UNIVERSIDADE FEDERAL DE PERNAMBUCO
UNIVERSIDADE FEDERAL DA PARAÍBA
PROGRAMA ASSOCIADO DE PÓS-GRADUAÇÃO EM EDUCAÇÃOFÍSICA UPE/UFPB
CURSO DE DOUTORADO

RELAÇÕES TRANSVERSAIS E LONGITUDINAIS ENTRE COMPORTAMENTOS DE MOVIMENTO – 24 HORAS E AUTORREGULAÇÃO EM PRÉ-ESCOLARES

NATÁLIA BATISTA ALBUQUERQUE GOULART LEMOS

JOÃO PESSOA, AGOSTO DE 2024

NATÁLIA BATISTA ALBUQUERQUE GOULART LEMOS

RELAÇÕES TRANSVERSAIS E LONGITUDINAIS ENTRE COMPORTAMENTOS DE MOVIMENTO – 24 HORAS E AUTORREGULAÇÃO EM PRÉ-ESCOLARES

Tese de Doutorado apresentada ao Programa Associado de Pós-Graduação em Educação Física UPE/UFPB como requisito parcial para obtenção do título de Doutora em Educação Física

Área de concentração: Saúde, Desempenho e Movimento Humano
Linha de Pesquisa: Atividade Física, Condições de Vida e Saúde
Orientadora: Prof. Dra. Clarice Maria de Lucena Martins

JOÃO PESSOA, AGOSTO DE 2024

Catalogação na publicação
Seção de Catalogação e Classificação

L557r Lemos, Natália Batista Albuquerque Goulart.
Relações transversais e longitudinais entre comportamentos de movimento - 24 horas e autorregulação em pré-escolares / Natália Batista Albuquerque Goulart Lemos. - João Pessoa, 2024.
169 f. : il.

Orientação: Clarice Maria de Lucena Martins.
Tese (Doutorado) - UFPB/CCS.

1. Comportamento - Autorregulação. 2. Comportamentos de movimento - 24 horas. 3. Pré-escolares. I. Martins, Clarice Maria de Lucena. II. Título.

UFPB/BC CDU 572.024(043)

Elaborado por WALQUELINE DA SILVA ARAUJO - CRB-15/514

UNIVERSIDADE DE PERNAMBUCO

UNIVERSIDADE FEDERAL DA PARAÍBA
PROGRAMA ASSOCIADO DE PÓS-GRADUAÇÃO EM EDUCAÇÃO FÍSICA
UPE-UFPB

CURSO DE DOUTORADO EM EDUCAÇÃO FÍSICA

A Tese **Relações transversais e longitudinais entre comportamentos de movimento-24 horas e autorregulação em pré-escolares.**

Elaborada por Natália Batista Albuquerque Goulart Lemos

Foi julgada pelos membros da Comissão Examinadora e aprovada para obtenção do título de DOUTORA EM EDUCAÇÃO FÍSICA na Área de Concentração: Saúde, Desempenho e Movimento Humano.

João Pessoa, 30 de agosto de 2024.

BANCA EXAMINADORA:

Prof.ª Drª Clarice Maria de Lucena Martins
(UFPB) - Presidente da Sessão

Prof. Dr Leonardo de Souza Fortes
(UFPB) – Membro Interno

Prof. Dr Rafael Miranda Tassitano
(UFRPE) - Membro Interno

Prof.ª Drª Carmen Silvia Grubert Campbell
(UCB) – Membro Externo

Prof. Dr Carlos Cristi Montero
(Pontificia Universidad Católica de Valparaíso) – Membro externo

DEDICATÓRIA

Para Gabriela, Fernando, Sandra, Eduardo, Camila, Regina, João, Geraldo (*in memoriam*), Vilma (*in memoriam*), Gessi (*in memoriam*) e Fred (*in memoriam*).

AGRADECIMENTOS

Sonhe, Acredite, Faça ... Repita!

Primeiramente, gostaria de agradecer a Deus, a Nossa Senhora e a Santo Expedito por todas as graças, desafios e pela fé que busco cultivar e fortalecer a cada dia. Obrigada por mais este acontecimento, obrigada por mais uma vitória!

É realmente desafiador expor em palavras o meu sentimento de gratidão. Foram diversas etapas nesse processo, desde o planejamento (Fazer ou não o doutorado?), passando pela seleção e ingresso, realização do projeto, até a finalização do trabalho. Diversas pessoas (e também não humanos) são listadas nesses agradecimentos. Cada um participou de alguma forma para a concretização desse trabalho, alguns em todas as etapas, outros foram surgindo ao decorrer, mas todos com um pedacinho de contribuição para o todo desta conquista pessoal e profissional.

Gostaria de iniciar agradecendo pela minha base, minha família! Vocês são a minha essência e meu fortalecimento diário.

Á minha *pixeza* Gabriela e ao meu companheiro Fernando. Meus amores, vocês são a razão de tudo. Não existem palavras para expressar nossa relação, é algo para além dessa vida. Crescemos muito enquanto família nesses últimos quatro anos e graças a deus estamos unidos, com muito mais força. A conclusão desse trabalho é uma vitória nossa. É pela família feliz, pelos *shishipechi*!!!!! Obrigada por existirem!

Aos meus filhos não humanos, Fred (*in memoriam*), Guria, Fofuchinho, Nenê, Fofinha e Fruki (sim, em casa tem mais bicho que gente!) por todo carinho diário que fortalece e energiza!

Aos meus tios/pais Sandra e Eduardo que me adotaram como filha, que sempre cuidaram dos meus estudos e me incentivam a chegar onde eu nem imagino, ou mesmo, dúvido. Como cair frente a força de vocês? Mesmo passando por uma situação inimaginável que foi aquele 2 de maio de 2024, e todas as consequências desse dia, vocês estão sempre em contato. Sempre um E aí, como está? Como vão as tuas coisas? Amo vocês meus guerreiros! Obrigada por tudo!

Á minha prima/irmã Camila, meu orgulhosinho! Que mulher forte, batalhadora e ao mesmo tempo, leve você se tornou. Obrigada por todo companheirismo e incentivo! Como é bom te ter na minha vida e na vida da tua afilhada.

Á minha mãe Regina que mesmo com todas as dificuldades não desistiu. Além de ter sido mãe solteira em uma época de um machismo fortíssimo, foi capaz, aos 60 anos, de se salvar (e salvar o spoke!) de um acontecimento que levou muitas vidas. Obrigada meu Deus por ter deixado minha mãe aqui nesse plano mais um pouco comigo. Te amo!

Ao meu pai João, minha madrasta Sandra, aos meus irmãos Bruna e Vitor, e meu sobrinho Arthur, pelo exemplo de união, fé e valorização de cada momento da vida, seja qual for a circunstância. Eu confio que nosso encontro foi no momento providenciado por Deus, que permitiu que esse amor pudesse existir, que essa família pudesse crescer! Amo vocês.

