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Original

Anthropometric characteristics of male rink hockey goalkeeper's according to their competitive level

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ABSTRACT

Objective: Evaluate the anthropometric characteristics of male rink hockey goalkeepers, and to compare the variation according to their competitive level (international vs. non-international).
Methods: Body mass, stature, sitting height, arm span, waist and hip circumferences and four skinfold measurements (triceps, medial calf, subscapular and supraspinale) of international (n = 12) and non-international (n = 23) goalkeepers were taken. Body mass index (BMI, weight/height^2), the sum of four skinfolds, the sitting height/stature ratio, waist/hip ratio and the relative arm span were also calculated.
Results: International rink hockey goalkeepers have lower values of subcutaneous adiposity for the sum of the four skinfolds (P = 0.042; d = 0.76) particularly in the triceps (P = 0.016; d = 0.87) and are taller than non-international goalkeepers (+3.8 cm [2.2%]; 180.5 ± 7.0 vs. 176.6 ± 4.8 cm; t = 1.920; P = 0.064; d = 0.65).
Conclusion: The findings could indicate that stature and body fat may have important implications for scouts regarding the selection process and coaches that work with players on developing performance. Future research should investigate the extent to which different anthropometric measures influence performance in rink hockey goalkeepers.
Keywords: Anthropometry; Adiposity; Body Fat Distribution; Skinfold Thickness.

Características antropométricas de los porteros masculinos de hockey sobre patines

RESUMEN

Objetivo: Evaluar las características antropométricas de los porteros masculinos de hockey sobre patines y comparar las diferencias según su nivel competitivo (internacional vs. no internacional).
Métodos: Se midieron la masa corporal, altura, altura sentada, envergadura, circunferencia de cintura y cadera y cuatro pliegues cutáneos (tríceps, pantorrilla medial, subescapular y suprailíaco) de porteros internacionales (n = 12) y no internacionales (n = 23). También se calculó el índice de masa corporal (IMC, peso/altura^2), la suma de los cuatro pliegues de grasa subcutánea, la relación altura/sentado, la relación cintura/cadera y la envergadura relativa.
Resultados: Los porteros de hockey sobre patines internacionales presentan valores más bajos de adiposidad subcutánea para la suma de los cuatro pliegues de grasa subcutánea (P = 0.042; d = 0.76) principalmente en el pliegue del tríceps (P = 0.016; d = 0.87) y son más altos do que los porteros no internacionales (+3.8 cm [2.2%]; 180.5 ± 7.0 vs. 176.6 ± 4.8 cm; t = 1.920; P = 0.064; d = 0.65).
Conclusión: Los resultados de este estudio pueden indicar que la altura y la grasa corporal pueden tener implicaciones importantes con respecto al proceso de selección tanto para los scouts como para los entrenadores que trabajan con los jugadores en el desarrollo del rendimiento. Estudios futuros deberían centrarse en investigar hasta qué punto las diferentes medidas antropométricas influyen en el rendimiento de los porteros de hockey sobre patines.
Palabras clave: Antropometría; Adiposidad; Distribución Grasa Corporal; Espesor Pliegue Cutáneo.

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Características antropométricas dos guarda-redes masculinos de hóquei em patins de acordo com o seu nível competitivo

RESUMO

Objetivo: Avaliar as características antropométricas dos guarda-redes masculinos de hóquei em patins e comparar as diferenças de acordo com seu nível competitivo (internacional vs. não internacional).
Métodos: Foi medida a Massa corporal, estatura, altura sentada, envergadura, circunferências da cintura e quadril e quatro pregas de gordura subcutânea (trícipital, geminal média, subescapular e suprailíaca) de guarda-redes internacionais (n = 12) e não internacionais (n = 23). O índice de massa corporal (IMC, peso/altura^2), a soma das quatro pregas de gordura subcutânea, a relação altura/estatura sentada, relação cintura/quadril e a envergadura relativa também foram calculadas.
Resultados: Os guarda-redes internacionais apresentam menores valores de adiposidade subcutânea para a soma das quatro pregas de gordura subcutânea (P = 0,042; d = 0,76) principalmente na prega tricípital (P = 0.016; d = 0.87) e são mais altos do que os guarda-redes não internacionais (+3.8 cm [2.2%]; 180.5 ± 7.0 vs. 176.6 ± 4.8 cm; t = 1.920; P = 0.064; d = 0. 65).
Conclusão: Os resultados deste estudo podem indicar que estatura e a gordura corporal podem ter implicações importantes no que diz respeito ao processo de seleção tanto para olheiros e treinadores que trabalham com jogadores no desenvolvimento de desempenho. Futuros estudos devem centrar-se em investigar até que ponto diferentes medidas antropométricas influenciam o desempenho dos guarda-redes de hóquei em patins.
Palavras-chave: Antropometria; Adiposidade; Distribuição Gordura Corporal; Espessura da dobra cutânea.

Introduction

The importance of anthropometric characteristics in sport performance is well established.[1-3] Athletes with an optimal anthropometric profile for a specific sport are adjudged to be more successful. This anthropometric information has been used to evaluate the training status and identify talented male and female athletes.[4]

There are numerous different methods for estimating body composition that provide reasonably similar assessments of body composition, being that the body mass index (BMI) (weight [kg]/height^2 [m]) and skinfold thicknesses are perhaps the most widely used anthropometric indicators for body composition. Despite this the use of the BMI in a population of athletes' presents some limitations, given to the large body size (height and mass) and relative leanness, also, skinfold measurements present some degree of error. However, these two methods are a basic tool for estimating body size and configuration, despite of having limited accuracy, because they are portable and inexpensive, the procedures are non-invasive and minimal training is required.[3]

Most research that has assessed the anthropometric characteristics of rink hockey players are conducted in youth athletes.[5,6] However, sport-specific body composition profiles have been developed by use of the Dual-energy X-ray absorptiometry (DXA) and anthropometry.[1] This involved a sample of adult male rink hockey players (n = 49), whereby the majority were outfield players. However, despite the growing research effort afforded to rink hockey goalkeepers,[7,8] there remains a paucity of work assessing the anthropometric profiles of this bespoke position.

There are several studies that have profiled the anthropometric characteristics of elite ice-hockey players and the impact on athletic selection and performance.[9,10] In these studies it was identified that stature and body mass play an important role in the selection process with goalkeepers being the tallest players. However, little is known as to what extent these findings translate to rink hockey goalkeepers.

Anthropometric profiles of elite athletes can provide pertinent information regarding the morphological requirements to compete at a higher level. Therefore, the purpose of this paper is twofold: 1) to evaluate the anthropometric characteristics of male rink hockey goalkeepers, and 2) to compare the variation according to their competitive level (international vs. non-international). This information may be useful to scouts and coaches for talent identification and development procedures. We hypothesised that international goalkeepers would have a greater stature, lower body mass and a reduced body fat compared with non-international goalkeepers.

Methods

The study received approval from the scientific commission and was conducted in accordance with recognised ethical standards.[11] Each team provided written informed consent, while assent was obtained from individual athletes. Participants were also informed that participation was entirely voluntary and that they could withdraw at any time. This research was observational in nature and as such, no intervention was undertaken.

Sample

A formal request to participate in the study was sent to all teams participating in the *Euro male senior Azeméis 2016* as well as to all teams of the Portuguese first league. Six of the eight teams participating in the *Euro male senior Azeméis 2016* agreed to participate in this study, while only one of the fourteen teams of the Portuguese first league did not participated in this study. The sample included 35 male rink hockey goalkeepers. The goalkeepers were classified as international and non-international. Twelve (two from each national team) international goalkeepers were selected for their national teams (Portugal, Spain, France, Germany, England and Austria) and participated in the *Euro male senior Azeméis 2016*, aged between 18 and 48 years old (29.9 ± 8.1). The non-international (23 goalkeepers) played in the Portuguese first league, aged between 17 and 42 years old (28.9 ± 7.2). No differences were observed in training time between the international goalkeepers (3.6 ± 1.7 sessions/week) and non-international goalkeepers (4.1 ± 0.7 sessions/week). All goalkeepers participated in a 10-month competitive season (September – June), involving 1 – 2 games/week.

Anthropometry

Body mass, stature, sitting height, arm span, skinfold assessments at four anatomical locations (triceps, medial calf, subscapular and supraspinale), and waist and hip circumferences were taken by a singled experienced observer following the protocol described in Lohman et al.[12]. Goalkeepers wore shorts and a T-shirt and shoes were removed. Body mass index (BMI, weight/height^2), the sum of four skinfolds,[13] the sitting height/stature ratio,[14] the waist/hip ratio[15] and the relative arm span[16] were calculated. Skinfolds were measured to the nearest mm using a Lange caliper (Beta Technology, Ann Arbor, MI, USA). Technical errors of measurement for body mass (0.47 kg), stature (0.27 cm), sitting height (0.31 cm), arm span (0.74 cm), skinfolds (0.47 – 0.72 mm) and circumferences (0.29 – 0.74 cm) were well within the range of several health surveys in the United States and a variety of field surveys.[14]

Statistical analysis

The Kolmogorov-Smirnov test was used to examine the degree of normality. Student *t*-tests were used to compare the anthropometric characteristics of the international and non-international goalkeepers. The magnitude of the effects was interpreted as follows: < 0.20 (trivial); 0.20 to 0.59 (small); 0.60 to 1.19 (moderate); 1.20 to 1.99 (large); 2.00 to 3.99 (very large); ≥ 4.00 (extremely large).[17] Alpha was accepted as $p \leq 0.05$ prior to analyses. Statistical analysis was completed using IBM SPSS Statistics (version 22.0, Chicago, Illinois, USA).

Results

International goalkeepers, on average played more games than non-international rink hockey goalkeepers (+7.1 games [24%]; 29.5 ± 7.2 vs. 22.4 ± 14.6 games; t = 1.931; P = 0.062; d = 0.61) (Table 1 and Figure 1)

Compared to non-international, international rink hockey goalkeepers are taller (+3.8 cm [2.2%]; 180.5 ± 7.0 vs. 176.6 ± 4.8 cm; t = 1.920; P = 0.064; d = 0.65). International goalkeepers had lower values of subcutaneous adiposity on the sum of 4 skinfolds compared with non-international goalkeepers (-14.6 mm [32.9%] 44.4 ± 16.6 vs. 59.0 ± 19.7 mm; t = -2.119, P = 0.042; d = 0.76) (Table 2).

International goalkeepers have lower fat content in the triceps (-3.8 mm [28%] 9.9 ± 4.1 vs. 13.7 ± 4.3 mm; t = -2.527; P = 0.016; d = 0.87). Moderate differences existed between groups in the supraspinale skinfold measurement (-6.0 mm [29%] 14.5 ± 6.9 vs. 20.5 ± 10.0 mm; d = 0.64), however this did not reach statistical significance (P = 0.073) (Figure 1).

Discussion

The purpose of this study was to evaluate the anthropometric characteristics of male rink hockey goalkeepers in relation to their competitive level. The results obtained in our study demonstrate that there is some differences in stature between international and non-international goalkeepers, although they are not statistically significant, have less body fat, and compete in a higher volume of games compared with non-international rink hockey goalkeepers. These data are novel and have implications for rink hockey talent identification staff networks attempting to identify goalkeepers based on their physical characteristics.

In the present study, international goalkeepers taller compared to non-international goalkeepers. The sample international goalkeepers are in the 95th percentile while non-international goalkeepers are in the 75th percentile in relation to the reference population of rink hockey players.[1] However, when comparing our results with professional ice-hockey goalkeepers, the values of our population are substantially lower.[9,10] These results are surprising given the similar competitive level and nature between the sports. Stature can determine the selection of goalkeepers, with those that are taller typically preferred in sports such as handball,[8] ice hockey[9,10] and football.[19] Therefore, determining the extent to which stature impacts upon goalkeeper performance is an avenue for future work.

Despite no significant differences for body mass existing between groups, international goalkeepers have lower values of BMI than the non-international. According to the World Health Organization,[15] the BMI of the international goalkeepers is considered normal (18.5 – 24.9) while non-international goalkeepers are overweight (25.0 – 29.9). However, these data must be interpreted with caution as the inherent limitations associated with BMI, such that that this measure does not account for differences in fat and muscle-mass, which could lead to erroneous and misleading conclusions.[20]

Moderate between-group differences in the sum of the four skinfolds and each of the individual sites were established. Specifically, our results show that non-international goalkeepers have higher values of subcutaneous adiposity, which could be

Table 1. Characteristics of the sample and comparisons between international and non-international rink hockey goalkeepers.

Variable	International level (n = 12)	Non international level (n = 23)	Comparison		Effect size	
	Mean ± SD	Mean ± SD	t	P	d-value	qualitative
Chronological age (years)	29.9 ± 8.1	28.9 ± 7.2	0.391	0.698	0.18	trivial
Training experience (years)	22.0 ± 7.7	22.4 ± 6.5	-0.159	0.874	0.06	trivial
Training sessions (sessions/week)	3.7 ± 1.7	4.2 ± 0.8	-0.969	0.350	0.33	small
Games played (number)	29.5 ± 7.2	22.4 ± 14.6	1.931	0.062	0.61	moderate

Table 2. Descriptive statistics for anthropometric and composite anthropometric variables and comparisons between international and non-international rink hockey goalkeepers.

Variable	International level (n = 12)	Non international level (n = 23)	Comparison		Effect size	
	Mean ± SD	Mean ± SD	t	P	d-value	qualitative
Stature (cm)	180.5 ± 7.0	176.7 ± 4.8	1.920	0.064	0.65	moderate
Body mass (kg)	81.0 ± 12.3	81.4 ± 7.5	-0.118	0.908	0.04	trivial
Sitting height (cm)	95.3 ± 3.7	94.7 ± 3.1	0.525	0.603	0.18	trivial
Arm span (cm)	190.3 ± 8.7	186.6 ± 5.6	1.517	0.139	0.10	trivial
Skinfolds :						
Triceps (mm)	9.9 ± 4.1	13.7 ± 4.3	-2.527	0.016	0.87	moderate
Subscapular (mm)	13.3 ± 5.0	15.9 ± 6.1	-1.302	0.202	0.44	small
Supraspinale (mm)	14.5 ± 6.9	20.5 ± 10.0	-1.852	0.073	0.64	moderate
Medial Calf (mm)	6.8 ± 3.3	8.8 ± 3.6	-1.623	0.114	0.55	small
Waist circumference (cm)	84.5 ± 8.6	88.0 ± 7.0	-1.293	0.205	0.45	small
Hip circumference (cm)	97.8 ± 5.7	99.6 ± 4.3	-1.061	0.296	0.36	small
BMI (%)	24.8 ± 2.8	26.1 ± 2.4	-1.486	0.147	0.50	small
Σ 4 skinfolds (mm)	44.4 ± 16.6	59.0 ± 19.7	-2.119	0.042	0.76	moderate
Sitting height/stature ratio (%)	52.8 ± 1.1	53.6 ± 1.5	-1.647	0.109	0.56	small
Waist/hip ratio (%)	86.3 ± 4.6	88.3 ± 4.7	-1.177	0.248	0.41	small
Relative arm span	105.4 ± 2.0	105.7 ± 2.4	-0.310	0.759	0.13	trivial

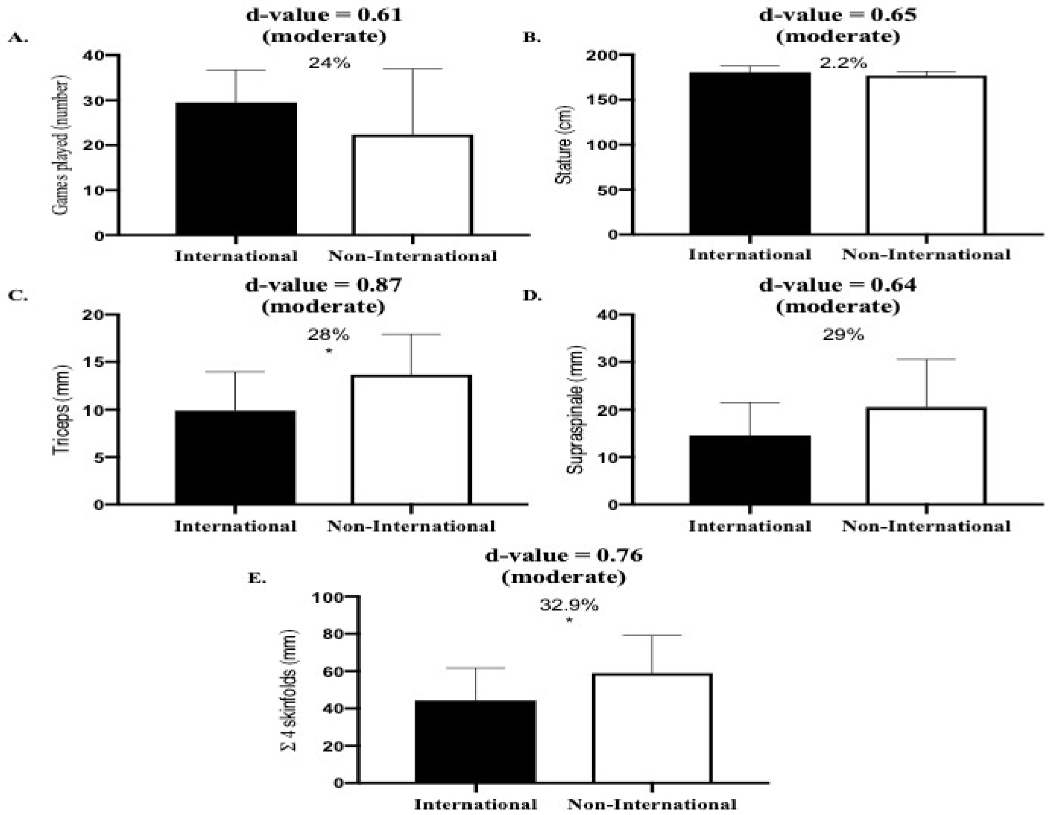

Figure 1. Games played (A), stature (B), triceps (C), supraspinale (D) and, Σ 4 skinfolds (E) in international rink hockey goalkeepers (black bars) and non-international rink hockey goalkeepers (white bars). Mean differences between groups (international vs. non-international level). * Indicates difference between the groups (P<0.05).

explained by the small sample used for the study. Rink hockey goalkeepers must perform dynamic movements, and maintain postural stability, whilst restricted by protective gear and in a crouched position.[5,7,8,21] This additional fat mass may have a major impact on non-international goalkeepers mobility, postural stability and performance.[22,23] The differences in subcutaneous adiposity between groups could be a consequence of the additional games played by the international goalkeepers. It is well documented that higher levels of training and competition exercise is correlated with a reduced body fat percentage.[24,25] However, a casual relationship between the number of games played and the amount of body fat cannot be confirmed. Further studies involving rink hockey goalkeepers should investigate the relationship between body compositions on subsequent performance.

Although the current study provides novel insights into such a specific population, our research has limitations. Specifically, the sample size was relatively small and only represents goalkeepers who had agreed to participate in the study. The use of anthropometry has some degree of measurement error, however is still a feasible tool available for coaches as opposed to expensive technology (e.g., air displacement, DXA etc.).[3] The discrepancy in number of goalkeepers used for each group, could potential confound the statistical inferences drawn from our research. Furthermore, there are disparities in training volume between national teams from different countries, thus the extent to which our findings translate to the rink hockey goalkeepers in other countries are unknown. Anecdotally, it is expected that international goalkeepers are superior to non-international pertaining to performance. However, due to the absence of performance measures, this premise was unable to be confirmed, leaving our data without valid conclusion as to how these measures influence performance. Therefore, this opens an avenue for future investigative work that could quantify a range of performance metrics alongside taking anthropometric measures in order to determine whether correlations are present between the two variables.

This study assessed the anthropometric characteristics of male rink hockey goalkeepers according to their competitive level (international vs. non-international). In agreement with the hypothesis, our findings suggest that international goalkeepers, play more games, are taller and have less subcutaneous adiposity compared to non-international goalkeepers. The differences found between the two groups could indicate that stature and subcutaneous adiposity can be used for scouting networks as part of a talent identification tool. However, it is key that future studies assess the effect that stature and subcutaneous adiposity have on subsequent performance in rink hockey goalkeepers.

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Original

Training cessation in 12 years old and under Age-Group Swimmers

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ABSTRACT

Objective: To verify if three-weeks of training cessation affects 200 m front crawl performance and kinematics in 12 years old and under age-group swimmers controlling for anthropometric changes.
Method: Sixteen age-group swimmers: 11 girls (age 10.0 ± 1.3 y) and 5 boys (age 10.5 ± 1.0 y) performed a 200 m front crawl test (T200) (time trial) PRE- and POST three-weeks (off-season), where performance, kinematics and anthropometrics variables were obtained.
Results: Height and arm span increased (height ~1.0 cm - CI: 0.70 to 1.3 cm; $p < 0.001$; $d = 1.22$; arm span ~1.0 cm - CI: 0.20 to 1.4 cm; $p = 0.007$; $d = 0.68$). Trivial changes were observed for performance (mean diff: 3.3 s CI: -6.7 to 13.9; $p = 0.69$; $d = 0.08$) and kinematical variables (p from 0.69 to 0.84; d = 0.04 to 0.17). High intraclass correlations (ICC: 0.69 to 0.84; $p < 0.001$) were observed for all variables after three-weeks, indicating stability over time.
Conclusion: Three-weeks off-season does not impair swimming T200 performance and kinematic variables in 12 years old and under age-group swimmers.
Keywords: Swimming; Detraining; Performance; Kinematics; Anthropometrics

Cese del entrenamiento en nadadores de 12 años y menores

RESUMEN

Objetivo: Verificar si tres semanas de interrupción del entrenamiento afectan el rendimiento y la cinemática de 200 m en nado crol en nadadores de 12 años y menores mientras se controlan los cambios antropométricos.
Método: Dieciséis nadadores de grupos de edad: 11 niñas (edad 10.0 ± 1.3 años) y 5 niños (edad 10.5 ± 1.0 años) realizaron una prueba de 200 m nado crol (contrarreloj) pre y post tres semanas (fuera de temporada), donde se obtuvieron el rendimiento, variables cinemáticas y antropométricas.
Resultados: La altura y la envergadura han aumentado (altura ~ 1.0 cm; IC: 0.70 a 1.3 cm; $p <0.001$; $d = 1.22$; envergadura ~ 1.0 cm; IC: 0.2 a 1.4 cm; $p <0.001$; $d = 0.68$). Se observaron cambios triviales para el rendimiento (diferencia media: 3.3 s IC: -6.7 a 13.9; $p = 0.69$; $d = 0.08$) y las variables cinemáticas (p de 0.69 a 0.84; d = 0.04 a 0.17). Se observaron altas correlaciones intraclase (CCI: 0.69 a 0.84; $p <0.001$) para todas las variables después de tres semanas, lo que indica estabilidad en el tiempo.
Conclusión: Tres semanas fuera de temporada no afecta el rendimiento en 200 m nado crol ni las variables cinemáticas en nadadores de 12 años y menores.
Palabras clave: Natación; Desentrenamiento; Rendimiento; Cinemática; Antropometría.

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Cessação do treino em nadadores com idade inferior a 12 anos

RESUMO

Objetivo: Verificar se três semanas de interrupção do treinamento afetam o desempenho e a cinemática em 200 m nado crawl de nadadores de até 12 anos de idade, controlando as alterações antropométricas.

Método: Dezesseis nadadores de grupos de idade: 11 meninas (idade 10.0 ± 1.3 anos) e 5 meninos (idade 10.5 ± 1.0 anos) realizaram um teste de 200 m em nado crawl (contrarrelógio) pré e pós três semanas (fora de temporada), quando o desempenho, variáveis cinemáticas e antropométricas foram obtidas.

Resultados: Estatura e envergadura aumentaram (estatura ~ 1.0 cm - IC: 0.70 a 1.3 cm; p <0.001; *d* = 1.22; envergadura ~1.0 cm - CI: 0.20 a 1.4 cm; p = 0.007; *d* = 0.68). Mudanças triviais foram observadas para desempenho (diferença média: 3,3 s IC: -6,7 a 13,9; p = 0,69; *d* = 0,08) e variáveis cinemáticas (p de 0.69 a 0.84; d = 0.04 a 0.17). Correlações intraclasse foram elevadas (ICC: 0.69 a 0.84; p <0.001) e observadas para todas as variáveis após três semanas, indicando estabilidade ao longo do tempo.

