obtenidos en esta investigación mostraron mejoras en la simetría en un 26%, además, hubo aumento en la distancia de los saltos, tanto bilateral como unilateral lo que indica que la intervención es efectiva para acercarse más al nivel de simetría deseado, sin embargo, se debe entender que, la rehabilitación del LCA no depende solo de las variables de salto, sino del nivel de fortalecimiento y la funcionalidad del control neural y muscular del individuo ya que el torque y fuerza producida no siempre tiene relación con la capacidad de salto[4].

Por último, los resultados pudieran ser relacionados a la producción de células satélite lo que estimula la regeneración muscular. Se ha evidenciado que, luego de una sesión de ejercicio excéntrico se dispara la formación de estas células hasta en un 141% luego de las primeras 24 horas post estimulo[20]. Sin embargo, no se puede asegurar, ya que este estudio no realizó biopsias o algún otro método de detección celular.

Los resultados de la presente investigación respaldan que, el entrenamiento y ejercicio de índole excéntrico es un protocolo viable para obtener mejoras en pacientes con cirugía de LCA en corto tiempo (8 semanas). Si bien la simetría es un parámetro fundamental para el proceso de rehabilitación o readaptación de lesiones, hay que tener en cuenta que, la funcionalidad se asocia con otras capacidades físicas como la fuerza máxima, potencia muscular, pliometría, rangos de movimiento, entre otras.

CONCLUSIÓN

Tras ocho semanas de intervención se concluye que el EAE es un protocolo eficaz para la mejora de la capacidad de salto, índice de simetría, ángulo de flexión de rodilla y profundidad de sentadilla, así como, en la funcionalidad de la rodilla. Coadyuvando en el proceso de rehabilitación física en paciente con doble intervención quirúrgica de LCA.

Sin embargo, para llegar a una conclusión más precisa es imperativo contrastar esta metodología con otros protocolos de entrenamiento y diversas herramientas tecnológicas para llevarse a cabo. A su vez, aumentar el número de pacientes para comprender y analizar más a detalle los efectos de este protocolo de ejercicio.

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