Ao meu avô Geraldo (*in memoriam*) meu anjo protetor, meu pai querido, meu grande amigo. Eu sei o quanto você faz parte dessa vitória. Obrigada por estar presente em um plano maior.

Agradeço minha sogra vilma (*in memoriam*) e a tia Gessi (*in memoriam)*! Que falta vocês fazem em nossas vidas. Obrigada por todos os momentos, pelos incentivos, acolhimento e ensinamentos.

Às minhas amigas de infância, minhas pétalas Hellen, Lissana, Luiza e Ananda. Eu amo nossa amizade. Amo o quanto somos diferentes e ao mesmo tempo tão parecidas. Mesmo cada uma morando em um canto, estamos sempre na torcida por todas.

Aos amigos que a vida me trouxe, Família Marquardt (Lara, Gustavo, Cecília e Nicholas), Família Sabino (Michele, Bruno, Bruna e Lis), Família Gonçalves (Mariah, Fernando e Leonardo), Família Dias (Solange e família), Família Brito (Jorge, Ohanna, Diego e Lucca) como é bom ter a família de vocês junto a nossa. Amigos que sempre estão torcendo e incentivando. Muito obrigada!

À minha terapeuta Vanessa Novais, um exemplo de profissional! Obrigada pelas conversas sobre Funções Executivas, Sistema Límbico e Córtex Pré-Frontal no meio das terapias!!! Obrigada por me auxiliar nesse processo e outros pontos da vida!

Quero agradecer à Ginástica, em especial a Ginástica Rítmica, pois foi essa modalidade esportiva que me direcionou profissionalmente. Agradeço a deus pela oportunidade que me foi ofertada na infância e que hoje posso passar a outras crianças.

Agradeço muito a minha profissão, que orgulho que eu tenho dela! A Educação Física me fez conhecer muitas pessoas que eu admiro e que eu trouxe para a minha vida, e também me oportunizou conviver com outras que escolhi não manter relacionamentos. Assim eu aprendi, e sigo aprendendo, que qualquer circunstância, é sim uma oportunidad de aprendizado.

Gostaria de agradecer aos meus colegas do Colegiado de Educação Física da Universidade Federal do Vale do São Francisco, que me deram todo suporte para o afastamento integral para cursar o doutorado. Em especial, agradeço ao meu colega Ferdinando Carvalho que me apresentou a professora Clarice Martins e o professor Jorge Mota, sendo o primeiro intermediador do processo e colaborador ao longo da pesquisa. Aos colegas que assumiram minhas disciplinas no início da pandemia, aos professores substitutos, e ao nosso técnico administrativo Luciano que está sempre solicito a resolver qualque questão.

Agradeço também à família Gymnações, aos ginastas e familiares que me deram muito incentivo para o afastamento e que ainda estão lá no grupo esperando nosso retorno.

Agradeço, imensamente, a minha orientadora professora Dr. Clarice Maria de Lucena Martins (que tem o nome comprido igual ao meu!). Professora Clarice é um exemplo em vários sentidos, como mulher, mãe e profissional. Eu tenho aprendido tanto com ela! Só ainda não consegui gerenciar todas essas áreas e ainda ser *Fitness!* Quem sabe agora finalizando o doutorado eu consiga! Professora, muito obrigada por compartilhar tanto conhecimento, por me encourajar a ir sempre mais longe, por tentar sempre trazer para a direção correta, que envolve responsabilidade, mas que não necessariamente precisa envolver sofrimento.

Ao Grupo de Estudos em Atividade Física e Desfechos em Saúde (GEADES-UFPB), por terem me acolhido e compartilhado todas as experiências e conhecimentos. Agradeço também a toda equipe que esteve envolvida na coleta de dados em Petrolina. Em especial, agradeço a minha parceira de doutorado Jéssica Mota, que é uma grande incentivadora, que além de cuidar do próprio trabalho, deu suporte para a realização do meu projeto. Minha admiração por você é enorme.

Ao Grupo de Pesquisa em Plasticidade Neuromotora (GPPN-UNIVASF), especial aos estudantes que fizeram parte da equipe que trabalhou diretamente comigo Bárbara, Pablo, Lívia, Karoline, Andressa, Hércules, Sarah e todos os estudantes que passaram algum momento conosco nesse projeto. Tudo aconteceu porque tive vocês firmes e fortes ao meu lado. Muito obrigada por tudo.

Agradeço o apoio e acolhimento da Secretaria de Educação de Petrolina, a todas gestoras e equipes dos CMEIs, em especial às creches que participaram como piloto, controle e experimental. A todas as família que contribuiram para a realização do traball e as crianças pelo carinho.

Gostaria de agradecer ao *Emerging Leaders in the Americas Programm*, ao governo do Canadá, à Universidade de Alberta e aos brasileiros que me ajudaram em diferentes fases dessa experiência internacional, especialmente Matheus, Ana Julia, Fernanda e Carminda. Agradeço ao acolhimento de todos os membros do *Behavioural Epidemiology Lab*, em especial a professora Dr. Valerie Carson, as coordenadoras Meddy e Morgan e aos colegas Shohreh e Yeongho por todo suporte, não somente em termos de conhecimento científico, mas também pelo acolhimento comigo e minha família durante o período que estive junto da equipe.

Agradeço a oportunidade de ter sido discente do Programa Associado de Pós-Graduação em Educação Física UPE/UFPB e parabenizo as coordenações e a equipe docente pela maneira como conduziram as nossas disciplinas durante a pandemia de COVID19 o qual foi um período de muita insegurança sobre como poderia ser o processo. Muito obrigada à Ricardo e Herson por responderem minhas questões de maneira rápida, detalhada e sempre em um tom cordial.

Por fim, gostaria de agradecer aos membros da banca por despenderem seu tempo para avaliar e contribuir com a construção deste trabalho.