Conclusão: Três semanas fora da temporada não prejudicam o desempenho de natação em 200 m nado crawl e as variáveis cinemáticas em nadadores de 12 anos e mais novos.

Palavras-chave: Natação; Destreinamento; Performance; Cinemática; Antropometria

Introduction

Regular swimming training leads to quite a lot of physiological and biomechanical adaptations, normally enhancing swimming performance.[1,2] The reverse path of this process is termed detraining,[3] i.e. the cessation or reduction of swimming training can induce in partial or complete reversal of these adaptations, thus impairing swimming performance.[4,5,6] Age-group swimmers training cessation may occur due to injuries, poor health conditions or while enjoying the off-season (e.g. summer break).[6] Studies with adult swimmers indicate an association between training or detraining and impaired physiological and biomechanical responses.[7]

Despite that, the effects of detraining in 12 years old and under age-group swimmers is few explored.[3,5,6] Impaired swimming performance in 11-12 years old swimmers was reported for 100 m front crawl after 11-weeks of training cessation[4,8] and for 400 m front crawl after 4-weeks in older swimmers (14-15 years old).[3] Swimming performance improvements related to growth after a 10-weeks cessation in age-group swimmers (11-13 years old) was also reported,[5] where swimmers were able to swim faster in the 25 m front crawl. In fact, the bigger the swimmer's height, the smaller the hull drag and higher the theoretical hull speed.[9] Also, higher swimming stroke length (SL) have been associated with higher swimming performance.[9,1]

However, detraining effects may be different between distinct swimming events,[3,10] mainly due to their distinct energetic profile.[11]. For instance, the aerobic contribution during a maximal 200-m front crawl effort is ~ 66%[12] when performed by adult elite swimmers. Since prepubertal individuals have less anaerobic capacity compared to adults,[13] the aerobic contribution may be greater in the same event. Besides, the duration of 200 m tests in 11 years old and under age-group swimmers (around 200 s)[14] can be close to the duration of the 400 m test (around 240 s) performed by adults. Furthermore, the 400 m swim test has been pointed out as a valid test for aerobic capacity and power assessment in swimming.[15]

Since it is reasonable to suggest that detraining might be more evident in longer distance events due to higher aerobic impairments,[5,6] the 200 m front crawl event could be assumed as a long- rather than a short-distance event for ~10 years old swimmers.[5] In this study we investigated possible effects on swimming performance and kinematics in 12 years old and under age-group swimmers during a 200 m front crawl test (T200) after three-weeks of training cessation while controlling for anthropometric changes.

Methods

Experimental Approach to the Problem

A longitudinal single cohort study was conducted. Swimmers were tested before (PRE) and after (POST) a three-weeks off-season period. Measures of performance-related kinematic variables, controlling for anthropometrics, were obtained. The experimental testing took place in a 25-m indoor pool (mean water temperature ~26ºC; air temperature ~28ºC). The first experimental testing (PRE) was conducted at the end of the season. Swimmers were then instructed to refrain from training during the whole off-season. The second experimental testing (POST) was conducted three-weeks later, at the beginning of the new season. After 400-m moderate intensity front crawl warm-up, swimmers performed a 200-m maximal effort front crawl swim test (T200) for performance and kinematic assessments (Figure 1). All participants avoided vigorous exercise in the previous 24 h, were well-hydrated for, at least, 3 h before testing and encouraged verbally during the T200. The T200 was chosen since it is a challenging event for young swimmers both in the technical and energetic domains, and because most of the competitive swimming events of this age group have distances up to 200 m.[16]

Subjects

The study included 16 age-group swimmers, 11 girls and 5 boys (10.2 ± 1.2 [9.5 – 10.9] years old), all inserted in competitive swimming training for at least 12 months, pooled in the same group.[17] Swimmers' parents were informed about the benefits and risks of taking part in the current study before signing an informed consent form, which was approved by the Local Ethics Committee and performed according to the Helsinki Declaration (approval number 20416119.5.0000.5347).

Procedures

Anthropometric profile composed by height and arm span was obtained at PRE and POST by the same researcher. A 250cm tape (VONDER®, Brazil) was used. For height, the subjects were

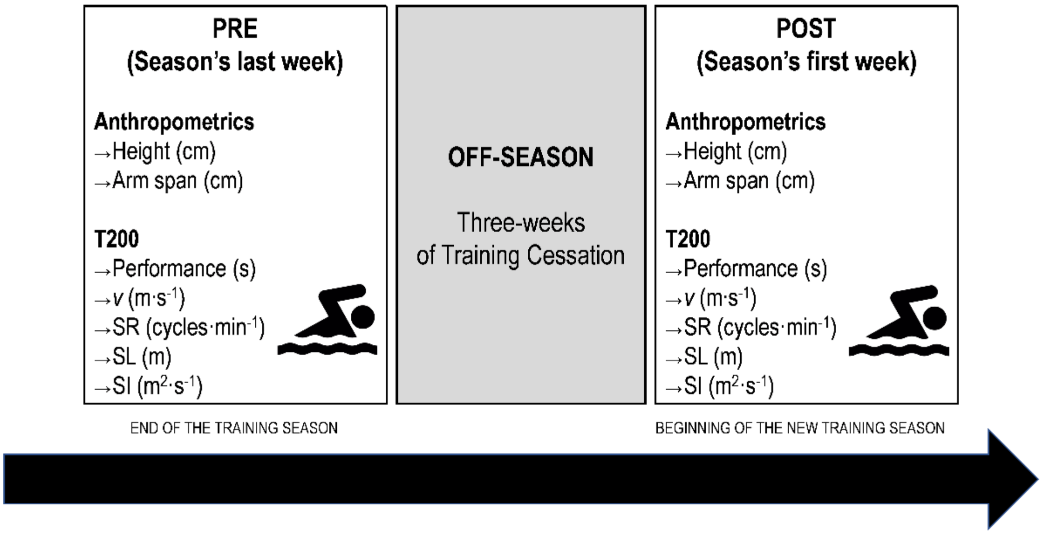

Figure 1. Study design.

Table 1. Effects of three-weeks off-season on age-group swimmers' height, arm span, performance, and kinematics. There are displayed the PRE and POST mean ± SD values, 95% confidence intervals, with respective mean differences and 95% confidence intervals, and comparison p-value and effect size, intraclass correlation coefficients with respective p-value.

	PRE	POST	Diff. PRE-POST	p-value	Cohen's *d*	ICC p-value
Height (cm)	141 ± 8.6	142.5 ± 8.7	-1.03	< 0.001	1.22	0.99
	139.9 to 146.0	137.8 to 147.1	-1.3 to - 0.7		large	< 0.001
Arm span (cm)	142.5 ±9.3	143.4 ± 9.2	-0.87	0.007	0.68	0.99
	137.5 to 147.5	138.5 to 148.3	-1.4 to -0.2		moderate	< 0.001
Performance (s)	240.8 ± 35.9	237.5 ± 39.11	3.3	0.69	0.17	0.93
	221.1 to 259.9	216.6 to 258.3	-6.7 to 13.9		trivial	< 0.001
v (m·s^{-1})	0.77 ± 0.11	0.78 ± 0.11	-0.004	0.71	0.11	0.82
	0.71 to 0.83	0.72 to 0.84	-0.05 to 0.04		trivial	< 0.001
SR (cycles·min^{-1})	37.3 ± 5.8	36.9 ± 6.6	0.49	0.79	0.06	0.69
	34.2 to 40.2	33.0 to 40.2	-0.4 to 0.06		trivial	< 0.001
SL (m)	1.27 ± 0.25	1.29 ± 0.18	-0.01	0.76	0.09	0.72
	1.13 to 1.41	1.19 to 1.39	-0.12 to 0.09		trivial	< 0.001
SI (m^2·s^{-1})	1.00 ± 0.32	1.01 ± 0.24	-0.008	1.00*	0.04	0.84
	0.83 to 1.17	0.88 to 1.14	-0.12 to 0.10		trivial	< 0.001

PRE: the first assessment; POST: the second assessment, ICC: intraclass correlation coefficient; v: swimming velocity; SR: stroke rate; SL: stroke length; SI: stroke index.
* Wilcoxon test

positioned with their backs to the wall with the tape demarcation. For arm span, the subjects remained lying in the supine position with shoulder abduction at 90º. The arm span is considered the distance between the distal extreme points of the middle fingers of both hands.

Soon after, T200 performance (in seconds) and kinematical data were collected manually[1] with stopwatches (CASIO HS-70w, Japan) by the same experienced and previously trained researcher to avoid subjectivity in the measures. To exclude the influence of the turning phase, the 10-m of each 25-m, within two points at 7.5 m from each end of the swimming pool, was used for kinematical assessments,[1] particularly the duration of the passage and the time of three complete stroke cycles (counting the entry of the right hand into the water three times in a row),[1] Thus, kinematics variables were calculated by the following equations:

(1) Swimming speed (m·s^{-1}): $v = 10\ \text{m}\cdot\text{time}^{-1}$
(2) Stroke rate (cycles·min^{-1}): $SR = (3\ \text{cycles}\cdot \text{time}^{-1})\cdot 60$
(3) Stroke length (m): $SL = v\cdot SR^{-1}$
(4) Stroke index (m^2·s^{-1}): $SI = v\cdot SL$

Mean values from all variables were calculated using all partial values, representing the T200.

Statistical Analyses

Normality was verified and confirmed with the Shapiro–Wilk test, except for the SI. Mean, standard deviation and 95% confidence intervals were calculated for all variables. Student's t test for dependent data (parametric data) and Wilcoxon test (non-parametric data) were used to compare differences between PRE and POST off-season for each variable. Effect sizes (Cohen's *d*) were interpreted as previously proposed:[18]

$$d=\frac{|\dot{m}_1-\dot{m}_2|}{\sqrt{s_1^2+s_s^2-(2\,rs_1 rs_2)}}$$

Where *m*, s, and r are, respectively, the means, standard deviations, and the correlation between the two conditions. Cohen's *d* was interpreted with the following criteria: 0–0.19 trivial, 0.2–0.59 small, 0.6–1.19 moderate, 1.2–1.99 large, 2.0–3.99 very large and >4.0 nearly perfect.[19] Intraclass correlation coefficient (ICC) between PRE and POST was calculated for all variables. Alpha significance level was established at 0.05.

Results

The pre- and post-three-weeks off-season anthropometrics, performance and kinematics results are in Table 1. All the variables, pre- and post-three-weeks off-season had parametric distribution, except the SI. Large and moderate changes were identified, respectively, in height and arm span, although just trivial changes in performance, *v*, SR, SL and SI. High and significant ICC were observed for all variables.

Discussion

This study aimed to investigate effects on swimming performance and kinematics in 12 years old and under age-group swimmers during the 200-m front crawl test after three-weeks of training cessation, while controlling for anthropometric changes. Trivial changes and high intraclass correlations were observed for all variables after three-weeks, suggesting stability over time, i.e., changes occurred in parallel. Specificity and reversibility training principles are widely reported for peripheral skeletal muscles.[20] While specificity denotes that the nature of changes in muscle structure and function relies on the nature of the applied stimulus, reversibility indicates that when physical training is stopped (training cessation), our body readapt in accordance with the reduced physiological demand.[20] Beneficial adaptations may be lost,[3] but in a three-week break it was not enough.

Relevant changes in anthropometry (including increases in height and arm span) can be observed in longer than three weeks break periods.[4,5,8] Some authors observed that fastest swimmers are those with the largest anthropometric dimensions after 10-weeks off-season.[5] In addition, Morais et al.[4] reported that impaired swimming performance after 11-weeks off-season was mitigated by height increase in swimmers, suggesting that anthropometrics may play a major role to changes in technical skills and performance in age-group swimmers. However, the three-week summer break, in the present study, was enough to observe a linear growth that could improve swimming performance. In fact, PRE and POST values for height and arm span values were significant, and effects sizes were, respectively, large, and moderate. In this regard, it is possible that their growth did not allow negative effects in performance that were expected due to reversibility principle.

Higher *v* in 12-15 years old swimmers along time have relation to increases in arm span, which affects SL.[21] When looking for a 4-weeks break (similar to 3-weeks conducted in our study), increases in anthropometrics, related to maturation status - Tanner stage IV to V -, were not sufficient to identify an effect of growth on performance in the 400 m front crawl test (a study carried out with 14-15 y males and females age-group swimmers).[3] In our study, swimmers (10.2 ± 1.2 years old) differ in this aspect, indicating that a late growth spurt would not have arrived yet.[22]

Trivial changes were observed for *v*, SR, SL, and SI in our study (Table 1), suggesting that three-weeks of training cessation was not enough to impair swimming technique. Moreira et al.[5] reported that SR in the 25 m front crawl remained similar after 10 weeks in ~12 years old swimmers, with increase in SL and SI, being explained by physical development. Same behavior was observed by Morais et al.[4] when the 100-m front crawl was studied after 11 weeks with ~12 years old swimmers. It is acceptable to suggest that kinematics may be stable or even increased during long off-season for this age group, being explained by growth.[5] Despite that, it is necessary to highlight that performance may be impaired.[4,8]

Reduction of the "water sensitivity" could also be associated with similar SR values, making the arm stroke less propulsive due to a long pause between seasons.[5] Perhaps, three-weeks training cessation was not enough to demonstrate these effects, but unfortunately, we did not test it. Also, there is an important issue in this discussion which is how active these young athletes were during summer break, including aquatic activities and how this could interfere their physiological and technique adaptations, including the "water sensitivity". However, there is a considerable range between three- and ten-weeks training cessation, making further studies necessary to identify a threshold for technique stabilization. In the light of our results, regardless of the level of performance, technique remained constant and stable, i.e. swimmers with the best performance before the break, continued as the best after the break.

Impaired performance was also observed in other studies,[3,4,8,23] but they diverge from our study by longer breaks,[4,8,23] older swimmers, and longer events tested (e.g. 400 m).[3] In fact, the negative effects of detraining on performance may be more evident over longer distances since there are important losses of aerobic over anaerobic power and capacity.[5] Reduction in cardiorespiratory fitness is the primarily responsible for performance impairment in well-trained athletes.[6] It explains some contradictory responses[5] when testing swimmers in 25 m front crawl efforts. Similar results[10] were observed after six weeks of strength training cessation, which were not enough to impair swimming performance at 25 and 50-m front crawl in ~12 years age-group swimmers. Likewise, strength remained stable after weeks of inactivity,[6] but even so the ability to apply force in the water can be reduced.[24] We investigated the effects of detraining in 200-m front crawl, in which the aerobic contribution reaches ~66% from aerobic, ~14% from anaerobic lactic and ~20% from anaerobic alactic energy sources in adults.[12] There are no data indicating the aerobic contribution for this age group, however, must be more than 66% given that they take more time to complete the distance than adults[25] (130.7 ± 6.5 s *vs*. ~ 140 s in our study).

A study close to the outline followed in this study is of the one from Zacca et al.,[3] despite older swimmers (~ 14 years *vs.* ~10 years). Zacca et al.[3] identified a substantial decrease (-3.8%) in the 400-m front crawl performance after four-weeks of training cessation. However, the differences from this study[3] to the present study (in which there is neither a worsening nor an improvement in performance) can be explained by: (i) one more week of summer break, (ii) the 400-m event instead the 200-m, (iii) the difference in age group, (iv) maturation status and/or (v) non-swimming specific physical activities during off-season (not controlled). Explained by the reversibility principle, the adaptations provided by training stimulus are reversed in losses when the training is stopped.[20] The decrease in maximum oxygen uptake after short detraining periods is greater in experienced athletes when compared to beginners.[6]

Those who work with child athletes usually do not have specific theoretical bases to inform themselves, only general of the individual's motor and maturational development. Nevertheless, the changes and behaviors related to swimming technique are poorly investigated,[3,5,6] requiring coaches to study from bases with post-puberal athletes or even adults. It is important to align the necessary motivation[26] for a child to get involved in a sport in a formal and competitive way with the requirements in sport initiation to mold and not waste promising future in the scenario of elite swimming. Three weeks of summer break after an entire season of regular training possible may not be enough for the child to return with renewed motivation for another year of intense work. However, coaches are concerned with losing physiological and technical gains from training during detraining. Being aware of detraining consequences for this population is necessary to avoid evasion in the sport. The possibility of adaptations due training in young are larger, and they are more sensitive to stimuli than adults, so there is no need to treat them as "miniature adults".[22]

We point out some limitations in our study: (i) the non-measurement of sexual maturation, whereas performance can be influenced by the actual stage; (ii) the non-investigation of the energetics, that provides a wealth of information about the physiological status of swimmers, but can be invasive methods for children; (iii) the relative small sample size (other possible participants, due to the parents' vacation, returned after the stipulated period); and (iv) the non-monitoring of the physical activities during the break, due to the inconsistence of their responses trying to remember the activities. Future research could investigate, either the break effects on the "water sensitivity".

Coaches usually shorten the vacation period as much as possible to avoid substantial losses in the ability of their swimmers. In this study, the three-weeks pause showed no substantial losses in performance and kinematics. Data with age-group swimmers are still scarce, and the majority studies are conducted with longer breaks (>10-weeks). Besides that, our study was the one with the longer distance test for this age-group and the stimulus-characteristics may affect the results of detraining. We presented data that until now were missing in swimming science. Understanding the interaction between growth and technique is important at younger ages, but further studies with this age group are needed to identify possible changes in other abilities beyond the maximum test of 200-m and other periods of detraining, longer than three-weeks and shorter than 10-weeks, with energetic assessments.

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Original

Ativação dos músculos do powerhouse durante os exercícios leg-circle do pilates realizados no solo e em equipamentos

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RESUMO

Objetivo: o objetivo do presente estudo foi testar a capacidade dos exercícios *leg-circle* para ativar os músculos do *powerhouse*.
Método: a amostra foi composta por onze instrutoras de Pilates com pelo menos seis meses de experiência. A eletromiografia (EMG) dos músculos reto abdominal, oblíquo interno, oblíquo externo e multífido foi registrada. Os dados EMG foram coletados durante a realização de 10 repetições do exercício *leg-circle* bilateralmente no *Reformer* e no *Cadillac*, e 10 repetições executadas unilateralmente no *Mat* com os membros inferiores direito e esquerdo (um total de 40 repetições). Como os dados não eram normais, foi realizada a ANOVA de Friedman. Os testes post-hoc de Wilcoxon foram realizados com a correção de Bonferroni ($p < 0.008$).
Resultados: Quando comparados os músculos em um mesmo aparelho, o reto abdominal e o multífido tiverem sempre os menores níveis de ativação, não sendo diferentes entre si em nenhum dos aparelhos. O obliquo externo sempre foi o músculo com maior nível de ativação, independente do aparelho. Quando comparados os aparelhos para um mesmo músculo, houve diferenças significativas no reto abdominal [χ^2 (3) = 26.89, $p < 0.001$] e no oblíquo interno [χ^2 (3) = 27.44, $p < 0.001$], onde a ativação elétrica foi maior nos exercícios realizados no *Mat* em comparação com aqueles realizados no *Cadillac* ou *Reformer*. Em contrapartida, não houve diferença entre os exercícios quanto à ativação dos músculos oblíquos externos ou multífidos.
Conclusão: A maior ativação ocorreu no obliquo externo, independente do aparelho analisado. Os exercícios realizados no solo tiveram maior ativação do reto abdominal e do obliquo interno comparativamente aos exercícios realizados nos aparelhos.
Palavras-chave: Eletromiografia; Exercício; Extremidade Inferior

Activación de los músculos de *powerhouse* durante los ejercicios *leg-circle* de pilates realizados en el suelo y en máquinas

RESUMEN

Objetivo: El objetivo del presente estudio fue probar la capacidad de los ejercicios *leg-circle* para activar los músculos de *powerhouse*.
Método: la muestra estuvo formada por once instructores de Pilates con al menos seis meses de experiencia. Se registró la electromiografía (EMG) de los músculos recto del abdomen, oblicuo interno, oblicuo externo y multífidos. Los datos de EMG se recopilaron durante 10 repeticiones del ejercicio de *leg-circle* bilateralmente en el *Reformer* y en el *Cadillac*, y 10 repeticiones realizadas unilateralmente en el *Mat* con las extremidades inferiores derecha e izquierda (un total de 40 repeticiones). Como los datos no eran normales, se realizó el ANOVA de Friedman. Las pruebas post-hoc de Wilcoxon se realizaron con la corrección de Bonferroni ($p < 0.008$).
Resultados: Al comparar los músculos en el mismo dispositivo, el recto abdominal y el multífidos siempre tienen los niveles más bajos de activación y no son diferentes entre sí en ninguno de los dispositivos. El oblicuo externo siempre ha sido el músculo con mayor nivel de activación, independientemente del dispositivo. Al comparar dispositivos en el mismo músculo, los resultados revelaron diferencias significativas en el recto abdominal [χ^2 (3) = 26.89, $p < 0.001$] y en el oblicuo interno [χ^2 (3) = 27.44, $p < 0.001$], donde la activación eléctrica fue mayor en ejercicios realizados en el *Mat* en comparación con los realizados en el *Cadillac* o *Reformer*. Por otro lado, no hubo diferencia entre los ejercicios en cuanto a la activación de los músculos oblicuos externos o multífidos.
Conclusión: La mayor activación se produjo en el oblicuo externo, independientemente del lugar donde se realizó el ejercicio. Los ejercicios realizados en el suelo presentaron una mayor activación del recto abdominal y del oblicuo interno en comparación con los ejercicios realizados en máquinas.
Palabra clave: Electromiografía; Ejercicio; Extremidad inferior

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Powerhouse muscle activation during pilates leg-circle exercises performed on mat and devices

ABSTRACT

Objective: The goal of the present study was to test the capacity of leg-circle exercises to activate core muscles.
Method: The sample comprised eleven female Pilates instructors with at least six months experience. The electromyography (EMG) of the rectus abdominis, internal oblique, external oblique, and multifidus muscles was recorded. EMG data were collected during the performance of 10 repetitions of the leg-circle exercise bilaterally on the Reformer and on the Cadillac, as well as 10 single leg-circle repetitions performed unilaterally on the Mat with both the right and left lower limbs (a total of 40 repetitions). Since the data were not normal, Friedman ANOVA was conducted. Post-hoc Wilcoxon tests were carried out using the Bonferroni correction ($p < 0.008$).
Results: When comparing the muscles in the same device, the rectus abdominis and the multifidus always have the lowest levels of activation and are not different from each other in any of the devices. The external oblique was always the muscle with the highest level of activation, regardless of the device. When comparing the devices in the same muscle, the results revealed significant differences in the rectus abdominis [$\chi^2(3) = 26.89$, $p < 0.001$] and in the internal oblique [$\chi^2(3) = 27.44$, $p < 0.001$], where the electrical activation was higher in the Mat-based exercises compared to those performed on the Cadillac or Reformer. By contrast, there was no difference between the exercises regarding activation of the external oblique or multifidus muscles.
Conclusion: The greatest activation occurred in the external oblique, regardless of the device analyzed. Exercises performed on the mat had greater activation of the rectus abdominis and internal oblique compared to exercises performed on devices.
Keywords: Electromyography; Exercise; Lower Extremity

Introdução

Os estúdios de Pilates têm sido cada vez mais procurados por pessoas com objetivos tão variados como praticar atividades físicas, melhorar o desempenho esportivo, reabilitar patologias e se recuperar de cirurgias musculoesqueléticas[1-2]. Para tornar a intervenção mais eficaz, é útil conhecer os aspectos biomecânicos e cinesiológicos dos exercícios e suas variações.

Alguns estudos que avaliam a atividade elétrica dos músculos têm mostrado que quando um exercício é realizado da mesma forma com outro aparelho, podem ocorrer alterações na ativação muscular[3-7]. Entender como diferentes exercícios abdominais estimulam a atividade muscular é útil para profissionais da saúde que utilizam estes exercícios para atingir suas necessidades e/ou objetivos de reabilitação ou treinamento[8]. Os músculos abdominais são comumente fortalecidos pela flexão ativa do tronco ou pela contração isométrica dos músculos respondendo a estímulos externos que desafiam a estabilidade do tronco[9].

Quando realizados dentro do ambiente do Pilates, os estudos enfocam a análise muscular com base em um dos seis princípios norteadores do método Pilates, conhecido como centralização[10]. A centralização é considerada o princípio mais importante do método Pilates, porque acredita-se que todo movimento não apenas começa, mas também é sustentado no centro do corpo humano (ou seja, o núcleo). No ambiente de Pilates, a circunferência da parte inferior do tronco - especificamente, os músculos abdominais, os músculos paravertebrais lombares, os flexores do quadril, os extensores do quadril e o assoalho pélvico - formam uma estrutura conhecida como "*powerhouse*", que sustenta o tronco[11,12].

Juntamente com os diferentes aparelhos, outro aspecto a considerar é a influência da estabilidade da superfície na atividade muscular, que parece ser dependente do músculo e do exercício. Já foi mostrado que exercícios de estabilização lombar em superfície instável potencializam a atividade dos músculos do tronco[10]. Em particular, a atividade dos músculos do tronco mais globais, como o oblíquo externo, foi maior na superfície instável[6,13]. Embora tenham sido identificados na literatura diversos exercícios de Pilates amplamente utilizados na prática clínica[3-7,10,12], até onde foi possível verificar, não foram avaliados exercícios de estabilização lombar onde os membros são usados para causar instabilidade, como os exercícios *leg-circle* do Pilates.

Os exercícios *leg-cirle* ou *hip-circle* têm diversas variações e podem ser realizados por meio de diferentes aparelhos: bilateralmente no *Cadillac*, bilateralmente no *Reformer* ou unilateralmente no *Mat* (*single leg-circle*). Em todas as variações, os círculos devem ser contínuos e suaves, envolvendo a circundução na articulação do quadril, mantendo o tronco e a pelve estáticos[14].

Entender quais músculos centrais são recrutados e quão ativos eles são durante a realização de uma variedade de exercícios *leg-circle* é útil para terapeutas e outros especialistas em saúde ou fitness que usam exercícios de Pilates para facilitar a reabilitação ou objetivos de treinamento para seus pacientes ou clientes. O objetivo deste estudo foi testar a capacidade dos exercícios *leg-circle* para ativar os músculos centrais do tronco. Foi hipotetizado que os sinais eletromiográficos (EMG) dos músculos centrais seriam significativamente maiores no aparelho *Reformer*, que tem uma superfície instável (carrinho com rodas) em comparação com outros aparelhos (*Cadillac* e *Mat*), e seriam significativamente menores no dispositivo *Cadillac*, que além de ter uma superfície estável também possui molas que podem ser utilizadas como suporte.

Metodos

Trata-se de um estudo descritivo observacional, que foi desenvolvido no Laboratório de Pesquisa do Exercício da Escola de Educação Física, Fisioterapia e Dança da Universidade Federal do Rio Grande do Sul, durante o ano de 2018. Uma estimativa amostral foi calculada no software G*Power, utilizando a família de testes F, assumindo um tamanho de efeito de 0.4, um erro de 0.05 e um poder de 80%, obtendo-se um n de 10 indivíduos. Para otimizar a qualidade do sinal EMG coletado, este estudo se limitou a uma amostra de conveniência de 11 mulheres saudáveis (Tabela 1) que apresentavam gordura corporal normal ou abaixo do normal para sua faixa etária, de acordo com os padrões estabelecidos pelo American College of Sports Medicine[16]. Além disso, a amostra foi restrita a instrutores de Pilates que, teoricamente, realizariam os exercícios com excelência, assumindo que estejam no estágio autônomo da aprendizagem motora[17]. Para a avaliação da massa foi utilizada uma balança digital com sensibilidade de 100 gramas. Os indivíduos foram posicionados sobre a balança, com o peso distribuído entre os dois pés. Para a avaliação da estatura foi utilizada uma fita métrica fixada à parede. As informações referentes à idade, frequência e tempo de prática foram auto reportadas.

Os seguintes critérios foram utilizados para definir a elegibilidade: os participantes deviam ser instrutores de Pilates há pelo menos seis meses, praticando Pilates pelo menos uma vez por semana no ano anterior; não apresentar dor lombar crônica ou aguda; não apresentar dores nos membros inferiores ou na região abdominal; não apresentar assimetria visíveis de membros inferiores ou de tronco. O convite para participar da pesquisa foi distribuído pelas redes sociais. Esta pesquisa foi aprovada pelo comitê de ética em pesquisa da universidade onde o estudo foi conduzido de acordo com a Declaração de Helsinque.

Tabela 1. Característica dos instrutores de Pilates (n = 11)

	Valores médios (± desvio)	Valor Máximo	Valor Mínimo
Idade (anos)	30 (±5)	40	24
Massa corporal (kg)	58 (±7)	68	49
Altura (cm)	163 (±7)	176	155
Prática de Pilates (frequência semanal)	2 (±1)	4	1
Tempo ininterrupto de prática (anos)	5 (±5)	17	1

Procedimento

Todos os participantes estavam suficientemente familiarizados com os aparelhos e os exercícios para identificar as molas com resistência semelhante às utilizadas durante a prática habitual de treinamento de Pilates. Eles foram solicitados a adotar o padrão respiratório de inspiração durante a execução da primeira metade do círculo e expiração durante a execução da segunda metade. Os participantes realizaram 10 repetições do exercício *leg-circle* bilateralmente no *Reformer*, bilateralmente no *Cadillac*, e 10 repetições do *single leg-circle* realizadas unilateralmente no *Mat* com o membro inferior direito e outras 10 repetições *single leg-circle* com o membro inferior esquerdo. A ordem de execução foi sistematicamente randomizada através de sorteio simples para evitar interferência da fadiga. Foi respeitado um intervalo de dois minutos entre cada exercício. A execução foi supervisionada por um instrutor de Pilates que encorajou verbalmente os participantes a contrair o *powerhouse* ao longo das 10 repetições. Para delimitar o início e o final de cada repetição, a coleta de dados foi filmada por meio de uma webcam (Microsoft Lifecan HD-6000) sincronizada com a aquisição dos dados eletromiográficos.

Exercícios

Para os exercícios *leg-circle* no *Mat* (Figura 1), o participante iniciava deitado de costas, flexionava um quadril 90º e realizava os círculos circundando a articulação do quadril na velocidade e amplitude normalmente utilizadas em seu treinamento regular. A ordem dos membros inferiores foi randomizada entre os participantes.

Os exercícios *leg-circle* no *Reformer* e no *Cadillac* começaram com os participantes deitados em decúbito dorsal e os pés juntos. Os participantes foram inicialmente solicitados a relaxar o *powerhouse* e os membros inferiores. Uma vez que os participantes estavam devidamente posicionados, eles foram solicitados a contrair o *powerhouse* e flexionar o quadril em um ângulo de 90º para realizar círculos externos bilaterais circunduzindo a articulação do quadril na velocidade e amplitude que usualmente usavam em sua prática regular.

Eletromiografia

Os dados de eletromiografia (EMG) foram coletados por meio de um sistema de aquisição de dados (Miotool Wireless USB) conectado ao software Miotec Suite (Miotec Equipamentos Biomédicos Ltda, Porto Alegre, Brasil). Cada sistema possui oito canais analógicos de entrada com uma taxa de amostragem de 2000 Hz e modo de rejeição comum de 126 dB. A aderência dos eletrodos e o registro do sinal eletromiográfico observaram rigorosamente todos os procedimentos - como tricotomia e abrasão - recomendados pela Sociedade Internacional de Eletrofisiologia e Cinesiologia, Sociedade Internacional de Biomecânica e Eletromiografia de Superfície para Avaliação Não Invasiva de Músculos Projeto[18].

Pares de eletrodos descartáveis (Meditrace-100; Ag / AgCl, autoadesivo de 10mm de diâmetro, configuração bipolar) foram fixados no ventre muscular, paralelos às fibras musculares, separados 2 cm um do outro. A simetria do sinal EMG tem sido demonstrada nos músculos centrais do corpo em exercícios executados nas posições supinas[19,20]. Considerando que o risco de contaminação do sinal EMG com sinal ECG é maior quando os eletrodos são colocados do lado esquerdo, e considerando ainda que a filtragem do sinal EMG não pode ser usada para remover o sinal de ECG, sendo necessários algoritmos específicos identificam a forma e o tempo do artefato ECG e o subtraem do registro sEMG[21], uma vez que o espectro de ECG se sobrepõe ao espectro de sEMG[21,22], optou-se por posicionar os eletrodos sempre do lado direito.

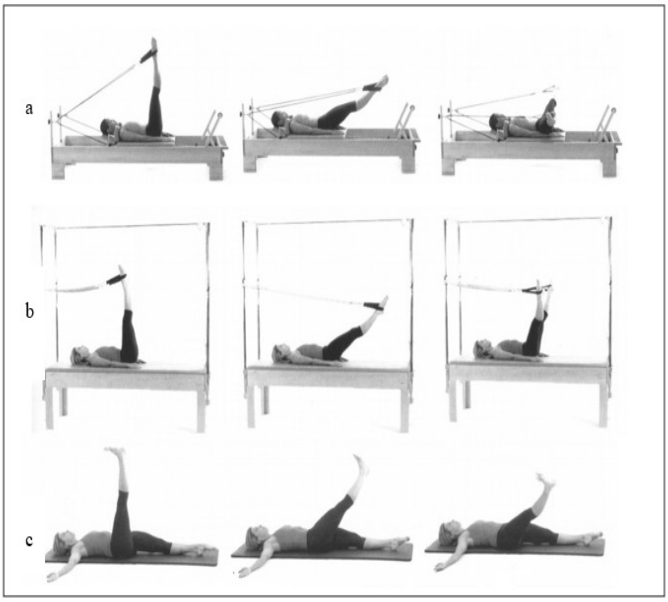

Figura 1. Variações do exercício leg-circle no Reformer (a), Cadillac (b) e no Mat (c). Adaptado de Isakowitz (2006).

Os pares de eletrodos do músculo multífido foram alinhados com a espinha ilíaca póstero-superior no espaço interespinhoso de L1 e L2 no nível da vértebra L5 (2–3 cm da linha mediana) (Projeto SENIAM). Os eletrodos do músculo oblíquo externo foram posicionados de acordo com Escamilla et al. (2006), acima da espinha ilíaca ântero-superior no nível da cicatriz umbilical[8]. Os eletrodos do músculo oblíquo interno foram colocados 2 cm acima da espinha ilíaca ântero-superior, dentro de um triângulo definido pelo ligamento inguinal, a borda lateral do músculo reto abdominal e a linha que liga a espinha ilíaca ântero-superior[23]. Os eletrodos do músculo reto abdominal foram colocados 2 cm lateralmente à cicatriz umbilical, e o eletrodo de referência foi colocado na face anterior da clavícula direita[24]. Para padronização, os sinais EMG foram normalizados com base em contrações isométricas voluntárias máximas (CIVM) de cinco segundos, durante os quais o participante recebeu estímulo verbal[8]. Para as CIVM dos músculos abdominais, o participante ficava deitado em decúbito dorsal, realizando uma flexão de tronco próxima a 30°, mantendo o quadril e os joelhos fletidos a 90° com os pés apoiados no solo. Para a CIVM do reto abdominal, o participante foi instruído a realizar uma flexão máxima de tronco. Já para os músculos oblíquos interno e externo, o participante realizou flexão máxima do tronco com rotação para os lados esquerdo e direito, alternadamente. Para a CIVM do músculo multífido, o participante realizava extensão de tronco deitado em decúbito ventral com os braços estendidos ao longo do corpo[8]. Todas as CIVM foram medidas com o participante contido para garantir a contração isométrica. A ordem de realização dos registros da CIVM foi aleatória e realizada duas vezes com intervalo de dois minutos para evitar interferência da fadiga. Foi utilizado o maior valor de ativação para cada músculo.

Análise de dados

Os dados foram processados com o software BIOMEC SAS, versão 1.0 (Movement Mechanic Investigation Group, disponível em www.ufrgs.br/biomec). O sinal foi filtrado usando um filtro digital passa-alta Butterworth de quarta ordem e um filtro digital passa-baixo Butterworth de quarta ordem com frequências de corte de 20 Hz e 500 Hz, respectivamente. As curvas foram cortadas com base no tempo de cada repetição fornecido pela gravação do vídeo. Para padronizar os desempenhos, foram utilizadas apenas as oito repetições centrais do exercício. A primeira e a última repetição de cada exercício foram excluídas.

Análise Estatística

Os dados foram analisados estatisticamente por meio do software SPSS 20.0. O nível de significância adotado foi de 5%. A normalidade foi avaliada pelo teste de Shapiro-Wilk. Como os dados não aderiram ao modelo normal, múltiplas ANOVAs de Friedman foram usadas, uma para cada músculo comparando os aparelhos (*Reformer, Cadillac* e *Mat* dir e *Mat* esq) e uma para cada aparelho comparando os músculos (Reto Abdominal, Obliquo Interno, Obliquo Externo, Multífido). Quando diferenças foram detectadas, o Teste de Wilcoxon foi aplicado para identificar onde a diferença ocorreu[19]. Com base no número de testes post hoc para cada ANOVA (n = 6), o valor de p sofreu uma correção de Bonferroni e ficou estabelecido como significativo um p <0.008. Os resultados são apresentados conforme sugerido por Field[25], relatando a estatística do teste, representada por χ^2, os graus de liberdade e a significância.

Resultados

Quando os músculos foram comparados entre si em um mesmo aparelho, sempre houve diferença com significância estatística, [$\chi^2(3) = 20.04$, $p<0.001$] no *Mat* com a perna direita, [$\chi^2(3) = 16.92$, $p<0.001$] no *Mat* com a perna esquerda, [$\chi^2(3) = 21.60$, $p<0.001$] no *Cadillac*, [$\chi^2(3) = 21.91$, $p<0.001$] no *Reformer*. O reto abdominal e o multífido tiverem sempre os menores níveis de ativação, não sendo diferentes entre si em nenhum dos aparelhos. O obliquo externo sempre foi o músculo com maior nível de ativação, independente do aparelho (Tabela 2).

Quando os aparelhos foram comparados entre si em um mesmo músculo, a ativação do reto abdominal apresentou diferenças significativas entre os dispositivos analisados [$\chi^2(3) = 26.89$, $p<0.001$], assim como a ativação do oblíquo interno [$\chi^2(3) = 26.43$, $p<0,001$]. Em ambos os grupos musculares, a ativação elétrica foi maior nos exercícios executados no *Mat* em comparação aos executados no *Cadillac* ou *Reformer*. Em contrapartida, a ativação dos músculos oblíquos externos [$\chi^2(3) = 4.09$, $p=0.266$] e dos músculos multífidos [$\chi^2(3) = 10.68$, $p=0.010$] não apresentou diferenças entre os exercícios realizados (Tabela 2) .

Discussão

Contrariamente à hipótese inicial, o aparelho mais instável (*Reformer*) não produziu a maior ativação, nem o aparelho mais estável (*Cadillac*) apresentou a menor ativação, em qualquer um dos músculos estudados. De fato, o dispositivo *Mat* apresentou a maior ativação nos músculos retos abdominais e oblíquos internos, enquanto não foram encontradas diferenças significativas entre os aparelhos para os músculos oblíquo externo e multífido.

Durante uma flexão do quadril em cadeia cinética aberta, o músculo reto abdominal atua junto com o músculo iliopsoas realizando um torque pélvico posterior, neutralizando o torque pélvico anterior oriundo do peso do membro inferior, a fim de manter a estabilidade da cintura pélvica[24]. Porém, quando o exercício *leg-circle* é realizado tanto no *Reformer* quanto no *Cadillac*, as molas utilizadas nesses aparelhos dão assistência ao exercício, gerando um torque que suporta parcialmente o torque do peso do membro inferior, reduzindo o torque resultante do exercício. Assim, a maior ativação dos músculos alcançada no *Mat* pode ser explicada pelo maior torque pélvico anterior gerado exclusivamente pelo peso do membro inferior.

Parece haver um consenso na literatura quanto a maior ativação muscular quando o exercício é realizado em situações instáveis. Os exercícios de estabilização lombar em superfície instável potencializam as atividades dos músculos do tronco, em geral[13]. Da mesma forma, a atividade EMG dos músculos oblíquo interno e transverso do abdome é maior durante o exercício abdominal realizado em rolo de espuma em comparação com o mesmo exercício realizado no *Mat*[26]. Czaprowski et al. (2014)[27] também compararam a atividade EMG do músculo abdominal durante exercícios de ponte em superfícies estáveis e instáveis e, quando uma diferença foi encontrada, maior atividade muscular foi encontrada em superfícies instáveis. Os resultados deste estudo contradizem esses relatos.

Por outro lado, os resultados deste estudo concordam, de certa forma, com os relatados por Loss et al. (2010)[3], que afirmam que o recrutamento muscular do *powerhouse* ocorre de acordo com as demandas mecânicas impostas pelo exercício. Assim, é importante ressaltar que, a estabilidade da superfície pode não ser o único, ou mesmo o principal, fator a ser considerado quando se pretende maior ativação dos músculos do tronco. Além disso, não foram encontradas diferenças significativas na ativação do músculo multífido entre as situações avaliadas. Considerando que os músculos multífidos são extensores de tronco, podemos supor que os exercícios avaliados não produziram demanda externa suficiente (ou seja, torque flexor de tronco) para induzir qualquer diferença.

Considerando o papel do músculo oblíquo externo na estabilização do tronco, uma maior ativação pode ser esperada durante os exercícios realizado no *Mat*, como ocorreu com os músculos oblíquo interno e reto abdominal. Estudos anteriores mostraram maior atividade do oblíqua externo durante situações

Tabela 2. Porcentagem da contração voluntária máxima (% CVM) e desvio padrão (DP) dos músculos reto abdominal, oblíquo interno, oblíquo externo e multifido (p <0.008) durante os exercícios

	Mat d		*Mat* e		*Cad*		*Ref*		
Músculos	% CVM	DP	% CVM	DP	% CVM	DP	% CVM	DP	p
Reto abdominal	9.7^{Aa}	±6.7	9.4^{Aa}	±5.8	3.2^{Ab}	±2.7	2.9^{Ab}	±2.4	<0.001
Obliquo interno	16.4^{Aa}	±9.6	20.8^{BCa}	±14.6	9.0^{Bb}	±8.2	8.4^{Bb}	±8.7	<0.001
Obliquo externo	35.3^{B}	±14.3	35.9^{C}	±28.3	31.0^{C}	±16.9	28.0^{C}	±14.1	0.266
Multifido	7.2^{A}	±5.8	7.8^{AB}	±7.2	6.5^{AB}	±7.9	12.7^{ABC}	±9.3	0.010
p	<0.001		<0.001		<0.001		<0.001		

Nota: "Mat d" = Mat com a perna direita; "Mat e" = Mat com a perna esquerda; "Cad" = Cadillac; "Ref" = Reformer; % CVM = Percentual da Contração Voluntária Máxima; DP = Desvio Padrão.

OBS 1: Para um mesmo músculo (mesma linha), letras minúsculas diferentes (em sobrescrito) indicam diferença significativa (p<0.008) entre os aparelhos. O valor de p na última coluna da linha indica a significância da ANOVA de Friedman para cada músculo.

OBS 2: Para um mesmo aparelho (mesma coluna), letras maiúsculas diferentes (em sobrescrito) indicam diferença significativa (p<0.008) entre os músculos. O valor de p na última linha da coluna indica a significância da ANOVA de Friedman para cada aparelho.

de instabilidade[10,18,21,22,26,27]. No presente estudo, não foi encontrada diferença estatisticamente significativa para a atividade do oblíquo externo entre as situações avaliadas. A estabilização da região lombo-pélvica tem sido atribuída a músculos mais profundos, como o Oblíquo interno e o Transverso do abdomen[29,30]. Esta justificativa também foi apresentada por Paula et al (2020)[7] que não encontrou diferença na ativação do obliquo externo em diferentes alturas de molas durante o exercício *leg-circle*. Entretanto, no presente estudo os valores de ativação do oblíquo externo foram sempre os maiores entre os músculos analisados em todas as situações, sugerindo que este músculo tem um importante papel na estabilidade deste exercício. Nesta perspectiva, uma possível explicação para a ausência de diferença, é que o efeito gerado pelos exercícios foi um falso negativo (erro Tipo II), visto que nosso tamanho de amostra foi pequeno (n = 11).

No que se refere a maior atividade dos músculos da loja anterior (flexores) comparativamente à loja posterior (extensores), os resultados do presente estudo são corroborados por estudos anteriores que também analisaram exercícios na posição supina[3,7-10,12,18]. Entende-se que este resultado reflete a postura utilizada durante os exercícios, onde as costas estavam sempre apoiadas, em todas as situações analisadas. Entre os músculos flexores, o reto abdominal sempre foi o músculo com menor ativação. Especulamos que este resultado está relacionado à isometria do tronco e à natureza do estímulo mecânico do exercício. Para todas as situações analisadas, o objetivo era manter o tronco estável, com a estabilidade sendo desafiada através de movimentos dos membros inferiores. Nestas circunstâncias, os níveis de ativação não foram muito elevados. Com base na mesma classificação utilizada por Escamila (2010)[24] para avaliar exercícios abdominais, multífido, reto abdominal e obliquo interno se enquadrariam na categoria "baixa ativação" (<20% da CVM), enquanto apenas o obliquo externo poderia ser considerado com "moderada ativação" (entre 20% e 40% da CVM). Neste sentido, do ponto de vista de estímulo à musculatura central, o exercício *leg circle* parece ser mais propício para o desenvolvimento de resistência muscular destes músculos. Entretanto, em recente estudo analisando o mesmo exercício, Paula (2020)[7] apresenta ativações acima de 60% da CVM para os oblíquos e próximas a 40% da CVM para o reto abdominal, sempre que o exercício era realizado no solo. Considerando que a amostra do presente estudo foi composta por praticantes experientes, especula-se que a menor ativação aqui encontrada seja devida justamente ao nível de prática dos participantes.

Limitações

Existem algumas limitações relacionadas a este estudo. Primeiro, o número de participantes é pequeno. Porém, isso é compensado pelo fato de a amostra ser composta exclusivamente por instrutores de Pilates. Além disso, a ativação muscular pode ser diferente em não praticantes ou mesmo em iniciantes. Por outro lado, entende-se que os instrutores já estejam no nível autônomo da aprendizagem motora o que deve diminuir a variabilidade das ativações musculares. Entretanto, nenhum teste objetivo foi realizado a fim de avaliar o estágio do nível de aprendizagem dos instrutores. Neste contexto, os resultados deste estudo precisam ser interpretados com muita cautela, não podendo ser extrapolados para outras populações. Em segundo lugar, a estabilização do tronco foi considerada simétrica, portanto, apenas os músculos do lado direito foram analisados. Cabe salientar que a eletromiografia do lado esquerdo, principalmente em músculos do tronco, tende a ser contaminada por ruído eletrocardiográfico. Terceiro, outros músculos importantes que também compõem o *powerhouse*, como o transverso do abdome e o quadrado lombar, não foram analisados devido à sua localização mais profunda. Em quarto lugar, a possibilidade de *crosstalk* ter ocorrido durante o monitoramento do músculo oblíquo interno com eletrodos de superfície deve ser levada em consideração. Em quinto lugar, é preciso salientar que os exercícios são ligeiramente diferentes no solo e nos equipamentos. O exercício leg-circle é executado no solo com um membro inferior de cada vez, enquanto nos equipamentos é executado com ambos os membros simultaneamente. Porém, se tivéssemos feito alguma adaptação (executar com os dois membros no solo ou com apenas um membro nos equipamentos) a limitação estaria por conta de não acompanharmos as instruções do Método Pilates, além dos participantes não estarem habituados a outro tipo de execução, o que poderia alterar o padrão de ativação. Optamos assim por analisar os exercícios como eles são executados no Método Pilates.