LISTA DE ABREVIAÇÕES

AF = ATIVIDADE FÍSICA

AFL = ATIVIDADE FÍSICA LEVE

AFM = ATIVIDADE FÍSICA MODERADA

AFMV = ATIVIDADE FÍSICA MODERADA À VIGOROSA

AFV = ATIVIDADE FÍSICA VIGOROSA

AR = AUTORREGULAÇÃO

ARCOG = AUTORREGULAÇÃO COGNITIVA

ARCOM = AUTORREGULAÇÃO COMPORTAMENTAL

AREM = AUTORREGULAÇÃO EMOCIONAL

CS = COMPORTAMENTO SEDENTÁRIO

CI = CONTROLE INIBITÓRIO

FC = FLEXIBILIDADE COGNITIVA

FE = FUNÇÕES EXECUTIVAS

HB = HABILIDADES COM BOLA

HMF = HABILIDADES MOTORAS FUNDAMENTAIS

MT = MEMÓRIA DE TRABALHO

MTVE = MEMÓRIA DE TRABALHO VISUOESPACIAL

LOC = LOCOMOÇÃO

LISTA DE TABELAS E QUADROS

LISTA DE FIGURAS

RESUMO

Introdução: A autorregulação (AR) é um componente essencial no desenvolvimento infantil, abrangendo os domínios cognitivo (ARCOG), emocional (AREM) e comportamental (ARCOM). Tem sido reportado que os comportamentos de movimento, como atividade física (AF), comportamento sedentário (CS) e sono, podem influenciar no desenvolvimento da AR na primeira infância. No entanto, as evidências atuais sobre as associações entre esses comportamentos e os domínios da AR em pré-escolares são limitadas e apresentam resultados mistos. Diante disso, é fundamental aprofundar a investigação dessas relações, incluindo não apenas a interação entre esses comportamentos ao longo de 24 horas, mas também os potenciais efeitos de intervenções de AF sobre esses comportamentos e a AR em pré-escolares. **Objetivo:** Investigar as possíveis relações transversais e longitudinais entre os comportamentos de movimento – 24 horas e os domínios da AR em pré-escolares. **Metodologia:** A construção da presente tese envolveu três etapas, que originaram quatro estudos. A etapa de investigação teórica culminou em uma análise bibliométrica de estudos de intervenção de AF e desfechos na cognição de crianças e adolescentes. Foram selecionadas publicações entre 2009 e 2019, indexados na base de dados *Web of Science.* Para busca dos estudos, foram utilizados os termos *meshs* e palavras-chaves. O software *Vantage point* foi utilizado para normalizar termos e os mapas bibliométricos foram construídos no software V*OSviewer*. A segunda etapa consistiu-se na investigação das relações transversais, composta pela elaboração de dois estudos: 1) Relação entre aderência aos comportamentos de movimento - 24 horas e ARCOG e ARCOM em pré-escolares e 2) Associação entre comportamentos de movimento - 24 horas e a ARCOG e ARCOM em pré-escolares: uma análise composicional e isotemporal. Participaram destes estudos 223 pré-escolares entre 4 e 5 anos, matriculados na rede pública do município de Petrolina (PE). A ARCOG foi avaliada por meio dos testes da bateria *Early Years Toolbox (EYT),* considerando o Controle Inibitório (CI), a Memória de Trabalho Visuoespacial (MTVE) e a Flexiblidade Cognitiva (FC). A ARCOM foi avaliada por meio do teste cabeça, ombro, joelho e pé revisado. A AF e o CS foram medidos de forma objetiva durante sete dias por meio do uso de um acelerômetro ActiGraph GT3X. O sono e o CS baseado em tela foi avaliado por meio de relato dos pais/cuidadores primários. A terceira etapa, de caráter longitudinal, objetivou investigar os efeitos de uma intervenção com AF, a partir de um protocolo de ginástica educacional, na AR, nas Habilidades Motoras Fundamentais (HMF) e nos comportamentos de movimento dos pré-escolares. Esta fase envolveu a participação de duas creches municipais, que foram randomizadas para grupos experimental (n=60) e controle (n=60). Além dos testes utilizados nos estudos transversais, incluiu-se a AR subjetiva avaliada por meio do Questionário de Autorregulação e Comportamento da bateria *EYT- versão brasileira,* considerando a ARCOG, ARCOM e AREM, bem como o Teste de Desenvolvimento Motor Grosso - 3º edição utilizado para avaliar as HMF de locomoção (LOC) e HMF com bola (HB). Todas as medidas foram realizadas em três fases: antes da intervenção (Julho/Agosto de 2022), pós-intervenção (Novembro/Dezembro de 2022) e 12 semanas após o final da intervenção (*Follow up* – Março/Abril de 2023). **Resultados:** Na fase teórica, observou-se uma rede robusta de colaboração entre autores de países de alta renda, com um foco predominante nas funções executivas e uma escassez de estudos direcionados à fase pré-escolar, demonstrando a necessidade de mais pesquisas voltadas para esta faixa etária específica. Os estudos transversais revelaram que a adesão às recomendações de AF e ao tempo de tela foi associada positivamente à FC ([β = 4.091091 (95% CI: 0.699, 7.754)]), enquanto a adesão às recomendações de AF e sono, apresentou uma associação negativa com a ARCOM ([β = -8.813 (95% CI: -15.794, -1.397)]). A análise composicional demonstrou que a composição dos comportamentos de movimento tem impacto positivo na ARCOM (13%) e que substituições teóricas de AF moderada a vigorosa por AF leve e CS podem potencialmente melhorar a ARCOM. Na fase longitudinal, o grupo experimental de ginástica educacional apresentou maiores escores do CI

(0.78 *vs* 0.59, p = 0.002), FC (7.51 *vs* 3.47, p < 0.001) e da ARCOM medida direta e indireta (ARCOM direta = 72.76 *vs* 44.61, p = 0.007; ARCOM indireta = 3.89 *vs* 3.03, p = 0.041), porém redução do tempo em AF leve (307.9 *vs* 347.0, p = 0.034) comparado ao grupo controle no pós-intervenção. Foi verificado efeitos significativos no período *follow-up* apenas na ARCOM medida direta para o grupo experimental (pré: 72.76; pós: 81.64, p < 0.001). Ambos os grupos melhoraram o escore total das HMF (Exppré = 46.73 vs Exppós = 63.95, p<0.001; Conpré = 49.81 vs Conpós = 58.13, p<0,05) e de LOC (Exppré = 24.02 vs Exppós = 35.89, p<0.001; Conpré = 26.73 vs Conpós = 33.18, p<0,001), porém somente o grupo experimental demonstrou aumentos nas HB (pré = 22.87 vs pós = 28.21, p<0.001). **Conclusão:** A presente tese evidenciou uma rede internacional de publicações na área de intervenções de AF, porém com menor enfoque na fase pré-escolar e oriunda de países de alta renda. As evidências empíricas transversais sugerem que as relações entre comportamentos de movimento e a AR variam conforme o domínio da AR, bem como a forma como os comportamentos são analisados, com associações positivas para a ARCOM quando observados os comportamentos em uma composição. A evidência experimental demonstrou que uma intervenção de AF, utilizando uma abordagem de ginástica educacional, foi efetiva na melhoria do CI, FC e ARCOM no pós-intervenção, porém com efeitos sustentados apenas na ARCOM.

Palavras-chave: Autorregulação, Comportamentos de Movimento - 24 horas, Pré-escolares

ABSTRACT

Introduction: Self-regulation (SR) is a critical component of child development, encompassing cognitive (CSR), emotional (ESR), and behavioral (BSR) domains. It has been reported that movement behaviors, such as physical activity (PA), sedentary behavior (SB), and sleep, may influence the development of SR in early childhood. However, the current evidence on the associations between these behaviors and SR domains in preschoolers is limited and presents mixed results. Therefore, it is essential to further investigate these relationships, including not only the interaction between these behaviors over 24 hours but also the potential effects of PA interventions on these behaviors and SR in preschoolers. **Objective:** To investigate the possible cross-sectional and longitudinal relationships between 24-hour movement behaviors and SR domains in preschoolers. **Methodology:** The development of this thesis involved three stages, which led to four studies. The theoretical investigation stage culminated in a bibliometric analysis of PA intervention studies and outcomes in the cognition of children and adolescents. Publications between 2009 and 2019, indexed in the Web of Science database, were selected. Mesh terms and keywords were used to search for studies. The Vantage Point software was used to normalize terms, and the bibliometric maps were constructed using VOSviewer software. The second stage consisted of investigating cross-sectional relationships, comprising the development of two studies: 1) The relationship between adherence to 24-hour movement behaviors and CSR and BSR in preschoolers; and 2) The association between 24-hour movement behaviors and CSR and BSR in preschoolers: a compositional and isotemporal analysis. These studies included 223 preschoolers aged 4 to 5 years, enrolled in public preschools in the municipality of Petrolina (PE), Brazil. CSR was assessed using the Early Years Toolbox (EYT) battery tests, considering Inhibitory Control (IC), Visuospatial Working Memory (VSWM), and Cognitive Flexibility (CF). BSR was evaluated using the Head, Toes, Knees, and Shoulders (HTKS) revised. PA and SB were objectively measured for seven days using an ActiGraph GT3X accelerometer. Sleep and screen-based SB were assessed through reports from parents/primary caregivers. The third stage, of longitudinal approach, aimed to investigate the effects of a PA intervention, based on an educational gymnastics protocol, on SR, Fundamental Motor Skills (FMS), and movement behaviors of preschoolers. This phase involved the participation of two municipal Early Childhood Education Centers, which were randomized into experimental (n=60) and control (n=60) groups. In addition to the tests used in the cross-sectional studies, subjective SR was assessed using the Child Self-regulation & Behaviour Questionnaire (CSBQ) from the EYT battery - Brazilian version, considering CSR-CSBQ, BSR-CSBQ, and ESR-CSBQ, as well as the Gross Motor Development Test (TGMD) - 3rd edition used to assess FMS in locomotion (LOC) and ball skills (BS). All measurements were conducted in three phases: pre-intervention (July/August 2022), post-intervention (November/December 2022), and 12 weeks after the end of the intervention (Follow-up – March/April 2023). **Results:** In the theoretical phase, a robust collaboration network was observed among authors from high-income countries, with a predominant focus on executive functions and a scarcity of studies directed at the preschool phase, demonstrating the need for more research focused on this specific age group. The cross-sectional studies revealed that adherence to PA and screen time recommendations was positively associated with CF ([β = 4.091091 (95% CI: 0.699, 7.754)]), while adherence to PA and sleep recommendations was negatively associated with BSR ([β = -8.813 (95% CI: -15.794, -1.397)]). The compositional analysis demonstrated that the composition of movement behaviors positively impacts BSR (13%) and that theoretical substitutions of moderate to vigorous PA with light PA and SB could potentially improve BSR. In the longitudinal phase, the experimental group involved in educational gymnastics showed higher scores in IC (0.78 *vs* 0.59, $p = 0.002$), CF (7.51 *vs* 3.47, $p < 0.001$), and directly and indirectly measured BSR BSR directly = 72.76 *vs* 44.61, $p = 0.007$; BRS-CSBQ = 3.89 *vs* 3.03, $p = 0.041$), but a reduction in light PA time (307.9 *vs* 347.0, $p = 0.034$) compared to the control group post-intervention. Significant effects were observed in the follow-up period only for directly measured BSR in the experimental group (pre: 72.76; post: 81.64, $p < 0.001$). Both groups improved TGMD (Exppre = 46.73 vs Exppost = 63.95, $p<0.001$; Conpre = 49.81 vs Conpost = 58.13, p<0,05) and LOC scores (Exppre = 24.02 vs Exppost = 35.89, $p<0.001$; Conpre = 26.73 vs Conpost = 33.18, p<0,001), but only the experimental group demonstrated increases in BS (pre = 22.87 vs post = 28.21, $p<0.001$). **Conclusion:** This thesis evidenced an international network of publications in the area of PA interventions, with less emphasis on the preschool phase and predominantly from high-income countries. Empirical cross-sectional evidence suggests that the relationships between movement behaviors and SR vary according to the SR domain, as well as how the behaviors are analyzed, with positive associations for BSR when movement behaviors are observed in a composition. Experimental evidence demonstrated that a PA intervention using an educational gymnastics approach was effective in improving IC, CF, and BSR post-intervention, but with sustained effects only on BSR.