Aplicações clínicas

Para tornar as intervenções prescritas mais eficazes, os instrutores de Pilates precisam entender o conceito de demanda muscular e como ela se relaciona com cada exercício e suas variações. Este estudo fornece aos instrutores de Pilates informações sobre as características EMG dos exercícios *leg-circle* em diferentes aparelhos, permitindo-lhes graduar o nível dos exercícios. Sugere-se, por exemplo, para aumentar a dificuldade, que os exercícios *leg-circle* devem ser iniciados no *Cadillac*, depois no *Reformer*, e executados no *Mat* como último nível. Entretanto, cabe salientar com relação aos exercícios *leg-circle*, que eles não apenas aumentam a estabilidade do tronco, mas também requerem alta atividade dos músculos flexores do quadril. Nesses exercícios, é esperado que o músculo psoas seja recrutado para a flexão do quadril, o que pode gerar altas forças de cisalhamento anterior, tendo em vista sua fixação na coluna vertebral. Estas forças de cisalhamento podem ser indesejáveis para aqueles indivíduos com instabilidade lombar e que apresentem também músculos abdominais mais fracos.

Conclusão

Entre os músculos analisados, o obliquo externo atingiu os maiores percentuais de ativação, independente do local de execução do exercício. Entre os abdominais, o músculo reto abdominal atingiu os menores percentuais de ativação em todos os exercícios analisados. A exigência muscular foi maior quando os exercícios foram realizados no solo, comparativamente às situações similares realizadas no *Reformer* e no *Cadillac*. A instabilidade da superfície não parece ter influenciado o nível de ativação muscular no exercício *leg circle*. Sugere-se que futuros estudos avaliam a ativação da musculatura do *powerhouse* levando em consideração aspectos como o nível de aprendizagem dos exercícios e bem como indivíduos portadores de patologias, como por exemplo dor nas costas de origem inespecífica.

Autoria. Todos os autores contribuíram intelectualmente no desenvolvimento do trabalho, assumiram a responsabilidade do conteúdo e, da mesma forma, concordam com a versão final do artigo. **Agradecimentos.** Os autores agradecem a empresa PhysioPilates pelos aparelhos cedidos para a pesquisa. **Conflito de interesses.** Os autores declaram não haver conflito de interesses. **Origem e revisão.** Não foi encomendada, a revisão foi externa e por pares. **Responsabilidades Éticas.** *Proteção de pessoas e animais:* Os autores declaram que os procedimentos seguidos estão de acordo com os padrões éticos da Associação Médica Mundial e da Declaração de Helsinque. *Confidencialidade:* Os autores declaram que seguiram os protocolos estabelecidos por seus respectivos centros para acessar os dados das histórias clínicas, a fim de realizar este tipo de publicação e realizar uma investigação / divulgação para a comunidade. *Privacidade:* Os autores declaram que nenhum dado que identifique o paciente aparece neste artigo.

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Efeitos da crioterapia por imersão sobre o desempenho sensório-motor de esportistas após protocolo de fadiga muscular

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RESUMO

Objetivo: O objetivo deste trabalho foi avaliar os efeitos da crioterapia por imersão (CI) sobre o desempenho sensório-motor de esportistas após protocolo para indução de fadiga muscular localizada.
Método: O presente estudo teve caráter experimental e delineamento prospectivo e teve participação de 36 esportistas universitários que foram divididos em três grupos: grupo recuperação passiva (RP), grupo crioterapia por imersão a 5°C (CI5°) e grupo crioterapia por imersão a 10°C (CI10°). Todos os grupos foram submetidos a protocolo de fadiga de membro inferior dominante em cadeira extensora. Posteriormente, o RP foi mantido em repouso, enquanto os demais grupos foram submetidos à imersão em água gelada a 5°C e 10°C, respectivamente, durante 10 minutos. Para avaliação do desempenho sensório-motor, foi utilizado o teste de equilíbrio (YBT), que foi realizado antes e no decorrer de 120 minutos após indução de fadiga.
Resultados: Embora os resultados absolutos tenham sido similares entre os grupos, em termos relativos (%), o CI5° mostrou menor desempenho sensório-motor do que RP, o que foi mais acentuado no membro não-dominante. Todos os grupos obtiveram maior desempenho no YBT após 120 minutos de recuperação, quando comparado aos primeiros momentos de análise.
Conclusão: Em conclusão, o protocolo de CI de 5°C durante 10 minutos aplicado após indução de fadiga neuromuscular resultou em menor desempenho sensório-motor no YBT, em comparação com o método de RP.
Palavras-chave: Fadiga Muscular; Crioterapia; Equilíbrio.

Efectos de la crioterapia de inmersión sobre el rendimiento sensoriomotor en deportistas después de un protocolo de fatiga muscular

RESUMEN

Objetivo: El objetivo de este trabajo es evaluar los efectos de la crioterapia (CI) por inmersión sobre el rendimiento sensoriomotor de deportistas tras un protocolo de inducción de fatiga muscular localizada.
Método: El presente estudio tuvo un carácter experimental y diseño prospectivo y contó con la participación de 36 deportistas universitarios que se dividieron en tres grupos: grupo de recuperación pasiva (PR), grupo de crioterapia a 5°C (IC5°) y grupo de crioterapia a 10°C (IC10°). Todos los grupos se sometieron a un protocolo de fatiga de miembros inferiores dominante en una silla de extensión. Posteriormente, la PR se mantuvo en reposo, mientras que los otros grupos se sumergieron en agua helada a 5°C y 10°C, respectivamente, durante 10 minutos. Para evaluar el desempeño sensoriomotor se utilizó la prueba de equilibrio (YBT), que se realizó antes y durante 120 minutos después de la inducción de fatiga.
Resultados: Aunque los resultados absolutos eran similares entre grupos, en términos relativos (%), el IC5° mostró un menor rendimiento sensoriomotor que el PR, que se acentuó más en la extremidad no dominante. Todos los grupos lograron un mayor rendimiento en los YBT 120 minutos de recuperación, en comparación con los primeros momentos de análisis.
Conclusión: En conclusión, el protocolo de CI de 5°C durante 10 minutos aplicado después de la inducción de fatiga neuromuscular resultó en un menor rendimiento sensoriomotor en YBT, en comparación con el método de recuperación pasiva.
Palabras clave: Fatiga muscular; Crioterapia; Equilibrio.

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Effects of cold-water immersion on sensorimotor performance of sportsmen after muscle fatigue protocol

ABSTRACT

Objective: The objective of this investigation was to evaluate the effects of cold-water immersion (CWI) on the sensorimotor performance of young athletes in response to local muscle fatigue.
Method: The present study had prospective experimental design and involved 36 university sportsmen who were divided into three groups: passive recovery group (PR), cryotherapy group at 5°C (CI5°) and cryotherapy group at 10°C (CI10°). All groups were submitted to a dominant lower limb fatigue protocol in an extension chair. Subsequently, the PR was kept at rest, while the other groups were immersed in cold-water at 5°C and 10°C, respectively, for 10 minutes. To assess sensorimotor performance, the Y balance test (YBT) was used, which was performed before and during 120 minutes after fatigue induction.
Results: Although the absolute results had been similar among groups, in relative terms (%), the CI5° showed less sensorimotor performance than PR, which was more accentuated in the non-dominant limb. All groups achieved greater performance in the YBT after 120 minutes of recovery, when compared to the first moments of analysis ($p<0.05$).
Conclusion: In conclusion, postexercise CWI to 5°C for 10 minutes resulted lower sensorimotor performance in YBT, compared to the PR method.
Keywords: Muscle fatigue; Cryotherapy; Balance.

Introdução

A fadiga pode ser caracterizada como redução da força muscular ou diminuição do desempenho durante atividades físicas e/ou cognitivas[1]. Por muito tempo, acreditou-se que a fadiga fosse algo repentino quando, na verdade, desenvolve-se progressivamente até o músculo não ter mais capacidade de manter a tarefa solicitada[2]. Por isso, tornou-se objeto de estudo de muitos pesquisadores, principalmente, pela importância representada para esportistas de competição. A fadiga tem caráter multifatorial e sua origem depende de diversos fatores, entre eles, características da atividade que está sendo executada[3].

De fato, no processo da fadiga muscular, ocorre redução do potencial elétrico das fibras musculares, o que pode acarretar declínio do desempenho muscular[4-6]. Por sua vez, a recuperação pós-esforço (RPE) consiste em reestabelecer a condição de homeostase do corpo, na busca de aperfeiçoar o desempenho físico-motor para uma nova carga de estímulos[7]. Entre os métodos de RPE, a crioterapia por imersão (CI) consiste na imersão de um ou mais segmentos em água gelada sob diferentes temperaturas, incluindo-se valores de 5° e 10°C [8].

Considerando-se efeitos da CI, pode-se destacar a redução na atividade metabólica e na velocidade de condução nervosa (VCN), além da diminuição de espasmos musculares e edema inflamatório[9]. No entanto, os efeitos da CI no contexto de RPE ainda são pouco compreendidos, principalmente, em razão da variedade de protocolos utilizados em termos de tempo e temperaturas utilizadas. Além disso, há importante evidência de que o resfriamento pode ocasionar alterações na condução neural, tanto nas aferências quanto nas eferências de comando motor[10], podendo prejudicar o desempenho do exercício e estabilidade sensório-motora.

A estabilidade ou equilíbrio sensório-motor pode ser caracterizado como a capacidade de manter o centro de massa sobre a base de suporte ortostático. Em geral, o equilíbrio sensório-motor é modulado por três sistemas de controle: sistema sensorial (visual, vestibular e somatossensorial), sistema musculoesquelético e sistema nervoso central[11]. Nessa perspectiva, o *Y Balance Test* (YBT) é um teste utilizado para avaliar o desempenho e estabilidade sensório-motor, por meio de mensurações da distância de alcance de cada membro inferior, obtida em três direções (anterior, póstero-medial e póstero-lateral)[12]. Entretanto, ainda não estão bem esclarecidos os efeitos da CI sobre o equilíbrio sensório-motor, utilizando-se o YBT como ferramenta principal de avaliação.

Sob essas considerações, o presente trabalho teve como objetivo avaliar os efeitos da CI sobre o desempenho sensório-motor de esportistas após protocolo de fadiga muscular localizada de membros inferiores. Tem-se por hipótese inicial que a CI prejudica a manutenção da estabilidade sensório-motora durante a execução do YBT.

Método

Casuística e delineamento de grupos

Este estudo teve caráter experimental e os procedimentos de análise foram realizados durante duas semanas. A casuística foi constituída por 36 atletas do sexo masculino praticantes de basquete e futebol. Como critérios de inclusão, foram considerados idade entre 15 e 30 anos, ausência de contraindicação para crioterapia, prática esportiva superior a um ano e estar atuando em treinamentos e competições regularmente. Como critérios de exclusão e não inclusão, foi considerada presença de lesão musculoesquelética no MI dominante nos dois meses antecedentes à coleta, doença de Raynaud ou alergias ao frio e atividade laboral que exija nível de esforço em intensidade que impossibilitasse que o participante esteja em condição orgânica de homeostase no momento de participação da pesquisa.

Os participantes foram distribuídos em três grupos de forma aleatória estratificada pela idade, considerando-se o tipo de intervenção recuperativa a ser realizada após o estabelecimento de fadiga: grupo Recuperação Passiva (RP), preenchido por participantes que foram mantidos em repouso pós-esforço; grupo CI a 5°C (CI5°), composto por participantes submetidos a protocolo de imersão em água gelada a 5±2°C; e grupo de crioimersão a 10°C (CI10°), com participantes submetidos a protocolo de imersão em água gelada a 10±2°C. O protocolo de indução à fadiga foi similar a todos os grupos e os protocolos recuperativos tiveram duração de 10 min. Os participantes dos grupos CI5° e CI10° foram mantidos em posição ortostática, no interior de um recipiente com capacidade de 240 litros, preenchido com água até a altura das gônadas. Para o resfriamento da água, foram utilizados cubos de gelo e a temperatura controlada por um termômetro flutuante. A escolha dos valores de temperatura e tempo foram feitas, considerando-se a maior frequência de uso em protocolos similares que visam a RPE em estudos previamente publicados[13, 14, 15].

Toda a pesquisa foi desenvolvida no Laboratório de Estudo do Músculo Estriado (LEME), situado na Clínica Escola Integrada (CEI), do Instituto de Integrado de Saúde (INISA/UFMS). As coletas de dados foram realizadas em ambiente com temperatura entre 21±2°C e umidade de 40 a 60%. Os participantes com 18 anos ou mais e os responsáveis assinaram um Termo de Consentimento Livre e Esclarecido (TCLE); já os participantes legalmente incapazes assinaram um Termo de Assentimento Livre e Esclarecido (TALE). A pesquisa foi aprovada pelo Comitê de Ética em Pesquisa Unidade Federal de Mato Grosso do Sul (UFMS) sob o parecer número 2.920.457 e foi registrado no Registro Brasileiro de Ensaios Clínicos (ReBEC; ID Number: RBR-2z73q5).

Procedimentos

Na primeira semana, foi realizada caracterização geral, avaliação antropométrica e familiarização do participante com o ambiente, equipamentos, instrumentos, posições, movimentos adequados do YBT e execução de esforços máximos e submáximos. Na segunda semana, os participantes retornaram para a realização do estudo experimental. Como procedimento padrão, para a familiarização e teste de exaustão, cada participante foi posicionado numa cadeira extensora, mantendo-se com o joelho flexionado a 90°, sendo estabilizado por duas fitas: uma na região proximal dos membros inferiores (MMII) e a outra no nível do tronco[16, 17, 18].

No teste de exaustão, primeiramente, foi determinada a força isométrica máxima, mediante a execução de um teste de contração isométrica voluntária máxima de extensão de joelho em cadeira extensora. A força isométrica máxima representou o máximo esforço exercido a partir de três esforços máximos, os quais foram realizados contra uma célula de carga[16]. Cada contração durou três segundos com intervalo de cinco minutos cada repetição, de forma a permitir recuperação dos músculos avaliados. Em seguida, cumpriu-se o protocolo de indução à exaustão, em que o participante realizava um esforço correspondente a 40% da força máxima até a exaustão. Esta condição foi determinada quando houvesse oscilação maior do que 5% no esforço a ser mantido ou até que o participante relatasse ser incapaz de continuar o protocolo de exaustão[17, 18]. Para a comprovação de fadiga e análise do desempenho neuromuscular, foi utilizada eletromiografia de superfície dos músculos *rectus femoris* (RF), *vastus lateralis* (VL) e *vastus medialis* (VM)[16]. Todos esses procedimentos foram feitos de forma unilateral, utilizando-se do membro inferior dominante. O eletromiógrafo utilizado foi da marca Miotec (Miotec Equipamentos Biomédicos LTDA, Porto Alegre, RS, Brasil), equipado com quatro canais aos quais foram conectados sensores e a célula de carga. Para análise do sinal eletromiográfico e confirmação de fadiga, foi utilizado o *software* MiotecSuite 1.0.

Para avaliar o equilíbrio e propriocepção, foi utilizado o YBT que consiste em linhas concentricamente dispostas no solo, separadas por uma angulação de 45°, cada uma medindo 120 cm, marcadas em uma escala de um centímetro. O teste foi realizado bilateralmente e tinha início sempre que o participante retirava um membro inferior (MI) do chão e então era realizado o alcance. O apoio bipodal só era permitido ao término de cada alcance, sendo realizadas três repetições de cada MI em cada uma das três direções, obedecendo sempre a sequência: anterior, póstero medial e póstero lateral[12]. O YBT foi realizado antes (momento pré-exaustão), imediatamente após o protocolo de fadiga (exaustão), aos 15 minutos (Rec15), 30 minutos (Rec30), 60 minutos (Rec60), 90 minutos (Rec90) e 120 minutos (Rec120) após a exaustão. Antes da primeira coleta do YBT, os participantes executavam o teste como forma de preparação e, somente na terceira, foram coletados os valores referentes aos alcances (Figura 1).

Análise estatística

As variáveis independentes do estudo foram: intervenção de RPE, distribuída em três níveis (RP, CI5°, CI10°) e momento de análise, formatado em até sete níveis de comparação. Já as variáveis dependentes foram idade, massa corporal, estatura, histórico de treinamento esportivo e carga horária semanal, que foram utilizadas na caracterização dos grupos estudados, além das medidas de desempenho no YBT em valores absolutos e relativos (%), considerando-se o momento pré-exaustão como referência.

As medidas de massa corporal e idade foram analisadas a partir do teste de Kruskal-Wallis (*Kruskal-Wallis One-Way ANOVA*), complementado com o teste de Dunn. As outras características gerais foram avaliadas mediante emprego da análise de variância (*One-Way ANOVA*). Para a análise dos resultados do YBT, considerando a combinação entre grupo e momento da análise, foi utilizada variância de duas vias, de medidas repetidas (*Two-Way RM ANOVA*), complementada com teste de Bonferroni. O nível de significância considerado foi de 5%.

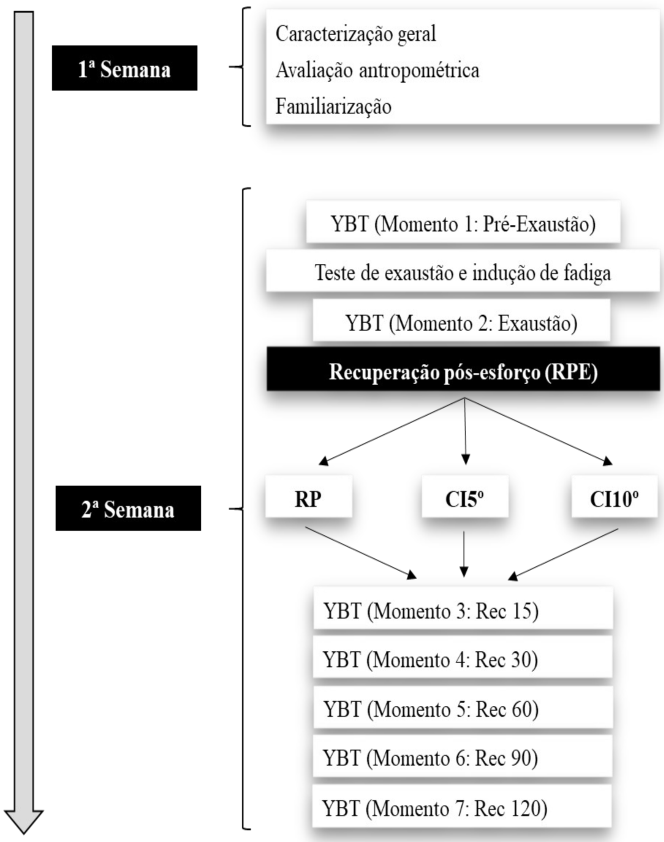

Figura 1. Fluxograma das etapas do estudo de acordo com o grupo e momento de avaliação; YBT, teste de equilíbrio Y; RP, grupo Recuperação Passiva (RP); (CI5°), grupo de crioterapia por imersão a 5±2°C; CI10°, grupo de crioterapia por imersão a 10±2°C; Rec 15, momento de recuperação de 15 minutos após fadiga; Rec 30, momento de recuperação de 30 minutos após fadiga; Rec 60, momento de recuperação de 60 minutos após fadiga; Rec 90, momento de recuperação de 90 minutos após fadiga; Rec 120, momento de recuperação de 120 minutos após fadiga.

Resultados

As características demográficas dos participantes da pesquisa são apresentadas na Tabela 1. Não foram observadas diferenças significativas nas comparações entre grupo.

Tabela 1. Características gerais dos participantes

Variável	Grupo		
	RP	CI5°	CI10°
Idade (anos)	17,0 (16,0−17,5)	17,0 (16,0−17,5)	16,0 (16,0−17,5)
Massa corporal (kg)	66,1 (61,8−80,8)	68,0 (63,8−76,9)	69,1 (63,2−83,8)
Estatura (cm)	176,9±6,1	177,8±8,0	180,5±7,6
H.Prática (anos)	5,58±2,91	5,92±2,91	6,42±4,54
C.H.Sem. (h)	12,0±9,2	12,3±6,2	11,2±5,3

H.Prática, histórico de prática esportiva; C.H.Sem., carga horária semanal de prática esportiva. Valores de idade e massa corporal expressos em mediana e semi-amplitude; Kruskal-Wallis One Way ANOVA. Outras variáveis são apresentadas em média ± desvio-padrão; One Way ANOVA (p>0,05).

Na Tabela 2, constam os resultados de YBT segundo lado, grupo e momento de avaliação. Não foi verificada interação entre os fatores avaliados (p>0,05). Além disso, não foram encontradas diferenças significativas no lado dominante quando considerada a combinação entre intervenção de RPE e momento de análise (p=0,254 e p=0,057, respectivamente). Por outro lado, quando fixado o grupo, o RP obteve menor escore no YBT no lado não-dominante no momento pré-exaustão, se comparado aos momentos Rec30, Rec60, Rec90 e Rec120 (p=0,002). Ademais, não foram constatadas diferenças estatisticamente significativas nas comparações entre grupos.

Os resultados relativos (delta) de YBT para membro dominante e não-dominante, levando-se em conta o momento pré-exaustão como referência, estão apresentados nas Figuras 2 e 3. Considerando-se o membro inferior dominante, no momento Rec60, o grupo CI5° apresentou maior escore relativo de YBT do que RP (Figura 2B). Na análise de momento de forma isolada, odesempenho no YBT foi maior no momento Rec120, quando comparado aos momentos Exaustão e Rec15 (Figura 2C).

Em relação aos resultados de membro inferior não-dominante, o grupo CI5° mostrou menor performance de YBT do que o RP (Figura 3A). Levando-se em conta a combinação entre grupo e momento, o grupo CI5° apresentou menores escores relativos de YBT do que RP nos momentos Rec15, Rec30 e Rec90 (Figura 3B). Quanto ao efeito de momento, o desempenho no YBT foi maior no momento Rec120, quando comparado aos momentos Exaustão e Rec15 (Figura 3C).

Tabela 2. Medidas descritivas de escore do *Y Balance Test*, segundo membro inferior, grupo e momento de análise.

Membro inferior	Grupo	Momento							P-Valor		
		Pré-exaustão	Exaustão	Rec15	Rec30	Rec60	Rec90	Rec120	Grupo	Momento	Interação
D	RP	67,6±8,7	67,7±10,0	68,2±9,5	68,7±10,0	69,4±9,2	69,4±9,1	69,7±9,1	0,254	0,057	0,085
	CI5°	64,9±5,3	64,4±5,2	63,4±5,3	63,4±5,3	63,2±5,3	63,8±5,5	64,6±6,1			
	CI10°	66,0±5,6	64,3±5,1	64,7±5,6	65,8±6,1	65,8±6,3	65,7±6,7	65,9±7,0			
ND	RP	67,6±7,6	69,0±7,6	69,1±8,4	69,9±8,0 *	70,2±8,5 *	70,2±7,8 *	70,8±7,6 *	0,355	0,002	0,074
	CI5°	66,7±5,5	65,6±5,8	64,6±5,5	65,4±5,1	65,8±5,1	65,5±5,1	66,6±5,0			
	CI10°	67,2±5,9	66,8±6,0	67,3±6,5	67,0±6,0	67,7±7,0	68,9±7,2	68,8±6,5			

D, membro inferior dominante; ND, membro não-dominante. Pré-exaustão, momento pré-exaustão (antes da fadiga); Exaustão (após fadiga); Rec15, momento de recuperação de 15 minutos; Rec30, momento de recuperação de 30 minutos; Rec60, momento de recuperação de 60 minutos; Rec90, momento de recuperação de 90 minutos; Rec120, momento de recuperação de 120 minutos. Valores expressos em média±desvio-padrão. * p<0,05 vs. momento Pré-exaustão (dentro do grupo). *Two-Way* RM ANOVA e teste de Bonferroni.