Key-words: Self-regulation, 24-hour movement behaviors, Preschoolers

RESUME

Introducción: La autorregulación (AR) es un componente esencial del desarrollo infantil, que abarca los dominios cognitivo (ARCOG), emocional (AREM) y conductual (ARCOM). Se ha reportado que los comportamientos relacionados con el movimiento, como la actividad física (AF), el comportamiento sedentario (CS) y el sueño, pueden influir en el desarrollo de la AR durante la primera infancia. Sin embargo, las evidencias actuales sobre las asociaciones entre estos comportamientos y los dominios de la AR en niños preescolares son limitadas y muestran resultados mixtos. Por lo tanto, es crucial profundizar en el estudio de estas relaciones, considerando no solo la interacción entre estos comportamientos durante las 24 horas, sino también los posibles efectos de las intervenciones de AF sobre estos comportamientos y la AR en preescolares. **Objetivo**: Investigar las posibles relaciones transversales y longitudinales entre los comportamientos de movimiento en un ciclo de 24 horas y los dominios de la AR en preescolares. **Metodología**: La construcción de esta tesis implicó tres etapas que dieron lugar a cuatro estudios. La primera etapa teórica culminó en un análisis bibliométrico de estudios de intervención de AF y sus efectos en la cognición de niños y adolescentes. Se seleccionaron publicaciones entre 2009 y 2019, indexadas en la base de datos Web of Science. Para la búsqueda de los estudios, se utilizaron términos MeSH y palabras clave, y se empleó el software Vantage Point para normalizar términos. Los mapas bibliométricos se construyeron con el software VOSviewer. La segunda etapa incluyó la investigación de relaciones transversales a través de dos estudios: 1) Relación entre la adherencia a los comportamientos de movimiento - 24 horas y la ARCOG y ARCOM en preescolares, y 2) Asociación entre los comportamientos de movimiento - 24 horas y la ARCOG y ARCOM en preescolares: un análisis composicional e isotemporal. Participaron en estos estudios 223 preescolares de 4 y 5 años, matriculados en la red pública del municipio de Petrolina (PE). La ARCOG se evaluó mediante las pruebas del Early Years Toolbox (EYT), considerando el Control Inhibitorio (CI), la Memoria de Trabajo Visuoespacial (MTVE) y la Flexibilidad Cognitiva (FC). La ARCOM se evaluó con la prueba revisada de cabeza, hombros, rodillas y pies. La AF y el CS se midieron objetivamente durante siete días con un acelerómetro ActiGraph GT3X. El sueño y el CS basado en pantalla se evaluaron a través de informes de los padres/cuidadores primarios. La tercera etapa, de carácter longitudinal, investigó los efectos de una intervención de AF, a través de un protocolo de gimnasia educativa, en la AR, las Habilidades Motoras Fundamentales (HMF) y los comportamientos de movimiento en preescolares. Esta fase involucró a dos guarderías municipales, que fueron asignadas aleatoriamente a un grupo experimental (n=60) y a un grupo control (n=60). Además de las pruebas utilizadas en los estudios transversales, se incluyó la evaluación subjetiva de la AR mediante el Cuestionario de Autorregulación y Comportamiento de la batería EYT - versión brasileña, considerando la ARCOG, ARCOM y AREM, así como el Test de Desarrollo Motor Grueso - 3ª edición para evaluar las HMF de locomoción (LOC) y habilidades con balón (HB). Todas las medidas se realizaron en tres fases: antes de la intervención (Julio/Agosto de 2022), post-intervención (Noviembre/Diciembre de 2022) y 12 semanas después de la intervención (Seguimiento – Marzo/Abril de 2023). **Resultados**: En la fase teórica, se observó una red robusta de colaboración entre autores de países de altos ingresos, con un enfoque predominante en las funciones ejecutivas y una escasez de estudios centrados en la etapa preescolar, lo que demuestra la necesidad de más investigaciones en esta población específica. Los estudios transversales revelaron que la adherencia a las recomendaciones de AF y tiempo de pantalla se asoció positivamente con la FC ([β = 4.091091 (95% CI: 0.699, 7.754)]), mientras que la adherencia a las recomendaciones de AF y sueño se asoció negativamente con la ARCOM ([β = -8.813 (95% CI: -15.794, -1.397)]). El análisis composicional mostró que la composición de los comportamientos de movimiento tiene un impacto positivo en la ARCOM (13%) y que las sustituciones teóricas de AF moderada a vigorosa por AF leve y CS pueden mejorar potencialmente la ARCOM. En la fase longitudinal, el grupo experimental que participó en la intervención de gimnasia educativa mostró mayores puntajes en CI (0.78 vs 0.59, p = 0.002), FC (7.51 vs 3.47, p < 0.001) y ARCOM medida directa e indirectamente (ARCOM directa = 72.76 vs 44.61, p = 0.007; ARCOM indirecta = 3.89 vs 3.03, p = 0.041), pero una reducción del tiempo en AF leve (307.9 vs 347.0, p = 0.034) en comparación con el grupo control después de la intervención. Se observaron efectos significativos en el seguimiento solo en la ARCOM medida directa en el grupo experimental (pre: 72.76; post: 81.64, p < 0.001). Ambos grupos mejoraron sus puntajes totales de HMF (Exppré = 46.73 vs Exppós = 63.95, p < 0.001; Conpré = 49.81 vs Conpós = 58.13, p < 0,05) y LOC (Exppré = 24.02 vs Exppós = 35.89, p < 0.001; Conpré = 26.73 vs Conpós = 33.18, p < 0,001), pero solo el grupo experimental mostró aumentos en HB (pre = 22.87 vs post = 28.21, p < 0.001). **Conclusión**: Esta tesis evidenció una red internacional de publicaciones sobre intervenciones de AF, aunque con menor énfasis en la etapa preescolar y predominantemente provenientes de países de altos ingresos. Las evidencias empíricas transversales sugieren que las relaciones entre los comportamientos de movimiento y la AR varían según el dominio de AR, así como la forma en que se analizan los comportamientos, con asociaciones positivas para ARCOM cuando se observan los comportamientos en una composición. La evidencia experimental demostró que una intervención de AF utilizando una aproximación de gimnasia educativa fue efectiva para mejorar el CI, FC y ARCOM en el post-intervención, con efectos sostenidos solo en la ARCOM.

Palabras clave: Autorregulación, Comportamientos de Movimiento - 24 horas, Prescolares

SUMÁRIO

1. INTRODUÇÃO

A primeira infância é reconhecida como uma fase crucial para o desenvolvimento humano, marcada por mudanças neurobiológicas significativas, com impacto duradouro em diversos domínios do desenvolvimento infantil. Durante esse período, ocorre o estabelecimento das bases para vários processos cerebrais, entre os quais a Autorregulação (AR) se destaca como um componente essencial para o funcionamento adaptativo ao longo da vida (MOFITTI et al., 2011; BLAIR et al., 2011; PERRY, 2019; KORUCU et al., 2022).

A AR refere-se à capacidade de gerenciar pensamentos, emoções e comportamentos, de acordo com objetivos internos e demandas externas (GARON et al., 2008; BLAIR, 2010; BLAIR & RAVER, 2012). Esse construto é um importante preditor de sucesso em habilidades pré-acadêmicas e competência socioemocional, sendo comumente operacionalizado pelo estudo de três domínios centrais interrelacionados, porém distintos: o cognitivo (ARCOG), o comportamental (ARCOM) e o emocional (AREM) (MCCLEEAND et al., 2007; GARON, 2016; BLAIR & RAVER, 2012).

No contexto do desenvolvimento cognitivo, a AR é associada às funções executivas (FE), que se constituem em três habilidades centrais: i) memória de trabalho (MT), caracterizada pela capacidade de reter e manipular informações em mente; ii) controle inibitório (CI), relacionado à habilidade de suprimir respostas irrelevantes ou automáticas; e iii) flexibilidade cognitiva (FC), operacionalizada pela capacidade de alternar entre diferentes tarefas ou estratégias em resposta a demandas mutáveis (GARON et al., 2008; HOFMANN et al., 2012; DIAMOND, 2013). As FE ocorrem a partir de circuitos neurais específicos que envolvem o Córtex Pré-Frontal (CPF) caracterizado por um longo período de maturação, que finaliza por volta dos vinte anos de idade (THOMPSON; NELSON, 2001; DIAMOND, 2011). De fato, MT e CI já são possíveis de serem identificados nos primeiros três anos de vida, e ao longo da primeira infância, essas habilidades vão progredindo para dar sustentação a processos cognitivos superiores, como planejamento, raciocínio e resolução de problemas mais complexos (DIAMOND, 2013).

As habilidades centrais da FE seguem trajetórias de desenvolvimento distintas durante a primeira infância e se manifestam de forma evidente na ARCOM, refletindo a capacidade da criança gerenciar e controlar suas ações, emoções e pensamentos para alcançar objetivos desejados ou se adaptar a diferentes situações (MCCLELLAND et al., 2007; MCCLELLAND et al., 2012; BURKE et al., 2023).

A AREM inclui tanto a capacidade de gerenciar com sucesso as próprias emoções quanto de utilizá-las de maneira adaptativa, dependendo da situação (D`CRUZ et al., 2024). Esse processo envolve a modulação da experiência emocional, a intensidade das emoções e as formas de expressá-las, sendo essencial para o bem-estar psicológico, as relações interpessoais e o funcionamento social adequado (EISENBERG et al., 2011). A partir dos três anos de idade, a AR começa a emergir e se desenvolver de maneira mais acentuada, exercendo uma influência considerável no estabelecimento de relações interpessoais e na adoção de comportamentos saudáveis que podem perdurar ao longo da vida (MOFFITT et al., 2011; MCCLELLAND & CAMERON, 2012).

Nessa perspectiva, estudos recentes têm investigado o quanto os comportamentos de movimento, nomeadamente a atividade física (AF), o comportamento sedentário (CS) e o sono, podem se associar com os domínios da AR na primeira infância (CLIFF et al., 2017; MCNEILL et al., 2020; TAYLOR et al., 2021; KUZIK et al., 2022; MCGOWAN et al., 2023). Essas abordagens têm se concentrado em entender estas relações sob duas perspectivas metodológicas: 1) a aderência às recomendações de comportamentos movimento – 24horas de maneira isolada ou em combinação e os desfechos na AR; e/ou 2) a composição dos comportamentos de movimento e suas relações com a AR (ROLLO et al., 2020; KUZIK et al., 2020; 2022). Os resultados reportados em estudos de revisões sistemáticas indicam que a aderência às recomendações de comportamentos de movimento -24 horas, seja de forma isolada ou em combinação, apresentam resultados mistos, dependendo do domínio da AR investigado (ROLLO et al., 2020; FENG et al., 2021). Por outro lado, crianças que aderem às recomendações de movimento de 24 horas, especificamente a mais de uma recomendação, tendem a apresentar melhores escores comportamentais (CARSON et al., 2019a; ZHU et al., 2023). Destaca-se que os poucos estudos transversais existentes sobre esta temática se centram em populações oriundas de países desenvolvidos e pouco se sabe sobre crianças residentes em países de média-baixa renda. Este é um fator preocupante, ao considerar que fatores como a escolaridade materna ou nível de renda da família são fortes preditores do desenvolvimento infantil (WHITE et al., 2022; SPENCER et al., 2022; REZAEIZADEH et al., 2024).

Até o presente momento, poucos estudos investigaram a relação entre a composição dos comportamentos de movimento e a AR em pré-escolares, e a maioria deles tem focado nos domínios cognitivos da AR, sugerindo associações positivas (KUZIK et al., 2020; BEZERRA et al., 2020; LU et al., 2023). No entanto, apenas um desses estudos avaliou os efeitos na ARCOM e AREM, avaliada de maneira subjetiva pelos pais/cuidadores primários, e não encontrou resultados significativos (KUZIK et al., 2020). Além disto, simulações matemáticas sugerem que a substituição de tempo entre comportamentos pode impactar a ARCOG. Bezerra et al. (2020) observaram que realocar 5 a 20 minutos de sono e AF leve (AFL) para AF moderada a vigorosa (AFMV) melhorou o CI em pré-escolares brasileiros. Lu et al. (2023) encontraram melhorias na FC em pré-escolares chineses ao substituir sono e CS por AFMV. Em uma amostra semelhante, Lau et al. (2024) também relataram que substituir CS e sono por AFMV melhorou o CI e que realocar AFL para AFMV, sono e CS aprimorou a MT. Contudo, faltam estudos sobre os efeitos dessas mudanças nos domínios comportamentais e emocionais da AR.

Nesta perspectiva, um crescente número de estudos tem buscado investigar o efeito da inserção de intervenções de AF na rotina das crianças e os efeitos crônicos sobre a AR (VASILOPOULOS et al., 2023; D`CRUZ et al., 2023; KANAYAMA et al., 2024). Justificativas teóricas têm sido propostas para explicar a possível conexão entre a AF, mudanças na estrutura cerebral e desenvolvimento da AR na infância (BECKER et al., 2014; DIAMOND; LING, 2016; MCCLELLAND; CAMERON, 2019). A exemplo, a perspectiva neurofisiológica destaca que a AF está relacionada a aumentos nos níveis de fatores neurotróficos derivados do cérebro (BDNF) e que pode facilitar o aprendizado e manter a capacidade cognitiva, melhorando a plasticidade sináptica (WALSH et al., 2020), porém esta abordagem tem sido enfatizada principalmente em pesquisas que envolvem crianças em idade escolar (HILLMAN; BIGGAN, 2017; ZHAO, G. et al., 2017; WALSH et al., 2020).

Por outro lado, estudos reportam que os benefícios da AF no desenvolvimento cerebral não necessariamente estão atrealados ao um limiar de AF, mas sim ao nível de controle e esforço mental exigido durante as tarefas motoras (DIAMOND; LEE, 2011; PESCE, 2012; TOMPOROWKSI; PESCE, 2019). Assim, tem sido abordado que, mais do que focar na intensidade da AF, intervenções destinadas à melhoria da AR devem priorizar a qualidade do movimento oferecido às crianças (DIAMOND; LING, 2019; MUIR et al., 2023; CALLAGHAN et al., 2024). Estes argumentos são pautados na inter-relação entre AR e o desenvolvimento das habilidades motoras fundamentais (HMF), já que o desenvolvimento motor está intimamente relacionado ao desenvolvimento cognitivo (DIAMOND, 2000; VAN DER FELS et al., 2015; SHI; FENG, 2022). Neste sentido, argumenta-se que intervenções que focam na competência motora, por meio da execução de HMF, tem um impacto positivo na ARCOG, que gera consequentes efeitos na regulação comportamental e emocional das crianças (DIAMOND, 2000; PESCE, 2012; MCCLELLAND; CAMERON, 2019).

Diversas revisões sistemáticas demonstram um aumento de evidências que sugerem efeitos positivos de intervenções motoras, ou seja, intervenções de AF com foco coordenativo, na AR em pré-escolares (VASILOUPOLOS et al., 2023; MUIR et al., 2023). Contudo, os estudos apresentam uma grande heterogeneidade relacionada à dose das intervenções (quatro semanas a seis meses, entre três e cinco dias na semana, de 20 a 60 minutos), ao conteúdo (ex: brincadeiras livres, jogos e brincadeiras com engajamento cognitivo, música e ritmo, habilidades esportivas e atividades que envolvem HMF), à forma de avaliação AR, com os domínios cognitivos e comportamentais algumas vezes utilizados indistintamente, bem como pouco detalhamento dos aspectos metodológicos, relacionados à variabilidade das atividades e à perspectiva pedagógica utilizada para estimular o engajamento e a motivação das crianças (WOOD et al., 2020; VASILOUPOLOS et al., 2023; D'CRUZ et al., 2023; MUIR et al., 2023; GUTIÉRREZ-CAPOTE et al., 2024; KANAYAMA et al., 2024).