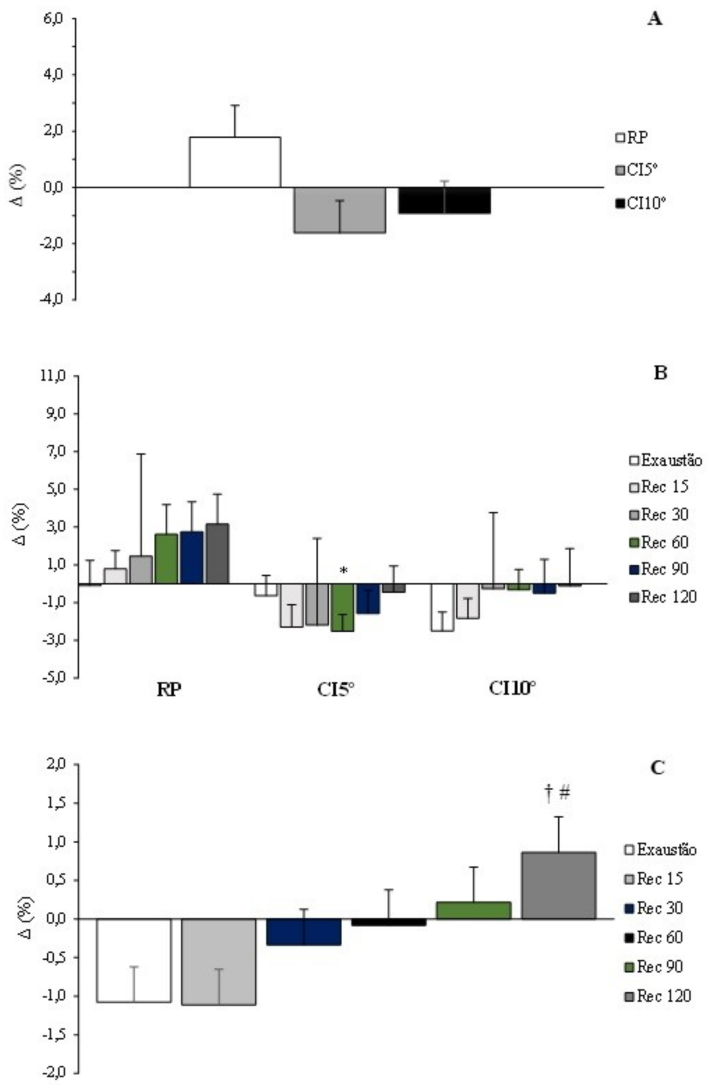

Figura 2. Valores relativos (Δ%) de escores do Y Balance Test, considerando-se o momento pré-exaustão para o membro inferior dominante. (A) Efeito de grupo; (B) Efeito da combinação entre grupo e momento, * p<0,05 vs. RP; (C) Efeito de momento, † p<0,05 vs. Exaustão; # p<0,05 vs. Rec 15; Two-Way ANOVA e teste de Bonferroni.

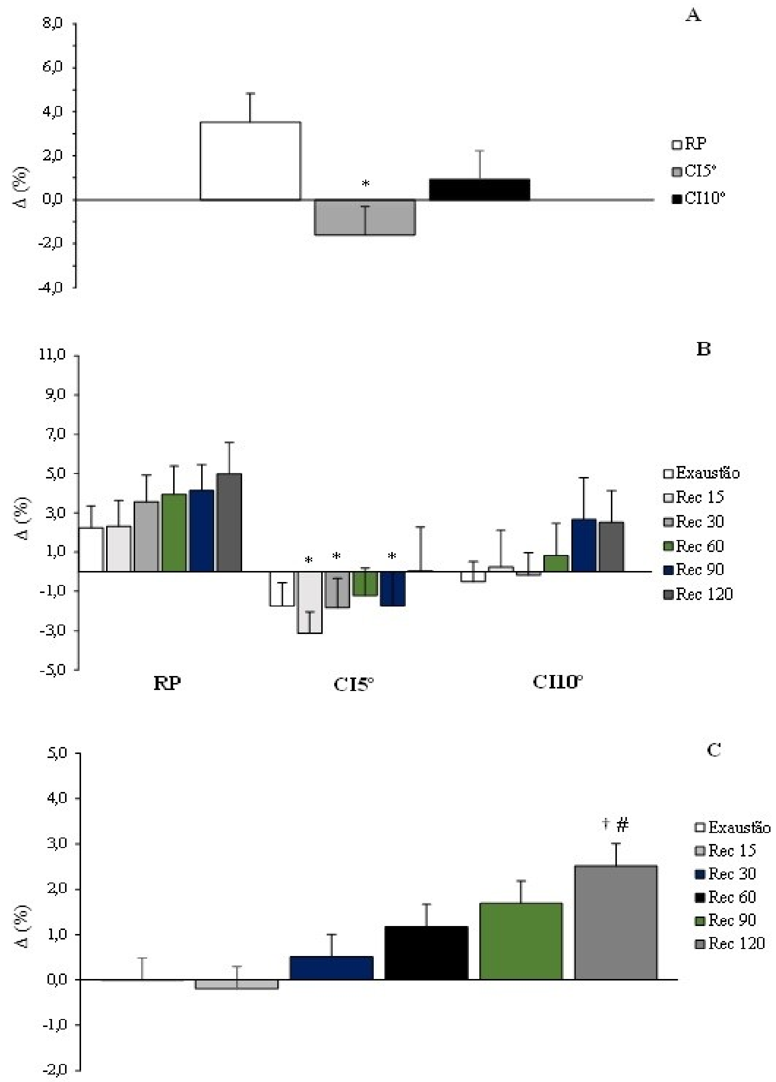

Figura 3. Valores relativos (Δ%) de escores do Y Balance Test, considerando-se o momento pré-exaustão para o membro inferior não-dominante, submetido apenas a recuperação. (A) Efeito de grupo, * p<0,05 vs. RP; (B) Efeito da combinação entre grupo e momento, * p<0,05 vs. RP; (C) Efeito de momento, † p<0,05 vs. Exaustão; # p<0,05 vs. Rec 15; Two-Way ANOVA e teste de Bonferroni.

Discussão

O presente estudo teve como objetivo avaliar o efeito da CI no desempenho sensório-motor de esportistas amadores, em resposta a um protocolo unilateral de fadiga muscular localizada. Em termos absolutos (Tabela 2), foram identificadas mudanças estatisticamente significativas apenas no grupo submetido a recuperação passiva (RP) no lado não dominante, o que foi sustentado por aumento progressivo do desempenho no YBT durante o período de recuperação. Considerando-se os valores relativos (delta), verificou-se que o desempenho funcional foi menor no grupo CI5°C em comparação ao RP (p<0,05) no membro não-dominante (Figura 3); em geral, os resultados se normalizaram com 120 min após a exaustão em ambos os MMII, sem diferenças entre os grupos (Figura 3C).

Segundo a hipótese inicial, a administração de CI reduz a manutenção da estabilidade sensório-motora, o que foi comprovado, principalmente, em resposta ao protocolo de 5°C quando comparado à RP (Figuras 2 e 3). Previamente, autores[19, 20] reportaram que o desempenho funcional e controle neuromotor foram afetados adversamente após resfriamento. Giemza et al.[21] verificaram que a intervenção crioterápica de corpo todo alterou a capacidade de adaptação e automação do controle postural; a menor estabilidade anteroposterior se associaria com maior resfriamento segmentar, especialmente, de joelhos e tornozelos. Nesse contexto, maiores valores de desempenho e de estabilidade sensório-motora do grupo RP seriam decorrentes de maior recrutamento muscular e controle motor em relação aos demais grupos, principalmente, ao grupo CI5°.

De fato, o controle neuromuscular é baseado em informação subconsciente a partir de mecanorreceptores e processos internos ao sistema nervoso central (SNC), os quais permitem controle de movimento por meio de atividade muscular coordenada. Essa resposta é mediada a partir de complexa interação entre mecanismos de controle por *feedback* e *feedforward*[2]. Entre diversos efeitos, a crioterapia reduz a temperatura do tecido e a VCN[10], conforme a hipótese inicial do presente trabalho. Contudo, reduções na temperatura superficial e profunda dependem do procedimento de aplicação, temperatura inicial, tempo de aplicação, tamanho área e localização anatômica[22].

Em termos de aplicação, os métodos mais comuns de crioterapia envolvem diferentes tipos de intervenção, como embalagem de gelo picado, imersão em água, pacotes de gel, ar frio, spray de evaporação ou líquido vaporizado[23]. A imersão em água gelada é o protocolo terapêutico mais efetivo para indução de resfriamento e redução da condução sensório-motora[22]. Apesar disso, a redução de desempenho funcional não foi tão acentuada em resposta ao protocolo de 10°C, o que pode ter decorrido da combinação entre temperatura e tempo de aplicação. Na temperatura de 10°C, Algafly & George[24] verificaram que o efeito fisiológico de mudança na VCN provinda da crioterapia se dá a partir de 20 minutos. Nesse sentido, é provável que o tempo dispendido na aplicação da CI a 10°C, isto é, 10 minutos, não foi suficiente para causar alterações na VCN e no desempenho sensório-motor. É possível que os efeitos do resfriamento não tenham atingido tecidos mais profundos, uma vez que a penetração depende de diversas características teciduais, como espessura, densidade da pele, tecido adiposo e muscular[22].

Intrigantemente, na análise do membro não-dominante, em geral, não submetido a fadiga, apresentou resultados mais importantes em relação aos efeitos da intervenção de recuperação. Esse impacto mais significativo da crioterapia, mediante menor VCN e controle motor, pode ter derivado de inervação cruzada, em que a sobrecarga imposta a um membro reflete em mudanças no membro contralateral[3]. O mecanismo para que ocorra este ganho ainda não está totalmente esclarecido. Há relatos de que a ativação muscular isométrica[25] de um dos membros produz ativação no córtex correspondente provocando adaptações neurais no lado contralateral, condizentes com maior desempenho funcional. Assim, é provável que um eventual maior desempenho no não-dominante em resposta ao estabelecimento de fadiga no membro dominante tenha sido fortemente inibido pela intervenção crioterápica de 5°C.

Em conclusão, pode-se afirmar o protocolo de CI de 5°C durante 10 minutos aplicado após indução de fadiga neuromuscular resultou em menor desempenho sensório-motor no YBT, em comparação com o método de RP.

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Original

Phase angle is moderately correlated with lower-body power and fitness capacity in junior Badminton players

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ABSTRACT

Objective: Phase angle (PhA) is derived from bioimpedance analysis (BIA) and is widely used as an indicator of cellular health, cell membrane integrity, and cell function. Lower-body power and fitness capacity are of paramount importance in success in several sports, including badminton. This study aimed to evaluate the relationship between PhA and lower-body power and fitness capacity in 22 junior badminton players (14 males, 8 females, 17.7 ± 1.4 years old).
Methods: Bioelectrical impedance was used to assess body fat (BF), muscle mass (MM) and PhA. Countermovement jump test and Yo-yo intermittent test level 2 were used to evaluate lower-body power and fitness capacity, respectively. Pearson's correlation was used to assess the relationship between PhA and lower-body power and fitness capacity, with multiple regressions considering the effect of BF, MM, and age.
Results: PhA exhibited a positive relationship with lower-body power ($\beta = 0.48$; $p < 0.02$) and fitness capacity ($\beta = 0.37$; $p < 0.04$). However, these relationships lost significance after adjustment for the co-variables MM, BF, and age ($p > 0.24$).
Conclusion: PhA is associated with lower-body power and fitness capacity in junior badminton players. However, these relationships are influenced by MM, BF, and age co-variables.
Keywords: Aerobic; Anaerobic; Athletes; Bioimpedance analysis; Body composition.

Ángulo de fase se correlaciona moderadamente con la potencia de los miembros inferiores y la condición física en jugadores de Bádminton junior

RESUMEN

Objetivo: El ángulo de fase (AF) se deriva del análisis de bioimpedancia (BIA) y es usado ampliamente como indicador de la salud celular, la integridad de la membrana celular y la función celular. La potencia de los miembros inferiores y la condición física son de gran importancia para el éxito en varios deportes, incluido el bádminton. El objetivo de este estudio fue evaluar la relación entre el AF y la potencia de los miembros inferiores y la condición física en 22 jugadores de bádminton junior (14 hombres, 8 mujeres, 17.7 ± 1.4 años).
Método: Se utilizó la bioimpedancia eléctrica para evaluar la grasa corporal (GC), la masa muscular (MM) y el AF. La prueba de salto en contramovimiento y la prueba YoYo de recuperación intermitente nivel 2 fueran utilizados para evaluar la potencia de los miembros inferiores y la condición física, respectivamente. Se calculó la Correlación de Pearson para evaluar a relación entre el AF y la potencia de los miembros inferiores y condición física, con regresiones múltiples considerando el efecto de GC, MM y edad.
Resultados: AF mostró una relación positiva con la potencia de los miembros inferiores ($\beta = 0.48$; $p < 0.02$) y la condición física ($\beta = 0.37$; $p <0.04$). Sin embargo, estas relaciones perdieron significación después de ajustadas con las covariables MM, GC y edad ($p > 0.24$).
Conclusión: El ángulo de fase se asocia con la potencia de los miembros inferiores y la condición física de jugadores de bádminton juveniles. Sin embargo, estas relaciones son influenciadas por las covariables masa muscular, grasa corporal y edad.
Palabras-clave: Aeróbico; Anaeróbico; Deportistas; Análisis de bioimpedancia; Composición corporal.

Ângulo de fase está moderadamente correlacionado com potência dos membros inferiores e aptidão física

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em jogadores juniores de Badminton

RESUMO

Objetivo: O ângulo de fase (AF) é derivado da análise de bioimpedância (BIA) e é amplamente usado como um indicador de saúde celular, integridade da membrana celular e função celular. A força dos membros inferiores e aptidão física são de grande importância para o sucesso em vários esportes, incluindo o badminton. O objetivo deste estudo foi avaliar a relação entre a AF e a potência dos membros inferiores e a aptidão física em 22 jogadores juniores de badminton (14 homens, 8 mulheres, 17,7 ± 1,4 anos).

Método: A bioimpedância elétrica foi utilizada para avaliar gordura corporal (GC), massa muscular (MM) e AF. O teste de salto com contramovimento e o teste intermitente Yo-yo nível 2 foram usados para avaliar a potência dos membros inferiores e a aptidão física, respectivamente. Correlação de Pearson foi usada para avaliar a relação entre AF e potência dos membros inferiores e aptidão física, com regressões múltiplas considerando o efeito do GC, MM e idade.

Resultados: AF exibiu uma relação positiva com a potência dos membros inferiores ($\beta = 0.48$; $p < 0.02$) e aptidão física ($\beta = 0.37$; $p < 0.04$). No entanto, essas relações perderam a significância após o ajuste para as covariáveis MM, GC e idade ($p > 0.24$).

Conclusões: AF está associado à dos membros inferiores e à capacidade física de jogadores juniores de badminton. No entanto, essas relações são influenciadas pelas covariáveis MM, GC e idade.

Palavras chave: Aeróbio; Anaeróbio; Atletas; Análise de bioimpedância; Composição corporal

Introduction

Badminton is a racket sport characterized by actions of short duration and long intensity, in combination with short resting time. It is a highly demanding sport, with an average heart rate of more than 90% of the maximal HR of the player and utilizes both aerobic and anaerobic systems (approximately 70 and 30%, respectively). Moreover, the sport demands high levels of lower-body power for jumping, moving, and covering the court.[1] High lower-body power plays a huge role in success in sports as it is associated with improvements in jumping, sprinting, and agility performance.[2] Vertical jump height is regarded as one of the most important parameters in many different sports, as they can be used to measure muscular performance of the lower limbs.[3] Similarly, aerobic and anaerobic fitness are key for optimal physical performance in several sports, including badminton.[4] The countermovement jump (CMJ) has been widely used to measure the reactive power of the lower limbs as it includes the eccentric component to the jumping movement,[5] whereas the Yo-yo intermittent test is commonly used to evaluate aerobic and anaerobic performance in athletes.[6]

Body composition may affect an athlete's potential for success for a given sport as it can influence an athlete's speed, endurance, and power, whereas body composition can affect an athlete's strength, and agility. A body with greater muscle/fat ratio is often advantageous in sports where speed and muscle power are involved.[7] Bioelectrical impedance analysis (BIA) is a non-invasive method for estimating body composition and nutritional status. The phase angle (PhA) is one of the parameters derived from the BIA, and is wide used as an indicator of cell membrane integrity.[8] It reflects the relationship between resistance, the pure opposition of tissues to the passage of electrical current, and reactance, the resistive effect produced by the interface of tissues and cell membranes.[9] Moreover, PhA has been pointed as an index of water distribution between the intracellular and extracellular compartments, not only for the general population but also among athletes.[10] It has been reported that PhA may be used to assess muscle intracellular mass and composition in untrained people,[11] as well as muscle tissue integrity,[12] quality and vitality of cells,[13] hydration status,[14] and intensity efforts[15] in athletes. Similarly, PhA has already been reported to be associated with cardiorespiratory fitness in adults,[16] as well as physical conditioning and body composition in children.[17] However, most of these studies did not investigate the effect of confounding factors which could interfere in the PhA evaluation, such as muscle mass, body fat, or age. Moreover, the relationship between PhA and lower-limb power and fitness capacity is yet to be investigated.

Therefore, the aim of this study was to assess the relationship between PhA and lower-body power and fitness capacity in badminton junior athletes considering the influence of muscle mass, body fat, and age.

Methods

Participants

This is a cross-sectional study carried out in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Universidade Federal do Piauí under protocol number 2.552.506. A convenience sample composed of 22 junior elite badminton players (14 males, 8 females) aged 17.7 ± 1.4 years old was used in this study. All athletes played for the Brazilian national badminton team, trained badminton 6 sessions per week for at least 1 year, and competed in events sanctioned by the Brazilian Badminton Confederation. Athletes were contacted by referral from coaches or sporting federations. The criteria for inclusion in the study were individuals who trained with competitive objectives, participated in regional, national or international events, and had hours of weekly training equal to or greater than 6 h. Demographic (age and sex) and training volume information was obtained through a questionnaire. All volunteers were previously notified about the experimental procedures. Participants signed assent forms and parent/guardians of the underaged volunteers provided informed consent, according to resolution 466/12 of National Health Council (Brazil). Subjects with any known chronic-degenerative disease, users of any anti-hypertension medicines, or who presented any physical adversity that would impair their maximum performance were excluded from this investigation.

Study design

The investigation was carried out during the pre-season preparation in two stages. On the first day, the individuals were anthropometrically evaluated, underwent the BIA for PhA evaluation and performed the CMJ test. On the second day, after 48 hours, the participants performed the Yo-yo endurance test (Level 2) in order to evaluate their fitness capacity. The tests took place at the Sports Center from Federal University of Piauí, Brazil. The volunteers were instructed to refrain from exercises for 48 hours before the experiment procedures and to avoid the intake of protein-rich foods, caffeine and alcohol during this period. The experimental design is shown in Figure 1.

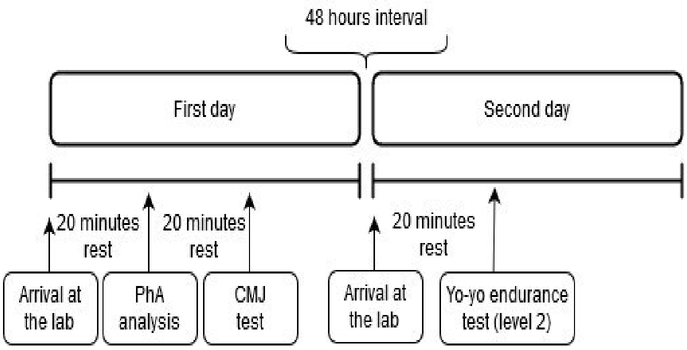

Figure 1. Schematic view of the procedures protocol. PhA, phase angle; CMJ, countermovement jump.

Anthropometry and phase angle evaluations

Body mass was assessed using a calibrated electronic scale (Tanita Solar Scale®, Brazil; 0.1kg). Height was measured using a stadiometer (0.1cm) attached to the wall (Wiso®, Brazil). The volunteers were asked to wear light clothes and no shoes. Body mass index was calculated by dividing the body mass in kg by the square of the height in meters.

Percentage body fat (%bf) and muscle mass (MM) were estimated using a bioelectrical impedance device (Inbody ®S10, Seoul, South Korea), previously validated by Fujii et al.[18] PhA was calculated as arc-tangent(reactance/resistance) × 180 °/π at a single frequency (50kHz). Before the measurements, the athletes were oriented to remove all metallic objects. They were instructed to lie in a supine position, with hands pronated and legs abducted. The skin region was cleaned with alcohol and the electrodes were placed in accordance with the manufacturer's instructions. The participants were instructed to refrain from intaking food and drink 4h, strenuous exercise 24h, and alcohol or caffeine consumption 48h prior to the measurements.

Lower-limb power evaluation

The height of the CMJ test was measured using the contact mat Jumptest® (Hidrofit Ltd, Brazil), connected to the software Multisprint® (Hidrofit Ltd, Brazil). The device has already been validated as a reliable tool to assess vertical jump performance.[19] All testing sessions were preceded by a 5-min standardized warm-up and all players were familiar with the test procedures. They were oriented to maintain their hands on their hips in upright standing position. Starting from orthostatic posture, they were instructed to flex their knees (approximately 90º) as fast as possible and immediately jump as high as possible in order to activate the SSC. They kept their hands on their hips in order to avoid interference of the arm swing on the jump performance. Knees and ankles were completely extended from the moment of the take-off to the landing. They were also asked to keep their heads facing forward at all times. The volunteers performed each jump type 3 times and all values were registered. There was a rest interval of 60 seconds between each jump repetition.[20] The mean of the jumps was used for the statistical analysis.

Fitness capacity evaluation

The fitness capacity was assessed with Yo-yo endurance test level 2. Participants were instructed to run out and back on a 20-meter course, with the required speed increasing at set intervals until they were unable to continue.[6] VO_2max (ml/kg/min) was estimated using the equation:

- $24.4 + 6 \times [\mathit{final\ speed}(km/h)]$ (for athletes aged >18 years old)
- $31.025 + (3.238 \times [\mathit{final\ speed}(km/h)]) - (3.248 \times age) + 1.1536 \times (\mathit{final\ speed} \times age)$ (for athletes aged <18 year).[21]

Statistical Analysis

Descriptive statistics are presented as mean and standard deviation. Data distribution was tested using the Shapiro-Wilk test. Standard error of measurements (SEM) was used to verify the reliability and Pearson's correlation was used to analyze the correlation between independent variables (PhA) and dependent variables (lower-body power and VO_2max). Multiple regression analysis was carried out to further test whether PhA is related with performance parameters, after adjusting for potential covariates, namely percentage body fat, muscle mass, and age. In all regression analyses, residuals were tested for normality. For all statistical analyses, significance was accepted at $p < 0.05$. The entire data analysis was performed using SPSS software version 20.0 (SPSS, Inc., Chicago, IL, USA).

Results

The general characteristics of the participants are described in Table 1. In the same table, the results of the tests of fitness capacity and CMJ can be seen. The athletes had mean values of BMI and %BF compatible with normal weight.

Table 1. Characteristics of the subjects

Variable	Mean ± SD	SEM
Age (years)	17.7 ± 1.4	0.61
Weight (kg)	62.1 ± 13.0	5.83
Height (cm)	170.4 ± 10.0	4.48
BMI (kg/m^2)	21.8 ± 1.7	1.41
BF (%)	16.3 ± 6.6	2.59
MM (kg)	30.0 ± 6.2	2.76
PhA (50 kHz)	7.7 ± 1.1	0.49
VO_2max (ml/min/kg-1)	40.6 ± 2.1	0.95
VVO_2max (km/h)	13.5 ± 1.3	0.58
CMJ height (cm)	37.7 ± 8.2	3.68

SD, standard deviation; SEM, standard error of measurements; BMI, body mass index; BF, body fat; MM, muscle mass; PhA, Phase angle; VO2max, maximal oxygen consumption; VVO2max, velocity at maximal oxygen consumption; CMJ, countermovement jump.

A moderate positive correlation was observed between PhA and CMJ height, and VO_2max (Figure 2). On the other hand, correlations of %BF were inverse and strong both for VO_2max ($r = -0.73$, $p < 0.01$) and for CMJ ($r = -0.76$, $p < 0.01$). Moreover, MM correlated positively in a high way with VO_2max ($r = 0.66$, $p < 0.01$) and very high with CMJ ($r = 0.75$, $p < 0.01$).

The multiple regression analyses between PhA and VO_2max are displayed on table 2. Three adjustment models are presented for body fat, muscle mass, and age. The correlation observed in the bivariate analysis was remained in the multivariate analysis of the regression ($\beta = 0.37$, $p < 0.04$), but this correlation did not prove to be independent of body composition (fat mass or muscle mass) or age.

The same behavior was observed when the relationship between PhA was related to CMJ in the multivariate analysis (table 2). A relationship was found between these two variables ($\beta = 0.48$, $p < 0.02$), but this relationship was not maintained when considering the covariates for body composition and age.

Discussion

The novelty of this study is that PhA was moderately associated with lower-body power and fitness capacity, which play key role in badminton performance. However, this relationship lost significance in models adjusted for body fat, muscle mass, and age. This suggests that the correlation between PhA and performance

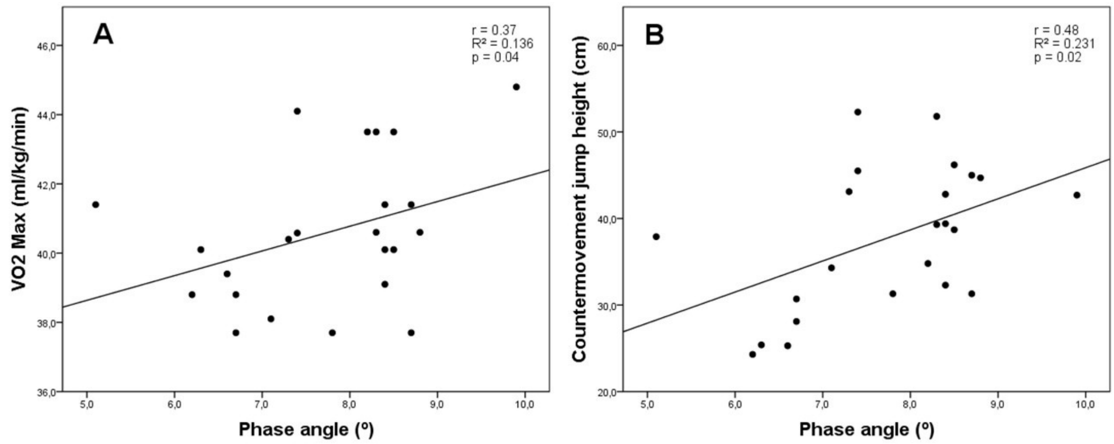

Figure 2. Pearson's correlation between phase angle and VO2max (Panel A) and countermovement jump performance (Panel B).p < 0.05.

Table 2. Influence of body composition and age in the association between PhA and fitness capacity and lower-body power

Independent variable	R^2	β	95% confidence interval	p-value
Phase angle and fitness capacity association				
Phase angle	0.14	0.37	-0.102–1.528	0.04
Model 1	0.53	0.69	-0.551–0.818	0.69
Model 2	0.60	-0.17	-1.186–0.520	0.42
Model 3	0.62	-0.17	-1.188–0.522	0.42
Phase angle and lower-body power association				
Phase angle	0.23	0.48	0.614–6.570	0.02
Model 1	0.61	0.19	-1.025–3.829	0.24
Model 2	0.68	-0.07	-3.453–2.418	0.72
Model 3	0.72	-0.07	-3.336–2.302	0.71

Linear regression with three models. Model 1: adjusted for percentage body fat; Model 2: adjusted for percentage body fat and muscle mass; Model 3: adjusted for percentage of body fat, muscle mass, and age.

is due to the muscle mass of these athletes. PhA is a novel prognostic factor already largely used in clinical context,[23] as well as in several sports disciplines, including volleyball,[24] soccer,[15] and swimming.[25] In spite of the crescent interest of researchers regarding PhA and sport performance,[15] the number of studies with specific sport disciplines, including badminton, is still scarce. Moreover, the majority of the studies assessing the relationship between PhA and performance does not take into consideration the adjustment for confounding variables. To the best of our knowledge, this is the first study to investigate this relationship in badminton players accounting for the effect of confounding factors.

The participants of this study presented similar values to the players of the Brazilian junior badminton team regarding age (17.7 vs. 16.2, respectively), height (170.4 vs. 168.1, respectively), body weight (62.1 vs. 64.7, respectively), and PhA height (37.7 vs 33.7, respectively). However, the volunteers of our study presented lower VO_2max (40.6 vs 46.3, respectively) when compared to national team players.[2]

While body composition and PhA are derived from the same BIA test, our findings indicated that PhA has a moderate association with performance. This is particularly important because PhA indicates a functional aspect of a primary body composition test, as the integrity state of the muscle tissue is determinant to its functioning.[26]

Body composition had stronger associated with fitness capacity and lower-body power than PhA. However, this information should be considered with caution. During the competition season, body composition may remain unchanged as the training results are stabilized.[27] Inversely, the integrity of the muscle tissue can alter in response to the training sessions and competition. Thus, PhA is an important variable for the assessment of sport performance regarding fitness capacity and lower-body power.

The positive correlation between PhA and power of lower limbs found in our investigation corroborates with a previous study.[15] The authors found a moderate association between PhA and short-term maximal intensity efforts in soccer players (β = 0.66; p < 0.001). However, the relationship remained significant even after adjustment for the co-variables fat-free mass and %BF (β = 0.52; p = 0.02), while the analysis in our investigation lost statistical significance using similar model (muscle mass and %BF). PhA values alter depending on the cell composition and water volume of the tissues, as well as its membrane potential.[28] Low PhA values indicate low resistance and reactance vectors, showing decrease of the cell integrity,[8] whereas high PhA values present high resistance and reactance vectors, related to a higher amount of intact cell membranes, which suggests an adequate health state.[28] Due to these technical implications, we consider that the PhA varies in relation to the integrity of the muscle tissue, which can be affected by extensive training load and eccentric exercise.[29]

This study was limited to a cross-sectional design, which does not allow establishment of a cause-effect relationship. It is noteworthy that this study was carried out during the pre-season training. Thus, these results may differ during the in-season period. Considering the methodological precautions taken before the data collection, we assume that the volunteers had no signs of muscle soreness. However, we suggest that the PhA and functional capacities evaluations should be conducted several times during the training season. This would be important to compare the stages of more and less training load and competition in order to verify possible influence of the state of physical demand in the association assessed in this study. The participants of the study were male and female badminton players, which may affect the homogeneity of the sample. In spite of these limitations, a strong point of this study is the adjustments for potential confounders in the association between PhA and aerobic and anaerobic parameters.

The main practical implication of this study is that PhA has a moderate relationship with lower-limb power and fitness capacity in junior badminton athletes. This opens the possibility of using the BIA-derived PhA as a new tool to evaluate lower-limb and fitness capacities. Therefore, PhA can play an important role in training load control, as it can be used to estimate aerobic and anaerobic capacities in junior badminton athletes. In addition, BIA is remarkably more accessible, simple to use, and affordable than similar lab-based devices. Further studies with greater sample size and other sport disciplines are suggested.

In conclusion, the results of this study indicate that PhA is associated with lower-body power and fitness capacity in junior badminton players. However, this relationship is influenced by muscle mass, percentage body fat, and age. Thus, PhA can be used as a prognostic estimator for physical performance.

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Original

Diseño y usabilidad de ParaSportAPP: una mHealth destinada a promocionar la actividad física en personas con lesión medular

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RESUMEN

Objetivo: Diseñar y evaluar la usabilidad de una *mHealth* destinada a aumentar los niveles de actividad física en personas con paraplejia usuarias de silla de ruedas manual.
Método: En primer lugar, se diseñó la *mHealth* ParaSportAPP mediante un comité de expertos en ejercicio físico y lesión medular. Posteriormente, una vez creada la *mHealth*, se instaló ParaSportAPP en los teléfonos inteligentes de 15 personas con lesión medular dorsal usuarias de silla de ruedas. 8 meses después de la instalación de la *mHealth*, se citó de nuevo a los participantes del estudio y cumplimentaron la Escala de Usabilidad del Sistema.
Resultados: Se creó una *mHealth* con 79 ejercicios físicos diferentes y con dos modos distintos de transmitirlos al usuario. Además, la aplicación es capaz de registrar los ejercicios físicos realizados al margen de los proporcionados por la misma y ofrece un informe a modo de *feedback* sobre el ejercicio físico realizado durante el día. Asimismo, los resultados hallados mostraron una puntuación media de 77.5 (18.85) en la Escala de Usabilidad del Sistema.
Conclusiones: Se ha conseguido diseñar y crear una *mHealth* funcional y con buenos niveles de usabilidad centrada en promocionar la actividad física en personas con lesión medular dorsal.
Palabras clave: App; Ejercicio físico; Paraplejia; Usabilidad.

Design and usability of ParaSportAPP: an mHealth aimed at promoting physical activity in people with spinal cord injury

ABSTRACT

Aim: To design and evaluate the usability of an mHealth aimed at increasing physical activity levels in people with paraplegia who use manual wheelchairs.
Method: Firstly, the ParaSportAPP mHealth was designed by a committee of experts in physical exercise and spinal cord injury. Subsequently, once the mHealth was created, ParaSportAPP was installed on the smartphones of 15 wheelchair users with dorsal spinal cord injury. 8 months after the installation of the mHealth, the participants were summoned again and completed the System Usability Scale.
Results: An mHealth was created with 79 different physical exercises and with two different ways of transmitting them to the user. In addition, the application is able to record the physical exercises performed in addition to those provided by the application itself and offers a feedback report on the physical exercise performed during the day. The results also showed an average score of 77.5 (18.85) on the System Usability Scale.
Conclusions: It has been possible to design and create a functional mHealth with good levels of usability focused on promoting physical activity in people with dorsal spinal cord injury.
Keywords: App; Physical exercise; Paraplegia; Usability.

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Design e usabilidade do ParaSportAPP: uma mHealth para promover a actividade física em pessoas com lesões da medula espinal

RESUMO

Objectivo: Conceber e avaliar a usabilidade de uma mHealth destinada a aumentar os níveis de actividade física em pessoas com paraplegia que utilizam cadeiras de rodas manuais.

Método: Primeiro, o ParaSportAPP mHealth foi concebido por um comité de peritos em exercício físico e lesões da medula espinal. Subsequentemente, uma vez criada a mHealth, o ParaSportAPP foi instalado nos smartphones de 15 utilizadores de cadeiras de rodas com lesão da espinal medula dorsal. 8 meses após a instalação do mHealth, os participantes do estudo foram novamente convocados e completaram a Escala de Usabilidade do Sistema.

Resultados: Foi criada uma mHealth com 79 exercícios físicos diferentes e com duas formas diferentes de os transmitir ao utilizador. Além disso, o pedido é capaz de registar os exercícios físicos realizados para além dos fornecidos pelo próprio pedido e oferece um relatório como feedback sobre o exercício físico realizado durante o dia. Além disso, os resultados encontrados mostraram uma pontuação média de 77.5 (18.85) na Escala de Usabilidade do Sistema.

Conclusões: Tem sido possível conceber e criar uma mHealth funcional com bons níveis de usabilidade centrada na promoção da actividade física em pessoas com lesões da espinal-medula dorsal.

Palavras-chave: App; Exercício físico; Paraplegia; Usabilidade.

Introducción

Convivir con una lesión medular (LM) da lugar a alteraciones sobre el organismo, pudiendo ocasionar cambios en los estilos de vida de la población con LM. Uno de los factores en los que las personas con LM se pueden ver afectadas es en la disminución de los niveles de actividad física (AF), lo cual puede repercutir en un mayor riesgo de padecer complicaciones secundarias a la lesión[1]. A su vez, esta disminución de los niveles de AF puede derivar en una pérdida de condición física, pudiendo afectar negativamente a su independencia[2].

Por otra parte, algunos estudios apuntan que mantener elevados los niveles de AF en esta población puede tener beneficios en diversas variables como la calidad de vida[3], niveles de ansiedad y depresión[4,5], niveles de comorbilidad[6], condición física y salud cardiometabólica[7].

Actualmente, el mundo está viviendo una situación de pandemia derivada de la aparición del coronavirus COVID-19. Como consecuencia de este hecho, se han aplicado diferentes medidas para la contención del virus, como la limitación de la movilidad y el cierre o limitación de los servicios de instalaciones deportivas. Estas medidas pueden afectar aún más a los niveles de AF de las personas con LM, habiendo autores que como Hall et al.[8] hablan sobre la aparición de una pandemia secundaria provocada por la inactividad. En esta línea, Marco-Ahulló et al.[9] expusieron mediante su estudio con una muestra de 20 personas con LM dorsal completa, que los participantes mostraron una disminución de los niveles de AF realizada cuando se compararon los datos en contexto pandémico con los previos a la aparición del virus.

En este escenario, donde parece que los bajos niveles de AF de las personas con LM se ven agudizados por la aparición de la pandemia, se ve aún más necesario si cabe el crear herramientas para aumentar los niveles de AF en esta población. De entre todos los recursos disponibles, parece que el tele-ejercicio puede ser una herramienta clave para la lucha contra la inactividad física en este contexto. Asimismo, aunque la literatura científica ha dedicado parte de sus esfuerzos a crear guías para la práctica de ejercicio físico e intervenciones para promocionar la AF en personas con LM[10,11], todavía a día de hoy son pocos los estudios que presentan herramientas de tele-ejercicio en sus propuestas.

De entre todas las herramientas disponibles en el mercado para llevar a cabo tele-ejercicio, las *mHealth* (aplicaciones móviles que tienen como objetivo mejorar o controlar algún factor relacionado con la salud) pueden resultar especialmente interesantes. Esto se debe a que el uso de los llamados teléfonos inteligentes o *smartphones* se ha extendido a nivel mundial, por lo que un gran porcentaje de la población tiene al alcance estos dispositivos[12]. Por tanto, son muchas las personas que pueden tener acceso a la descarga de *mHealth* sin que suponga ningún costo adicional. Además de su alcance, este tipo de herramientas puede tener un impacto significativo sobre las variables que trata, ofreciendo una atención de alta calidad. Sin embargo, al ser una tecnología novedosa y relativamente poco estudiada hasta el momento, es necesario aumentar tanto el número de *mHealth* existentes en el mercado como los estudios de usabilidad y de intervención que las hagan visibles para la comunidad científica.

Por todo lo anteriormente expuesto, el objetivo principal de este estudio es diseñar y evaluar la usabilidad de un *mHealth* destinada a aumentar los niveles de AF en personas con LM dorsal completa usuarias de silla de ruedas manual.

Material y métodos

Diseño de la mHealth

Para realizar el diseño de la *mHealth* ParaSportAPP se requirió de un equipo humano multidisciplinar creado por médicos rehabilitadores especialistas en LM, profesionales de ciencias del deporte e ingenieros informáticos especialistas en neurorehabilitación. La persona encargada de la conducción y coordinación del grupo de discusión fue un especialista en ciencias del deporte con un gran bagaje científico en el ámbito de la LM. El grupo de investigación se reunió un total de tres ocasiones.

La primera sesión se centró en la discusión sobre las funciones que debían de ser implementadas en la *mHealth* y la manera óptima para llevarlas a cabo. Una vez decidida la arquitectura de la *mHealth* se repartieron las tareas para la segunda sesión en la que los especialistas en ciencias del deporte tuvieron el encargo de diseñar un banco de ejercicios lo más amplio posible y los médicos rehabilitadores tuvieron la tarea de crear un banco de consejos de vida saludable específicos para personas con LM. Por último, los ingenieros informáticos especialistas en neurorehabilitación se encargaron de tener preparada una versión operativa de la *mHealth* a falta de incluir los datos de los ejercicios y consejos de vida saludable. En la segunda sesión (realizada dos meses después de la primera), se puso en común el trabajo realizado por cada subgrupo de trabajo y se decidió conjuntamente la inclusión/exclusión de los ejercicios/consejos en la aplicación. De los 91 ejercicios físicos presentados inicialmente por los especialistas se decidió eliminar 12 por razones de dificultad o falta de apropiación para la población objetivo, siendo definitivamente 79 ejercicios físicos los implementados en la *mHealth.* Cabe decir que se intentó lograr un equilibrio entre los grupos musculares y las cualidades físicas a trabajar para que no quedaran descompensados, primando ejercicios compuestos que pudiesen abarcar diversos grupos musculares. Por último, los médicos rehabilitadores presentaron 21 consejos de vida saludable, los cuales se aceptaron en su totalidad. Una vez decididos los ejercicios, se pasó a realizar una sesión fotográfica de los mismos, para incluir una demostración gráfica en la *mHealth*. De esta manera se le facilitó todos los datos a los ingenieros informáticos para que los incluyeran en la aplicación definitiva. Finalmente, en la tercera y última reunión se instaló la aplicación definitiva en los *smartphones* de todos los miembros del grupo de investigación y los ingenieros informáticos guiaron al resto de componentes en la exposición de la APP final.

Este grupo de trabajo se reunió en diversas ocasiones con el fin de decidir la estrategia para la promoción de la AF, los ejercicios físicos específicos a implementar en la *mHealth* y la forma de transmitir el *feedback* del ejercicio físico realizado al usuario.

Usabilidad de la mHealth

Participantes

Un total de 15 participantes con LM dorsal completa compusieron la muestra de este estudio (Tabla 1). Los sujetos cumplieron con los siguientes criterios de inclusión: i) tener una LM entre T2 y L5 de al menos un año de evolución, ii) ser usuarios de silla de ruedas a tiempo completo, iii) haber perdido completamente la función motora de sus extremidades inferiores, descrita en una puntuación de 0 en los ítems de las extremidades inferiores de la escala AIS (*Asia Impairment Scale*, la cual describe el deterioro funcional de una persona como resultado de una LM.) y iv) tener disposición a tiempo completo de un *smartphone* con un sistema operativo Android.

Este estudio fue aprobado previamente a su inicio por el comité de ética de nuestra organización [código de identificación PR(ATR) 85/2017]. Además, todos los sujetos firmaron un consentimiento informado antes de su participación en el estudio.

Instrumentos

La usabilidad es un aspecto clave cuando se habla de la calidad de un producto, siendo muchos los trabajos de investigación que la utilizan como variable para evaluar herramientas informáticas (softwares, APP...)[13,14]. Este término hace referencia al "grado en el que un producto puede ser utilizado por usuarios específicos para lograr metas determinadas con efectividad, eficiencia y satisfacción en un contexto particular de uso"[15].

Para evaluar la usabilidad de la *mHealth* ParaSportAPP los sujetos tuvieron que completar la versión original de la Escala de Usabilidad del Sistema validada al español[16]. Dicho cuestionario obtuvo un Alpha de Cronbach's de 0.89 (basado en los datos de nuestro estudio).

La Escala de Usabilidad del Sistema consta de 10 ítems (5 positivos y 5 negativos) con un sistema de respuesta tipo Likert del 0 al 4, siendo 0 "estoy totalmente en desacuerdo" y 4 "estoy totalmente de acuerdo". Los 10 ítems que componen dicha escala son: 1) Me gustaría utilizar este Sistema frecuentemente; 2) Encuentro el sistema demasiado complejo; 3) Creo que el sistema es fácil de usar; 4) Creo que necesitaría ayuda de una persona especialista para poder utilizar el sistema; 5) Creo que las funciones del sistema están bien integradas; 6) Creo que hay demasiadas inconsistencias en el sistema; 7) Creo que la mayoría de personas podrían aprender a utilizar el sistema rápidamente; 8) Encuentro el sistema muy incómodo de usar; 9) Me siento seguro utilizando el sistema; 10) Necesito aprender muchas cosas antes de poder emplear el sistema.

Procedimiento

En primer lugar, una vez obtenida una versión funcional de la *mHealth* ParaSportAPP se citó a los participantes individualmente para proceder a la firma de los consentimientos informados y a la instalación de la aplicación para evitar cualquier problema durante este proceso y asegurarse de su buen funcionamiento en primera instancia.

Una vez descargada e instalada ParaSportAPP, se les hizo una breve explicación del funcionamiento de esta a los participantes y se les animó a probarla durante un período de 8 meses. Una vez pasado este tiempo se les volvió a citar y completaron la Escala de Usabilidad del Sistema. En ese momento también se realizó una pequeña entrevista a los participantes para cerciorarse de que habían hecho uso de la aplicación y si conocían las funcionalidades de esta.

Análisis de los datos

Los datos de la Escala de Usabilidad del Sistema se digitalizaron en un documento Excel (Microsoft, Washington, EEUU). Posteriormente, se siguieron las indicaciones de los autores de la Escala de Usabilidad del Sistema y se invirtieron las puntuaciones de las preguntas negativas de la escala. Una vez realizado este proceso, se multiplicó cada ítem por 2,5 y se llevó a cabo el sumatorio de todos los ítems para hallar la puntuación final.

Análisis estadístico

Se hizo uso del Statistical Package for the Social Sciences (SPSS) versión 24 (SPSS inc., Chicago, IL, EEUU) para llevar a cabo el análisis estadístico. En este caso, primeramente, se le demandó al programa los estadísticos descriptivos (media y desviación típica) de las puntuaciones de cada ítem y totales la Escala de Usabilidad del Sistema. Una vez halladas estas puntuaciones se realizó la comprobación del supuesto de normalidad mediante la prueba de Kolmogorov-Smirnov. Posteriormente, una vez confirmado el incumplimiento de dicho supuesto, se aplicó la prueba de U de Mann-Whitney para analizar si hubo diferencias entre las puntuaciones de los sujetos según la altura de su lesión. Finalmente, se aplicó la prueba del coeficiente de correlación de Spearman para analizar si existía una asociación entre la usabilidad referida por los usuarios y su edad.

Resultados

Diseño de la mHealth

Como resultado del procedimiento de diseño se consiguió crear la *mHealth* ParaSportAPP para *smartphones* con sistemas operativos Android. La aplicación móvil ParaSportAPP se basa en la provisión de ejercicios físicos diseñados específicamente para personas con LM dorsal completa y el registro del ejercicio físico de los usuarios con el fin de aumentar la carga de AF realizada por estos.

Tabla1. Características de los participantes.

Edad (años)	Sexo (M/H)	Peso (Kg)	Altura (cm)	Altura lesión dorsal (Alta/baja)	Tiempo de lesión (años)
43.14 (9.49)	3/12	70.96 (12.92)	174.07 (9.37)	7/8	16.57 (11.03)

*Los datos están expresados mediante la media (desviación típica). M/H: Mujer o hombre. Se considera una lesión alta cuando se establece en un nivel D6 o superior.

Figura1. Ejemplos de ejercicios físicos proporcionados a demanda por la mHealth ParaSportAPP. *En la parte izquierda se puede observar un ejemplo de ejercicio físico de fuerza con implementos. En cambio, en la parte derecha se observa un ejercicio físico de la misma capacidad pero sin implementos.

ParaSportAPP tiene integrados 79 ejercicios físicos diferentes que se proveen de dos formas distintas: a demanda del usuario o de manera planificada. La primera opción se refiere a cuando un usuario decide por su cuenta realizar un ejercicio físico y recurre a la *mHealth* para ello. El otro caso hace referencia a que la *mHealth* envía cinco notificaciones diarias para realizar ejercicio físico, que de ser aceptadas proporcionarán al usuario 3 ejercicios físicos para su realización. Cada vez que se le proporciona un ejercicio al usuario, se le facilita una pequeña descripción escrita de este, una imagen en movimiento formato GIF para su visualización y las series y repeticiones que debe de realizar (en el caso de los ejercicios de resistencia se informa del tiempo que debe realizar la acción mediante una cuenta atrás).

Como se puede observar en la Figura 1, mediante la modalidad a demanda, los usuarios pueden elegir la capacidad física principal a trabajar (fuerza, resistencia o flexibilidad) y si desean hacerlo con implementos (pesas y gomas elásticas, o en su defecto, botellas de agua y toallas) o no. En cambio, en la modalidad de provisión de ejercicio de manera planificada, los ejercicios son seleccionados aleatoriamente de entre la base de datos del grupo que no necesita implementos para llevarlos a cabo. El comité de expertos decidió que fuese de este modo para que los usuarios pudiesen realizar los ejercicios en cualquier contexto sin depender del material (e.g. oficina de trabajo).