Criar ambientes de aprendizagem "enriquecidos", onde as crianças são desafiadas a controlar seus movimentos de maneira intencional e consciente, parece não apenas impulsionar o desenvolvimento da AR, mas também promover benefícios nas HMF e na AF (DIAMOND; LING, 2016; PESCE et al., 2016). Além disso, estudos reportam que programas estruturados de AF implementados no ambiente pré-escolar podem ser uma estratégia eficaz para melhorar o desenvolvimento integral das crianças, abrangendo competências motoras, cognitivas e sociais, além de aumentar os níveis de AF (CARSON et al., 2017; MARTINEZ-MERINO; RICO-GONZÁLEZ, 2024; OLIVE et al., 2024). Isso é especialmente relevante considerando que as crianças passam uma parte significativa do seu dia nesses espaços (MAVILID et al., 2023).

Dentre as diferentes atividades que poderiam integrar as características supracitadas, destaca-se a Ginástica, praticada em nível educacional, a partir da experimentação de movimentos gímnicos baseados nas HMF (NILGES-CHARLES, 2008; BAUMGARTEN; PAGNANO-RICHARDSON, 2010; ANDERSON et al., 2022; RUSSELL, 2013). Do ponto de vista motor, a ginástica educacional proporciona a vivência de diferentes padrões de movimento, a partir de habilidades como saltar, equilibrar, balancear, rotacionar, rolar e girar (NILGES, 1997b, 2008; RUDD et al., 2017). Em relação ao aspecto socioemocional, a ginástica educacional pode desenvolver a autoexpressão, a criatividade, a confiança e a sociabilidade, por meio da experiência de movimentos individuais e em grupo (BAUMGARTEN; PAGNANO-RICHARDSON, 2010). Do ponto de vista cognitivo, todos os movimentos gímnicos apresentam graduação de dificuldade, sendo possível organizar um programa de intervenção com progressão adequada às individualidades das crianças (NILGES, 1997; NILGES-CHARLES, 2008; BAUMGARTEN; PAGNANO-RICHARDSON, 2010). Entretanto, até o momento, não são conhecidos estudos que tenham verificado os efeitos de uma intervenção de ginástica educacional na AR, HMF e AF em pré-escolares.

O aumento na quantidade de estudos nos últimos anos demonstra o crescente interesse dos investigadores na compreensão das possíveis relações entre AF e AR, com um especial enfoque no domínio cognitivo durante a primeira infância (LI et al., 2020; SONG et al., 2022; MUIR et al., 2023). No entanto, vale destacar que além de compreender os resultados das intervenções, é importante examinar a origem da produção científica nesse campo de investigação. Observa-se que grande parte dos estudos publicados provém de países de alta renda. Consequentemente, diferenças culturais, socioeconômicas e contextuais podem influenciar tanto a implementação das intervenções, quanto os resultados reportados. Além disso, ainda parece incipiente afirmar o quanto intervenções delineadas para promover melhorias na AR podem, simultaneamente, gerar benefícios nos comportamentos de movimento – 24 horas em pré-escolares, uma vez que as poucas evidências que avaliram os efeitos destas intervenções nos comportamentos de movimento apresentaram resultados inconclusivos para a AF, com poucas evidencias para o CS e o sono (D'CRUZ et al., 2023; CALLAGHAN et al., 2024; AADLAND et al., 2024).

Com base no exposto, esta tese doutoral pretende responder às seguintes questões problema: 1) Como se apresenta o estado da arte em relação às intervenções com AF e desfechos na cognição de crianças e adolescentes? Quais as redes de publicação em relação a este tema, os principais desfechos investigados e o número de publicações em relação a faixa etária? 2) Existe associação entre aderir às recomendações de comportamentos de movimento – 24 horas e ARCOG e ARCOM em pré-escolares? 3) As associações entre comportamentos de movimento – 24 horas e ARCOG e ARCOM se comportam de maneira diferente quando se considera os comportamentos como uma composição? 4) Mudanças teóricas no tempo entre os comportamentos de movimento se associam positivamente com a ARCOG e a ARCOM em pré-escolares? 5) Uma intervenção de AF com foco coordenativo, pautada na abordagem da ginástica educacional, é capaz de gerar efeitos positivos na AR, nas HMF e nos comportamentos de movimento – 24 horas em pré-escolares? 6) Os efeitos desta intervenção são mantidos 12 semanas após o final da intervenção?

1.1 Objetivo Geral

Investigar as possíveis relações transversais e longitudinais entre comportamentos de movimento – 24 horas e AR em pré-escolares.

1.1.1 Objetivos Específicos e Hipóteses

Os objetivos específicos e suas respectivas hipóteses são apresentados no quadro 1, e contemplados em artigos originais que compõem este trabalho.

Quadro1. Objetivos específicos e hipóteses.

Objetivos	Hipóteses
1. Explorar e sumarizar as publicações relativas aos efeitos das intervenções de AF e desfechos cognitivos em crianças e adolescentes, por meio de uma análise bibliométrica.	Será observado que as publicações são oriundas de redes de colaboração entre países de alta renda, com foco na faixa etária da segunda infância.
2. Investigar as associações entre aderir às recomendações de comportamentos de movimento -24horas e os domínios cognitivos e comportamentais da AR em pré-escolares.	Aderir as recomendações de AF, tempo de tela e sono se associa positivamente à ARCOG e à ARCOM em pré-escolares.
3. a) Investigar a associação entre a composição dos comportamentos de movimento-24horas e os domínios cognitivos e comportamentais da autorregulação em pré-escolares; b) Investigar as mudanças teóricas na autorregulação cognitiva e comportamental quando diferentes tempos nos comportamentos de movimento são realocados.	A composição dos comportamentos de movimento -24h está positivamente associada à ARCOG e à ARCOM. A substituição do tempo despendido em diferentes comportamentos por mais tempo em AFMV se associa positivamente com a ARCOG e a ARCOM dos pré-escolares.
4. a) Investigar os efeitos de uma intervenção com AF, a partir de um protocolo com foco na ginástica educacional, na AR, HMF e comportamentos de movimento – 24horas em pré-escolares; b) Investigar a manutenção dos efeitos desta intervenção após um período de 12 semanas pós-intervenção.	Será evidenciada melhores resultados na AR, HMF e comportamentos de movimento nos pré-escolares do grupo experimental, comparados ao grupo controle. Os efeitos da intervenção serão mantidos após um período de 12 semanas pós-intervenção.