Por otra parte, ParaSportAPP es capaz de registrar el ejercicio físico realizado mediante el acelerómetro triaxial del *smartphone* y una ecuación específica para el cálculo del gasto energético en personas con LM dorsal completa extraída del trabajo de Marco-Ahulló et al.[17]. Para ello, los usuarios únicamente deben de ajustarse el *smartphone* al brazo no dominante (en la superficie lateral del brazo a mitad de camino entre la apófisis del acromion y el epicóndilo lateral del húmero) y presionar el icono "registrar" para iniciar la grabación y pulsando finalizar para darla por terminada y guardarla.

Adicionalmente, los usuarios pueden consultar el *feedback* del ejercicio físico realizado durante el día pulsando sobre el icono "seguimiento". Aquí encontrarán información sobre los ejercicios realizados y de su actividad presentada mediante un sistema de semáforo. El verde es indicativo de que el usuario ha alcanzado el objetivo diario, el amarillo significa que está cerca de hacerlo, y el rojo que todavía está lejos de alcanzarlo. Para alcanzar el color verde es necesario que el usuario realice al menos 12 ejercicios de los proporcionados por ParaSportAPP o 30 minutos de ejercicio físico a una intensidad moderada/vigorosa o su combinación equivalente, para el amarillo que realice al menos 5 ejercicios o 15 minutos de ejercicio físico a una intensidad moderada/vigorosa o su combinación equivalente, siendo clasificado como rojo toda cantidad de ejercicio físico por debajo de estos niveles. Estos grados de consecución de los objetivos diarios de AF fueron creados teniendo en cuenta las directrices científicas para personas con LM[11,18]. En dichas especificaciones se indica que las personas con LM deben de realizar al menos 20 minutos de ejercicio aeróbico a una intensidad moderada-vigorosa combinados con tres series de ejercicios de fuerza a la misma intensidad por cada grupo muscular funcional (dos veces por semana) para obtener beneficios en la fuerza muscular y capacidad cardiorrespiratoria. Sin embargo, para hallar mejoras sobre la salud cardiometabólica se indica que las personas con LM realicen al menos 30 minutos de ejercicio aeróbico a una intensidad moderada-vigorosa tres veces por semana. En el caso de nuestro trabajo, el grupo de discusión de expertos decidió fijar los objetivos diarios de ejercicio físico en 30 minutos de ejercicio físico a una intensidad moderada-vigorosa para que con alcanzar el objetivo diario 3 veces a la semana alcancen el mínimo expuesto en las directrices para la mejora de la salud cardiometabólica.

Por último, la *mHealth* ofrece diariamente una notificación informativa sobre el ejercicio físico realizado el día anterior y un consejo de vida saludable específico para población con LM dorsal completa (aleatorio de entre los 21 incluidos en la aplicación).

Usabilidad de la mHealth

Una vez realizado el análisis de los datos y estadístico, se halló una puntuación total media de 77.5 con una desviación típica de 18.85 en la Escala de Usabilidad del Sistema. Este resultado se encaja en la descripción de una usabilidad "excelente". En la Figura 2 se pueden apreciar las distribuciones de las puntuaciones de cada ítem de la escala.

Por otra parte, los análisis no mostraron diferencias significativas entre los resultados de ninguno de los ítems ni puntuación total según la altura de la LM dorsal ($z = -0.467$; $p = 0.69$; $r = -0.12$).

Finalmente, tampoco se halló una asociación estadísticamente significativa entre la usabilidad referida por los usuarios y su edad ($r = 0.315$; $p = 0.25$).

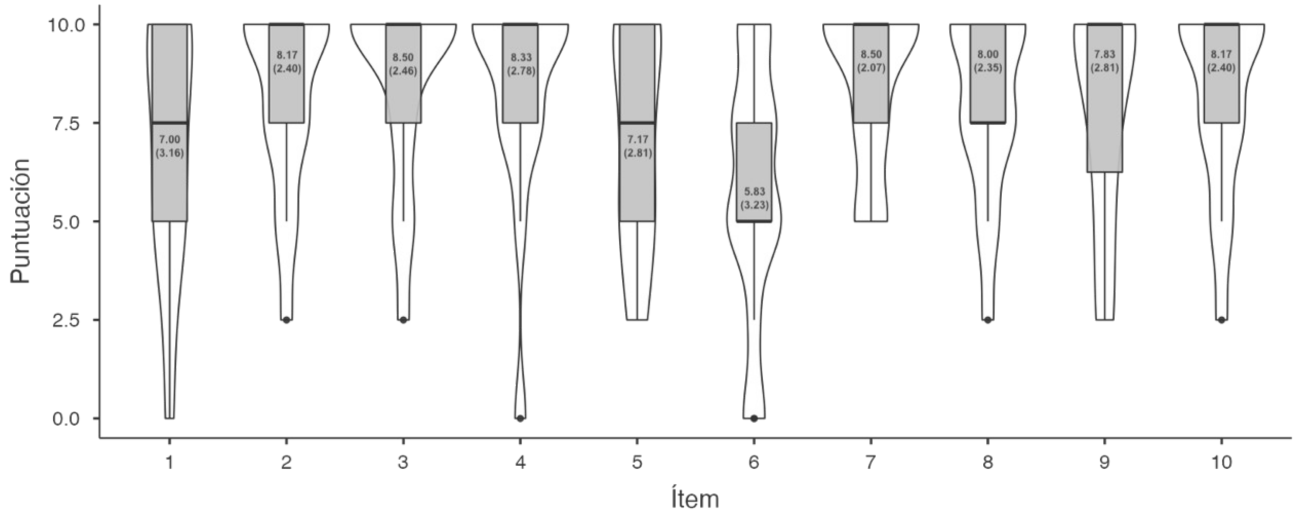

Figura 2. Diagrama de cajas de las puntuaciones de cada ítem de la Escala de Usabilidad del Sistema. *En el interior de cada caja se muestra la media (desviación típica) de cada ítem de la escala.

Discusión

Como resultado de este estudio se ha conseguido diseñar y evaluar la usabilidad de una *mHealth* creada específicamente para promocionar la AF en personas con LM dorsal completa usuarias de silla de ruedas, alcanzando de esta manera los objetivos planteados en la introducción.

Si nos centramos en los resultados hallados sobre la usabilidad de ParaSportAPP, estos indican que los participantes valoraron positivamente este aspecto de la *mHealth*. Entre los hallazgos encontrados se debe destacar que los participantes notificaron que la aplicación era fácil de usar, en cambio, los resultados relacionados con las inconsistencias del sistema, aunque buenos, se mostraron inferiores a los anteriormente mencionados. Estas puntuaciones pudieron deberse a que algunos de los sujetos reportaron que en ciertas ocasiones durante la intervención tuvieron falta de acceso a los ejercicios por la caída de alguno de los servidores de la *mHealth*. Por último, la puntuación total hallada de 77.5 se interpreta como una buena usabilidad (tan sólo a 2.5 puntos de clasificarse como excelente), incluyéndose en el índice de aceptabilidad más alto[19].

Por otra parte, no se encontraron diferencias en la usabilidad referida por los participantes según la altura de su lesión. Asimismo, tampoco se consiguió hallar una correlación estadísticamente significativa entre la usabilidad referida por los usuarios y su edad. Estos análisis parecen indicar que los usuarios refieren niveles similares de usabilidad sin importar si su lesión se establece en un nivel neurológico calificado como alto o bajo. De la misma manera, parece que la edad no es un factor que se relacione con los niveles de usabilidad de ParaSportAPP.

Una reciente revisión sobre las APP destinadas para personas con LM[20] puso en relieve la necesidad de realizar trabajos utilizando estas herramientas como medios de promoción de AF. Dicha revisión señaló un único estudio donde el objetivo fue aumentar los niveles de AF en esta población. De hecho, el artículo identificado por los autores fue el llevado a cabo por Coulter et al.[21], siendo un estudio en el que además no se hizo uso de una *mHealth* en sí, si no que se hizo uso de una plataforma web para proveer ejercicio físico.

Dicho esto, aunque la citada revisión es muy reciente, existen ya trabajos publicados posteriormente en los que se hace uso de una *mHealth* como herramienta para promocionar AF en personas con LM. Asimismo, trabajos como los de Hiremath[22] y Canori[23] mostraron aplicaciones más básicas en cuanto a contenido y con una estrategia más focalizada en proporcionar *feedback* sobre la AF realizada mediante la metodología JITAI (diseño de intervención que utiliza las *mHealth* para ofrecer información en momentos y contextos apropiados para apoyar los comportamientos de salud de los individuos). Asimismo, ninguna de las aplicaciones de estos estudios incluyó ejercicios físicos en sus propuestas.

Dejando de lado los trabajos de intervención de AF mediante *mHealth*, si nos abrimos a los estudios conducidos mediante tele-ejercicio, hallamos resultados esperanzadores en variables relacionadas con la condición física o la calidad de vida tanto en personas con LM[21,22,24] como en otro tipo de poblaciones[25,26]. Por tanto, la aplicación desarrollada en este estudio puede ser de gran importancia para lanzar nuevos trabajos de intervención con el fin de promocionar la práctica de ejercicio físico en la población de personas con LM. De hecho, como se ha comentado en la introducción, esta puede ser una herramienta con un gran potencial de aplicación en el contexto pandémico en el que actualmente se ve inmersa la sociedad derivado de la aparición del virus COVID-19.

Este estudio no estuvo exento de limitaciones. En primer lugar, durante los 8 meses en los que los participantes hicieron uso de la *mHealth* se produjeron varios cortes de luz en el lugar donde estaban emplazados los servidores de la aplicación. Durante este tiempo la *mHealth* quedó inhabilitada, lo cual ha podido afectar a las puntuaciones de usabilidad facilitadas por los participantes. Por otra parte, no se pudo incluir una base de datos de los ejercicios para que los usuarios pudiesen elegir cuál querían realizar, sino que se le proporcionaban aleatoriamente. Se decidió hacerlo de esta manera, porque en los testeos previos al estudio se vio que el tamaño de la *mHealth* aumentaría considerablemente, dificultando la instalación en teléfonos con una memoria limitada. Por último, el hecho de que ParaSportAPP sólo se pudo diseñar para un entorno Android es una de las limitaciones más relevantes, no sólo para este estudio sino para los futuros trabajos de intervención que se realicen con ella. Si en un futuro se pudiese extender también a un entorno iOS, aumentaría el alcance de los potenciales beneficios de la aplicación a personas con *smartphones* con dicho sistema operativo.

Por último, y a modo de conclusión, se debe exponer que mediante este trabajo se ha conseguido crear un *mHealth* centrada en la promoción de la AF en personas con LM dorsal usuarias de silla de ruedas manual. Esta aplicación consigue proporcionar una variedad de 79 ejercicios físicos diferentes, facilitándolos mediante 2 vías distintas. Asimismo, es capaz de registrar el ejercicio físico realizado fuera de los proporcionados por la propia aplicación, además también proporciona *feedback* sobre el ejercicio físico realizado durante el día. Por otra parte, los resultados mostraron que ParaSportAPP obtuvo unos valores de usabilidad identificados como buenos y muy cercanos a una calificación de excelentes. Finalmente, no se observaron diferencias en la usabilidad referida por los usuarios según su nivel de lesión, ni tampoco una asociación estadísticamente significativa entre la usabilidad referida por los usuarios y su edad.

Autoría. Todos los autores han contribuido intelectualmente en el desarrollo del trabajo, asumen la responsabilidad de los contenidos y, asimismo, están de acuerdo con la versión definitiva del artículo. ***Financiación.*** Este trabajo ha sido financiado por la Fundació de la Marató de TV3 bajo el número de proyecto 201720-10. ***Agradecimientos.*** Los autores agradecen a los participantes la dedicación de su tiempo para la consecución del presente estudio. ***Conflicto de intereses.*** Los autores declaran no tener conflicto de intereses. ***Origen y revisión.*** No se ha realizado por encargo, la revisión ha sido externa y por pares. ***Responsabilidades éticas.*** Protección de personas y animales: Los autores declaran que los procedimientos seguidos están conforme a las normas éticas de la Asociación Médica Mundial y la Declaración de Helsinki. Confidencialidad: Los autores declaran que han seguido los protocolos establecidos por sus respectivos centros para acceder a los datos de las historias clínicas para poder realizar este tipo de publicación con el objeto de realizar una investigación/divulgación para la comunidad. Privacidad: Los autores declaran que no aparecen datos de los pacientes en este artículo.

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Revision

Suicidal behaviors and sedentary behavior in adolescents: systematic review and meta-analysis

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ABSTRACT

Objective: To determine the association between suicidal behaviors (ideation, planning and attempt) and sedentary behavior in adolescents.
Method: Systematic searches were performed in eight databases (MEDLINE/PubMed; Web of Science; Scopus; SPORTDiscus; LILACS; SciELO; PsycINFO; CINAHL). The effect measures used for meta-analysis were odds ratios and 95% confidence intervals, directly collected from included studies.
Results: Eleven studies were included in the systematic review and six articles were included in the meta-analysis. The meta-analysis showed that adolescents who used video games/computers for ≥3 hours/day were more likely of having suicidal ideation. Adolescents who used television or video game/computer for ≥3 hours/day were more likely of having suicide attempt. Boys who spent ≥3 hours/day in combined sedentary behavior were less likely of having suicidal attempt.
Conclusions: There is an increased likelihood of suicidal behaviors, in special suicide ideation and attempt in adolescents who used video games/computers and watched television for ≥3 hours/day.
Keywords: Sedentary behavior; Adolescent; Suicidal ideation; Suicidal planning; Suicide attempted.

Comportamientos suicidas y sedentarismo en adolescentes: revisión sistemática y metaanálisis

RESUMEN

Objetivo: Determinar la asociación entre comportamientos suicidas (ideación, planificación e intento) y sedentarismo en adolescentes.
Método: Se realizaron búsquedas sistemáticas en ocho bases de datos (MEDLINE/PubMed; Web of Science; Scopus; SPORTDiscus; LILACS; SciELO; PsycINFO; CINAHL). Las medidas de efecto fueron los odds ratios y intervalos de confianza del 95%, recopilados directamente de los estudios.
Resultados: Se incluyeron once estudios en la revisión sistemática y seis estudios en el metanálisis. El metanálisis mostró que los adolescentes que usaban videojuegos/computadoras durante ≥3 horas/día tenían más probabilidades de tener ideación suicida. Los adolescentes que usaban televisión y videojuego/computadora durante ≥3 horas/día tenían más probabilidades de tener un intento de suicidio. Los niños que pasaron ≥3 horas/día in comportamientos sedentarios combinados tenían más probabilidades de tener intento de suicidio.
Conclusiones: Existe una mayor probabilidad de conductas suicidas, en ideación e intento de suicidio en adolescentes que usaron videojuegos/computadoras y vieron televisión durante ≥3 horas/día.
Palabras clave: Conducta sedentaria; Adolescente; Ideación suicida; Planificación suicida; Intento suicidio.

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Comportamentos suicidas e sedentarismo em adolescentes: revisão sistemática e meta-análise

RESUMO

Objetivo: Determinar a associação entre comportamentos suicidas (ideação, planejamento e tentativa) e comportamento sedentário em adolescentes.
Método: Pesquisas sistemáticas foram realizadas em oito bancos de dados (MEDLINE/PubMed; Web of Science; Scopus; SPORTDiscus; LILACS; SciELO; PsycINFO; CINAHL). As medidas de efeito utilizadas para a metanálise foram odds ratio e intervalos de confiança de 95%, coletados diretamente dos estudos.
Resultados: Onze estudos foram incluídos na revisão sistemática e cinco artigos foram incluídos na meta-análise. A meta-análise mostrou que os adolescentes que usavam videogame/computador por ≥3 horas/dia tinham maiores chances de ter ideação suicida. Os adolescentes que usavam televisão ou videogame/computador por ≥3 horas/dia apresentaram maiores chances de tentativa de suicídio. Os meninos com ≥3 horas/dia em comportamentos sedentários combinados apresentaram menores chances de reportar tentativas de suicídio.
Conclusões: Existe maiores chances de comportamentos suicidas, em especial ideação e tentativa de suicídio em adolescentes que usavam videogame/computador e assistiam televisão por ≥3 horas/dia.
Palavras-chave: Comportamento sedentário; Adolescente; Ideação suicida; Planejamento suicida; Tentativa suicídio.

Introduction

Considered a complex public health problem, suicide is responsible for the deaths of about 800000 people a year worldwide.[1] Among adolescents (aged 10-19 years) suicide is considered the third leading cause of death, already among youth (aged 15-24 years) is the second, and although it affects all socioeconomic groups, higher prevalence is found in socially vulnerable and male adolescents.[2-6] In contrast, nonfatal suicidal behaviors (ideation, planning, and attempt) are more prevalent in females, younger and single people, or those with psychiatric disorders.[1]

Suicidal behaviors are risk factors for suicide, non-fatal actions that precede suicide, and are considered potential risk factors for suicide.[2] During adolescence, hormonal, bodily and social environment changes occur,[1,7] which lead to greater attention to adolescent health. Adolescents are more prone and vulnerable to mental health problems such as depression, anxiety, eating disorders, substances and psychotics use disorders.[1,7] In this context, inadequate lifestyle habits such as inadequate sleep quality, sedentary behavior, difficulties in relating to friends, alcohol consumption and cigarette and drug use are associated with higher prevalence of suicidal behaviors.[8] In addition to these habits, due to technological development, evidence suggests that sedentary behavior can also interact with mental health, and deserves attention for maintaining health.[9]

Studies have shown a strong relationship between long screen time with symptoms of depression, anxiety, hyperactivity, inattention, low levels of psychological well-being and perceived quality of life.[10,11] In addition, for adolescents who stay in front of the screen for more than two hours a day, the likelihood of presenting suicidal behavior may be aggravated regardless of other factors such as weight status, eating habits or levels of physical activity.[10-14]

A systematic review has shown that adolescents with high sedentary time are more likely of reporting suicidal ideation, but because only three of the five studies evidenced this relationship, the findings were considered insufficient.[9] No systematic review with meta-analysis has associated suicidal planning with sedentary behavior; however, original studies have reported that the longer the screen-based sedentary behavior, such as video game and computer games, the greater the likelihood of adolescents having suicidal planning.[15] In meta-analysis with data of original studies from 43 countries, leisure-time sedentary was associated with increased likelihood of suicide attempts in adolescence.[16] No systematic reviews with meta-analysis that analyzed the three suicidal behaviors related to sedentary behavior were found. In this sense, the aim of the present study was to determine the association between suicidal behaviors (ideation, planning and attempt) and sedentary behavior in adolescents by systematic literature review with meta-analysis.

Method

This systematic review and meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines[17] and followed recommendations of the Cochrane Collaboration Handbook[18] to respond to the following question: What is the association between suicidal behaviors (ideation, planning and attempt) and sedentary behavior in adolescents? The study protocol was registered in the PROSPERO database (registration number: CRD42019131556).

Systematic Search Strategy

Systematic searching was performed on MEDLINE (by PubMed), Web of Science, Scopus (by Elsevier), SPORTDiscus (by EBSCOhost), LILACS (by Virtual Health Library), SciELO, PsycINFO (by American Psychological Association - APA) and CINAHL (by EBSCOhost) databases.

Search terms, keywords, health science descriptors (DECS) or medical subject headings (MESH) related to the PECO acronym (patient / population, exposure, comparison and outcome) were used. In this sense, Population (P) was composed of children and adolescents (adolesc* OR teen OR teenager OR child* OR youth OR scholar OR students OR “school children” OR “school teenager” OR teenage OR adolescence OR student OR “young people”); Exposure (E) was composed of sedentary behaviors (“sedentary behavior” OR “sedentary lifestyles” OR “screen time” OR “sitting time” OR “sedentary time” OR “screen-based” OR “television viewing” OR driving OR “video game” OR computer OR “adolescent behavior” OR “sedentary lifestyle” OR “TV viewing” OR videogame OR “time in the sitting position” OR “watching TV” OR “sedentary behavior” OR “computer use”); Comparison (C) was not applied in the search strategy; and Outcome (O) was composed of suicidal behaviors (suicid* OR “self-harm” OR “self-poisoning” OR “Self-injurious behavior” OR “self-mutilation”).

The search terms were combined using Boolean operators (OR was used to combine search terms from the same PECO group and AND to combine search terms from different groups). Truncation symbols (*) were also used to search for all words derived from the same prefix; quotation marks (“”) to search for exact terms. Filters were used to refine the search as document type (article and inpress article), keyword related to the search area.

The search was performed in November 2018 and updated in June 2019 and September 2020, considering all articles published up to these dates. Additionally, references from eligible studies and those related to the subject of this review were manually searched to find other relevant studies.

Eligibility Criterion

Articles were included in the systematic review according to the following criteria: 1) children and adolescents aged 2-19 years (when the study only reported average age values, this average should be up to 19 years); 2) all types of study design (cross-sectional, longitudinal, clinical, cohort studies, interventions, case-controls); 3) studies that analyzed the association between suicidal behaviors and any type of sedentary behavior in children and adolescents.

Review articles, course conclusion works/dissertations/theses, abstracts, book chapters and expert opinions were excluded, because, in general, these documents are transformed into articles, which would increase the duplicity of files.

Study selection and data extraction

Records retrieved by the database search strategy were exported to reference management software and duplicates were accounted for and excluded. Records were initially screened by title and abstract. Potentially eligible records were evaluated for the full text to confirm the inclusion criteria. Both steps were independently performed by two reviewers (AFS and CAAJ), who screened records by title and abstract and in case of disagreement, a third reviewer (DASS) was consulted.

The following data were extracted: authors' names and year of publication, location and year of data collection, study design, age group, type of suicidal and sedentary behavior measure. In case of divergence among data independently extracted by two reviewers (AFS and CAAJ), the article was consulted again and in the absence of consensus, a third (DASS) reviewer resolved the conflict.

When data required for meta-analysis were not available in the full record, authors were contacted by email to obtain data.[15] In the absence of feedback, results were included in the graphical presentation of the meta-analysis, but without considering them as the final result.

Risk of bias assessment

As with the other steps, the risk of bias was independently assessed by two reviewers (AFS and CAAJ) and, in the absence of consensus, a third author (DASS) was consulted. Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies of the National Institutes of Health[19] was used to assess the risk of bias. For each criterion evaluated, the following scores were assigned: "no" (N), "not reported" (NR), "yes" (Y) and "not applicable" (NA). At the end of the study classification, a total score was assigned to each study based on the number of positive responses. Each study was rated as good (i.e., most criteria had low risk of bias) - score from 13 to 14; average (i.e., some criteria had moderate bias risk) - score from 9 to 12; or poor (i.e., few criteria met and with high risk of bias) - score below 9[19,20] (Supplementary Table 1).

Statistical analysis

Independent meta-analysis were performed for each type of exposure (sedentary behavior measure: television time, video game or computer time and combined sedentary behavior measures) and outcome (suicidal behaviors: ideation and suicide attempt). The effect measures used for meta-analysis were odds ratios (OR) and their respective 95% confidence intervals (95% CI), directly collected from included studies, with adjusted values. For all analyses, OR and 95% CI were transformed into natural logarithms.

To assess the heterogeneity between the studies the participants characteristics and the study methods were considered. In addition, the heterogeneity were considered significant when p <0.1 in the chi-square test or I^2> 50%. Meta-analyses were performed by subgroups when the presentation of the study effect measure represented a source of heterogeneity (measure for female, male or both sexes). For some variables, data from primary studies were not comparable (effect measure presented by sex). Therefore, were presented in meta-analysis graphs only for viewing these data. In these cases, the authors of these studies were contacted to obtain the necessary information for data comparability, but there was no return or availability of information.

For this reason, the overalls measures obtained in meta-analysis were not considered as results of the present study. Data were comparable and, therefore, compatible with the statistical summarization for: 1) Subgroup "measure for both sexes" in the television time and video game / computer time for both suicidal behaviors (ideation and attempt); 2) Subgroups "measure for females" and "measure for males" in the combine sedentary behaviors for both ideation and suicide attempt meta-analyses. For these analyses, we use the fixed or random effect model based on data characteristics (age group, exposure and outcome assessment methods and measurement presentation) and heterogeneity results.

Sensitivity analysis to verify the influence of each effect measure on the overall OR obtained in the analysis was performed by subgroups already specified as comparable (items 1 and 2) when the meta-analysis combined three or more studies results. Publication bias analysis was not performed because the minimum number of studies for the implementation of this test (≥ 10 studies) was not reached. Statistical analyses were performed using STATA® software version 13.0 (StataCorp LP, Texas, USA).

Results

Study Selection

The literature search identified a total of 3466 publications in databases. After removal of duplicate studies (n = 603) and reading of titles and abstracts, 127 articles were read in full. At the end of the search, 10 articles were included in the systematic review. In addition, after reading the reference list, another article was included, totaling 11 studies included in the systematic review[15,16,21-29] (Figure 1).

Of the total systematic review studies (n = 11), five were included in the meta-analysis graphs because presented the same metrics for outcomes and exposures.[15,25-28] Of the six studies that were excluded from the meta-analysis, two were excluded because they analyzed suicidal behaviors in a clustered manner;[21,22] two analyzed data from different countries;[16,29] one stratified by ethnicity;[24] and one presented different analysis models, being incomparable to the other studies[23] (Figure 1).

Study characteristics

Six studies were carried out in the United States,[15,21,22,24-26] one in Canada,[28] one in the Netherlands,[23] one comprised samples from Cambodia, Indonesia, Malaysia, Myanmar, the Philippines, Thailand and Vietnam,[27] one used data from 43 countries subdivided into regions[16] and one used data from 52 countries subdivided into regions.[29] All articles included in the final analysis had cross-sectional design (n = 11) (Table 1).

Of the 11 studies included in this review, eight analyzed suicidal ideation,[15,23-29] two analyzed suicide planning,[15,29] six analyzed suicide attempt[15,16,25,26,28,29] and two articles identified grouping of the three suicidal behaviors.[21,22] The most prevalent measures of sedentary behavior in studies were hours of use or playing on the computer, hours playing video games and hours watching television[15,16,21-29] (Table 1)

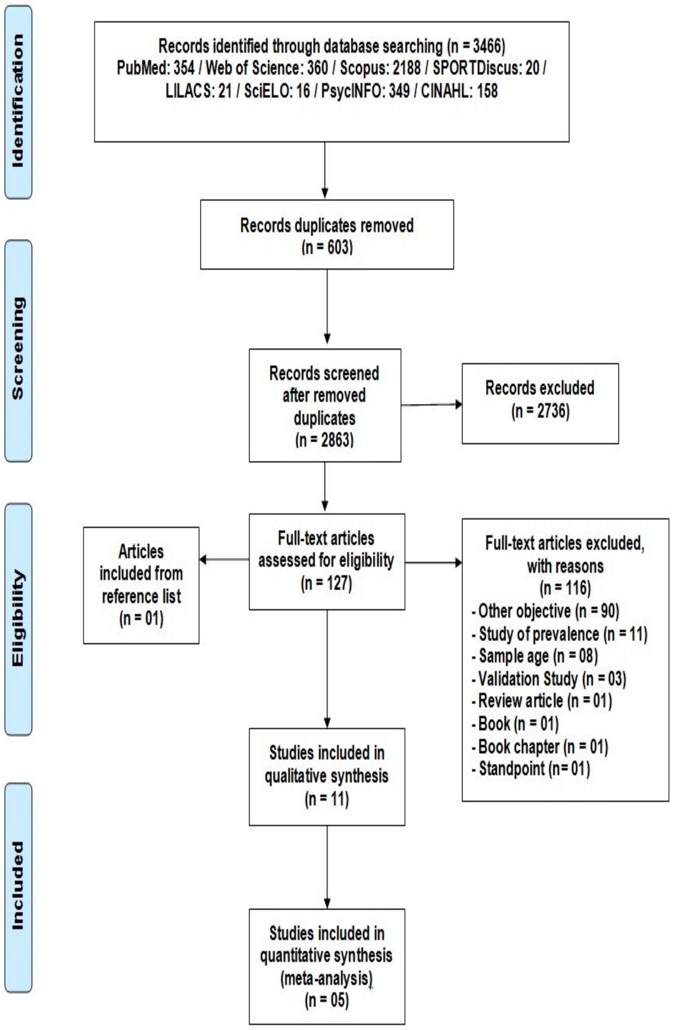

Figure 1. Flowchart of the selection of studies on the association between suicidal behaviors and sedentary behavior included in the systematic review and meta-analysis.

Risk of bias

Regarding the risk of bias of investigated studies, all studies (n = 11) presented regular risk of bias[15,16,21-29] (Table 2).

Meta-analysis and sensitivity analyses

Among the 11 studies included in the systematic review, only four[15,25,26,28] had characteristics compatible with the meta-analysis, and a study was inserted only as a graphic representation.[27] The meta-analysis showed that there is no significant increase in the odds of adolescents having suicidal ideation when presenting long television time (OR: 1.12; 95% CI: 1.00 - 1.26; p = 0.056) (Figure 2A). On the other hand, there is significant increase in the likelihood of adolescents having suicidal ideation when presenting long video games/computers use time (OR: 1.49; 95% CI: 1.29 - 1.72) (Figure 2B). The combined sedentary behaviors were pooled in the meta-analysis according to sex. There was no significant association with suicidal ideation (female OR: 0.93; 95% CI: 0.57 - 1.53; male OR: 0.89; 95% CI: 0.70 - 1.14) (Figure 2C).

In the meta-analysis for suicide attempt, both the television time (OR: 1.24; 95% CI: 1.08 - 1.43) and the video game/computer time (OR: 1.69; 95% CI: 1.43 - 2.00) were directly associated with suicide attempt in analysis for both sexes (Figure 3A-B). For combined sedentary behaviors and suicide attempt, the studies were pooled in female and male subgroups. For female there was no significant association (OR: 1.20; 95% CI: 0.90 - 1.59), but in male sedentary behaviors was associated with lower probability of suicide attempt (OR: 0.78; 95% CI: 0.61 - 0.98) (Figure 3C).

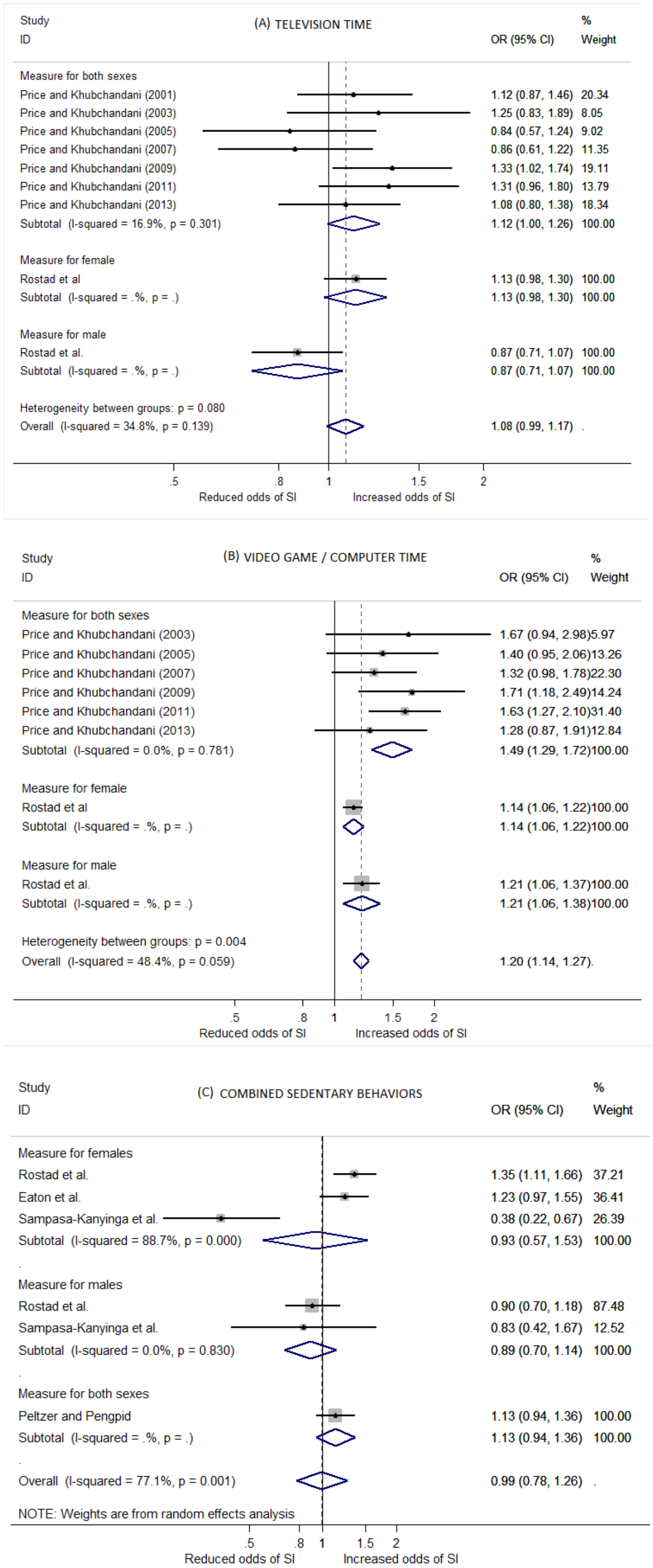

Figure 2. Forest plot showing odds ratio (OR) and 95% Confidence Intervals (CI) for the association between television time (Figure 2A), video game/computer time (Figure 2B), combined sedentary behavior (Figure 2C) and suicidal ideation (SI). Subtotal and overall estimates were obtained by meta-analysis with fixed effects.

Table 1. Description of studies on suicidal behavior and sedentary behavior in adolescent included (n=11).

Reference	Country/Research year	Design	Quality Score	Age (years)	Populaton/Sample	Suicidal behaviors	Measure of Sedentary behavior
Arat[24]	United States/2013	Cross-sectional	11/14	12-18	NR/10563	Ideation	Use of television (hours/day)
Eaton et al.[25]	United States/2007	Cross-sectional	12/14	14-18	6942/ ♀: 6322	Ideation and attempt	Use of video games, and computer (hours/day)
Lowry et al.[21]	United States/1991 - 2011	Cross-sectional	10/14	14-18	NR/ about 14000	Grouping of suicidal behaviors (ideation, planning and attempt).	Use of television, video game, and computer (hours/day)
Mérelle et al.[23]	Nederland/2013 - 2014	Cross-sectional	12/14	Average : 14.4	21053 ♂: 10400 ♀:10653	Ideation	Use of computer (hors/day)
Peltzer and Pengpid[27]	Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Thailand and Vietnam/2007 - 2013	Cross-sectional	10/14	13-15	NR / 30284 ♂: 14750 ♀:15534	Ideation	Total screen time, use of television, video game, talking to friends, and playing cards (hours/day)
Price and Khubchandani[26]	United States/2001 - 2013	Cross-sectional	09/14	14-18	NR/ 13721	Ideation and attempt	Use of television, and video game (hours/day).
Rostad et al.[15]	United States/2015	Cross-sectional	12/14	14-18	NR / 15506 ♂: 7749 ♀: 7757	Ideation, planning and attempt	Total screen time, use of television, video game and computer (hours/day).
Sampasa-Kanyinga et al.[28]	Canadá/2015 and 2017	Cross-sectional	12/14	11-20	NR / 10183 ♂: 4520 ♀: 5663	Ideation and attempt	Total screen time use of watching TV/movies, playing video/computer games, chatting on a computer, emailing, or surfing the Internet (hours/ day)
Twenge et al.[22]	United States/2009 - 2015	Cross-sectional	11/14	13-18	NR/ 506820	Grouping of suicidal behaviors (ideation, planning and attempt).	Use of television, computer, and video game (hours/day).
Uddin et al.[29]	52 countries 2003 - 2015	Cross-sectional	11/14	13-17	NR/206357 ♂: 101115 ♀: 105242	Ideation, planning and attempt.	Time sitting and watching television, playing computer games, talking with friends, or doing other sitting activities (hours/day).
Vancampfort et al.[16]	43 countries/2009 - 2015	Cross-sectional	12/14	12-15	NR/126.392 ♂: 64586 ♀:61806	Attempt	Use of television, computer, talking with friends, or doing other sedentary activities (hours/day).

NR: Not reported; ♂: male; ♀: female

Table 2. Bias risk assessment of studies included in the systematic review.

Reference	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Total score
Arat[25]	Y	Y	Y	Y	Y	N	N	Y	Y	NA	Y	NA	NA	N	11
Eaton et al.[26]	Y	Y	Y	Y	Y	N	N	NA	Y	NA	Y	NA	NA	Y	12
Lowry et al.[21]	Y	N	Y	N	Y	N	N	Y	Y	NA	Y	NA	NA	Y	10
Mérelle et al.[24]	Y	Y	Y	Y	Y	N	N	NA	Y	NA	Y	NA	NA	Y	12
Peltzer and Pengpid[28]	Y	Y	Y	N	Y	N	N	NA	Y	NA	Y	NA	NA	N	10
Price and Khubchandani[27]	Y	Y	N	N	N	N	N	Y	Y	NA	Y	NA	NA	Y	09
Rostad et al.[15]	Y	Y	Y	Y	Y	N	N	Y	Y	NA	Y	NA	NA	Y	12
Sampasa-Kanyinga et al.[29]	Y	Y	Y	Y	Y	N	N	Y	Y	NA	Y	NA	NA	Y	12
Twenge et al.[22]	Y	Y	Y	N	Y	N	N	Y	Y	NA	Y	NA	NA	Y	11
Uddin et al.[30]	Y	Y	Y	N	Y	N	N	NA	Y	NA	Y	NA	NA	Y	11
Vancampfort et al.[16]	Y	Y	Y	Y	Y	N	N	Y	Y	NA	Y	NA	NA	Y	12

Y: Yes; N: No; NA: Not applicable; NR: Not reported. Q1: Was the research question or objective in this study clearly stated?; Q2: Was the study population clearly specified and defined?; Q3: Was the participation rate of eligible persons at least 50%?; Q4: Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?; Q5: Was a sample size justification, power description, or variance and effect estimates provided?; Q6: For the analyses in this study, were the exposures of interest measured prior to the outcome(s) being measured?; Q7: Was the time frame sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?; Q8: For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as a continuous variable)?; Q9: Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?; Q10: Were the exposures assessed more than once over time?; Q11: Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?; Q12: Were the outcome assessors blinded to the exposure status of participants?; Q13: Was loss to follow-up after baseline 20% or less?; Q14: Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposures and outcomes?

Heterogeneity (I^2> 50%; p<0.1) was observed only in the suicidal ideation meta-analysis for the subgroup of "measure for female". For this reason and the characteristics of individual studies, the random effect model was applied. For the other meta-analysis, the fixed effect model was applied (data not shown in tables / figures).

Discussion

The present meta-analysis showed greater likelihood of suicide attempt among adolescents who spent more time sedentary behavior in front of the television. Watching television has often been associated with depressive symptoms, physical and sexual victimization among adolescents and being bullied in the school environment, i.e., bullying experiences that could be associated with contents broadcasted on television shows, whose violent nature promotes suicidal behavior.[15,22] In a study of trends of suicide attempts in Latin adolescents from 2001 to 2013, no significant results for association between watching television for three hours or more and suicide attempts were reported.[26] However, literature shows that higher duration and frequency of television watching are associated with unfavorable body composition, increased risk of cardiometabolic diseases, unfavorable behavioral conduct, premature death from all causes, and physiological and psychological problems.[14,30] Thus, discouraging excessive screen time may be beneficial in reducing the risk of suicide attempt.[15]

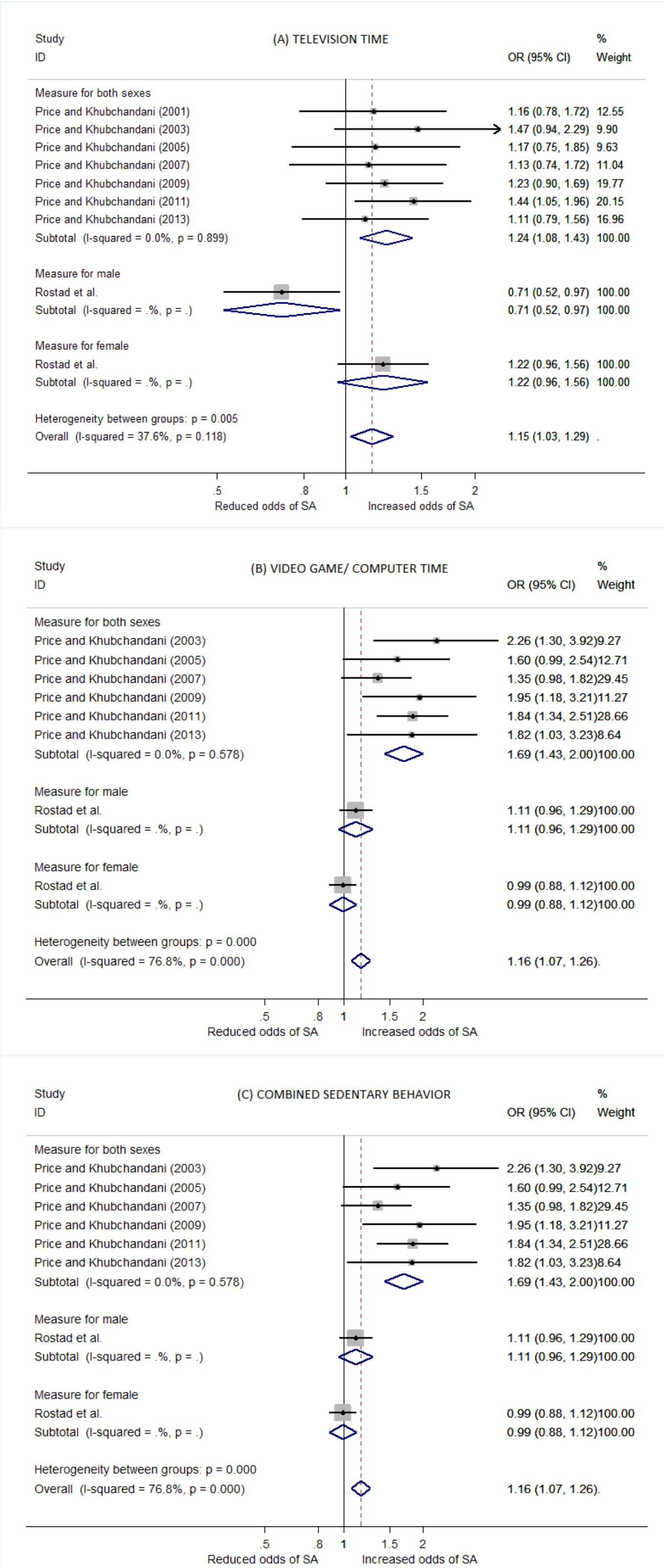

Figure 3. Forest plot showing odds ratio (OR) and 95% Confidence Intervals (CI) for the association between television time (Figure 3A), video game/computer time (Figure 3B), combined sedentary behavior (Figure 3C) and suicidal attempt (SA). Subtotal and overall estimates were obtained by meta-analysis with fixed effects.

Regarding video game/computer time sedentary behavior, the present meta-analysis found increased likelihood of suicidal ideation and suicide attempt in adolescents who spend more time using these devices. Results similar to those of the present study had already been reported by original articles.[15,26] Possible justification for this finding is that exposure to media through computer can lead to victimization, in the form of cyberbullying, which occurs through defamatory messages or threats via email, social networks, blogs and mobile phones.[15,31]Moreover, both computer games and video games can lead to increased aggression, social isolation, depressive and attention-deficit symptoms, which ultimately favor suicidal ideation.[15,32]

Only for the male three hours or more of combined sedentary behavior (television hours, video games, computer games, computer use and total screen time) was associated with decrease in the likelihood of suicidal attempt. On the one hand, the technological advances have increased the availability of information and presented new ways to connect and learn but, increased use of media by youth may have some adverse consequences, for example experiences of bullying, teen dating violence, and suicide risk.[15] Patterns differ for male and female adolescents because males may be more frequently playing video games than using social media, potentially compromising their development of interpersonal skills and making them vulnerable to all forms of bullying, but, not suicide risk and may also play video games to cope with real-life problems.[15]

In addition, this meta-analysis reported no significant increase in the likelihood of suicidal ideation, for adolescents both sexes, and suicidal attempt to female adolescents who reported three hours or more combined measures of sedentary behavior (television hours, video games, computer games, computer use and total screen time), as reported in other studies.[26,28,33] However, it should be noted that a study developed with both sexes show that more time spent in combined sedentary behavior is associated with increased odds of suicide attempts.[16] In the sensitivity analysis the combined sedentary behaviors and suicidal ideation for females showed the most important differences. When the impact of individual results was assessed, by removing analyses one at a time, withdrawing the Sampasa-Kanyinga et al. study from the meta-analysis, the result becomes significant (OR: 1.29; 95% CI: 1.06 – 1.52). The observed discrepancies may be explained, at least in part, by the difference in the cutoff point of time in sedentary behavior adopted in each study or by some random difference in the sample cut.

Finally, this meta-analysis reported no significant increase in the odds of suicidal ideation for adolescents who watched television for three hours or more, as reported in a study with Latin adolescents[26] and a trend study (2001-2013) with students from the United States.[15] Thus, the lack of association between suicidal ideation and time watching television may be justified because in the last decade, the preference of adolescents was for other electronic media that allow choice of content,[15] which in general, is not allowed by television. However, the significance values found in the analysis were borderline and the sensitivity analysis performed leaves room for a possibility of association. In addition, it was possible to perform a meta-analysis between television time and suicidal ideation with only one study of different cross-sections,[26] which may have been insufficient to analyze such association with greater sensitivity. When the impact of individual results was assessed, by removing analyses one at a time, was observed that in sensitivity test for television time and suicidal ideation the withdrawal of any study from the meta-analysis alters the result to a significant association in the same direction.

Half of the studies in this systematic review took place in the United States. From 1999 to 2016, suicide rates have been increased significantly in 44 states, and 25 states experienced increases increased 30%. In 2016 nearly 45,000 suicides (15.6/100,000 population) occurred in the United States among persons aged ≥10 years.[34] However, the differential rate of decrease in suicidal ideation versus attempts, seen over the past 20 years, suggests the pool of adolescents who have seriously considered or planned for suicide without actually attempting suicide has been decreasing, but this that impulsive or unplanned suicide attempts may have become more common.[21] In addition to mental health conditions and prior suicide attempts, other contributing circumstances include social and economic problems, access to lethal means (e.g., substances, firearms) among persons at risk, and poor coping and problem-solving skills.[34] According to studies, compared with students with no suicidal ideation or attempts, carry a weapon on school property was one of the health-risk behaviors most strongly associated with suicide attempts among female students.[21,26] Therefore, we realized through the period of the research that both the oldest studies, as well as the newest and longest-lasting studies occurred in the United States, which shows greater concern in researching this subject and treating it more openly in society.

The fact that all included studies had cross-sectional design is among the limitations of this meta-analysis, which does not allow for temporal or causal relationships. Due to the small number of studies, it was not possible to perform meta-regression analyses to explore sources of heterogeneity, and because there is only one study on the association between suicidal planning and sedentary behavior, it was not possible to perform meta-analysis with this behavior.

Conclusion

The present meta-analysis reported that there is an increased likelihood of suicide attempt in adolescents who watch television for more than three hours, but showed no association between television time and suicidal ideation. In addition, adolescents of both sexes who reported spending more than or equal to three hours playing video and computer games or using the computer were more likely to have suicide ideation and attempt. For the combination of three or more hours in different types of sedentary behaviors (television, video games, computer games, computer use and total screen time), male adolescents were less likely of having suicidal attempt, but female adolescents showed no association between combination sedentary behaviors time and suicidal attempt. Also, adolescents that combination of three or more hours in different types of sedentary behaviors showed no association with suicidal ideation.

Thus, time spent in sedentary behaviors, such as hours of watching television, playing video games, playing computer games, or using computers, can cause social and emotional problems that lead to isolation, searching for inappropriate content and bullying, and can lead to suicidal behaviors such as ideation and attempt. This information serves as a warning to parents, teachers and government organizations for possible interventions aimed at reducing sedentary behavior in the domestic, school and other social areas. For, the primary prevention of sedentary lifestyle can come from simple actions such as breaking the sedentary time, the modest reduction in screen time and the replacement of electronic games by recreational and socially interactive games.

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