1.2 Estrutura da Tese

Esta tese doutoral foi construída a partir de três etapas distintas e complementares (Figura 1). A etapa I, correspondente à investigação teórica, culminou na elaboração de um estudo original de análise bibliométrica acerca de estudos de intervenção com AF e desfechos na cognição de crianças e adolescentes. A segunda etapa consistiu-se na investigação das relações transversais entre as variáveis exposição (comportamentos de movimento – 24horas) e o desfecho principal da tese (AR e seus diferentes domínios). Esta etapa culminou na elaboração de dois estudos originais. A terceira etapa, de caráter longitudinal, objetivou investigar os efeitos de uma intervenção com AF, a partir de um protocolo de ginástica educacional, na AR, nas HMF e nos comportamentos de movimento dos pré-escolares, resultando na elaboração de um estudo original.

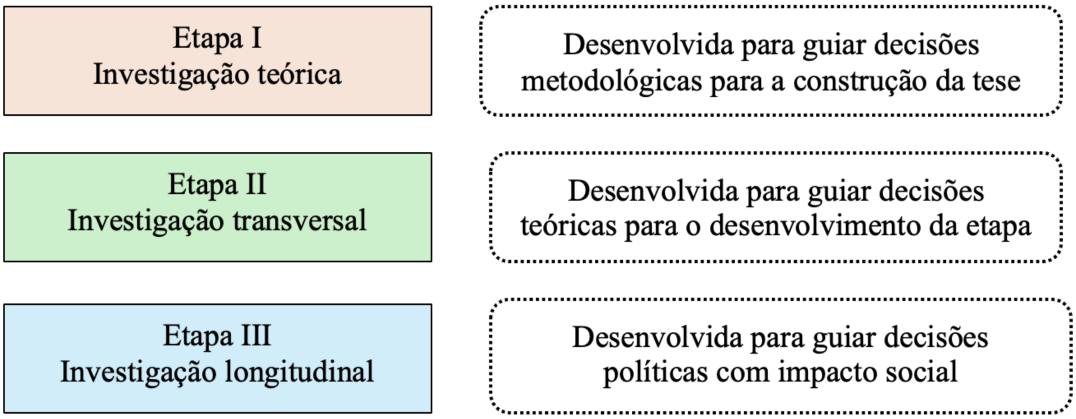


Figura 1: Esquema da tese

A tese está estruturada no modelo alternativo, de acordo com a norma 2002/2015 do Programa Associado de Pós-Graduação em Educação Física UPE/UFPB, que dispõe sobre o exame de qualificação, pré-banca e defesa. Desta forma, a seção "Resultados" será constituída pelos quatro artigos elaborados ao longo do período doutoral, sendo cada um deles correspondente a um objetivo específico acima mencionado.

2. REFERENCIAL TEÓRICO

2.1 Autorregulação: processos, domínios e desenvolvimento na primeira infância

AR é um processo central no desenvolvimento humano, caracterizando-se pela capacidade do indivíduo de gerenciar e ajustar seus pensamentos, emoções e comportamentos em resposta às demandas internas e externas (GARON et al., 2008; BLAIR, 2010; BLAIR & RAVER, 2012; RAVER et al., 2015). Este conceito abrange uma gama ampla de habilidades que permitem as pessoas adaptar-se a diferentes situações, manter o foco em objetivos de longo prazo e resistir a impulsos imediatos que possam ser contraproducentes (ZELAZO et al., 2008; MOFFITT et al., 2011; BLAIR & RAVER, 2012; ZELAZO & CARLSON, 2012). A autorregulação é essencial, não apenas para o bem-estar pessoal, mas também para o sucesso em diversas áreas da vida (ZELAZO et al., 2008; BLAIR, 2010; MOFFITT et al., 2011; HOFMANN et al., 2012; DIAMOND, 2013).

O desenvolvimento da AR está intimamente relacionado ao funcionamento de áreas cerebrais específicas, com o CPF sendo amplamente reconhecido como a região cerebral mais associada às funções cognitivas superiores, como planejamento, tomada de decisões e controle de impulsos (MILLER & COHEN, 2001; FUNAHASHI; ANDREAU, 2013; FRIEDMAN & ROBBINS, 2022). Além do CPF, a amígdala, os gânglios basais e cerebelo desempenham papéis críticos na regulação emocional e comportamental. A amígdala é essencial no processamento de emoções, especialmente em resposta a ameaças ou situações de estresse (LEDOUX, 2000; KIM & WHALEN, 2009; BERBOTH; MORAWETZ, 2021), enquanto os gânglios basais e o cerebelo estão envolvidos no reconhecimento de estímulos emocionais, modulação de comportamentos motores e na formação de hábitos (GRAYBIEL, 2008; RUSU; PENNARTZ, 2020; PIERCE; PERON, 2020).

A interação entre essas áreas cerebrais é mediada por mecanismos de regulação "*top-down*" e "*bottom-up*" (GARON, 2016). A estratégia regulatória descendente "*top-down*", controlada pelo CPF, envolve a modulação consciente das respostas emocionais e comportamentais, influenciando a tomada de decisão por meio do aspecto racional e cognitivo, a partir de representações mais estáveis contidas na memória de longo-prazo, ou seja, um conhecimento já experienciado. Em contraste, a regulação ascendente "*bottom-up*", mediada por estruturas como a amígdala, gera respostas automáticas e rápidas a estímulos emocionais. Essas ações estão relacionadas às sensações ou estímulos externos que são recebidos para, em seguida, serem processados de maneira implícita. O equilíbrio entre esses dois mecanismos é crucial para uma AR eficaz, permitindo ao indivíduo ajustar suas respostas de maneira adequada ao contexto (BLAIR & RAVER, 2015; GARON, 2016).

Recentemente, Blair e Ku (2022) propuseram um modelo teórico que conceitua a AR como um sistema hierárquico integrado, composto por cinco domínios inter-relacionados: cognitivo, emocional, comportamental, fisiológico e genético, que operam em uma rede complexa e recursiva de influências mútuas (Figura 1). FE, associadas ao domínio cognitivo, desempenha um papel central na regulação emocional e comportamental, sendo essencial para a adaptação às demandas ambientais (DIAMOND, 2013). Habilidades como MT, CI e FC são fundamentais na regulação descendente, relacionadas à execução de ações orientadas por objetivos, especialmente em situações de incerteza ou complexidade (GARON, BRYSON, & SMITH, 2008). No domínio fisiológico, a resposta ao estresse, mediada pelo sistema nervoso autônomo e pelo eixo hipotálamo-pituitária-adrenal (HPA), é descrita como essencial para a regulação emocional e comportamental, com hormônios como o cortisol e neuromoduladores, nomeadamente a a norepinefrina, modulando a atividade neuronal no CPF e na amígdala (ARNSTEN, 2009; BLAIR, 2010; ARNSTEN et al., 2015). Já o componente genético do modelo reconhece que fatores hereditários influenciam a sensibilidade ao estresse e a capacidade de regulação, e que variações genéticasnos receptores de cortisol, por exemplo, impactam diretamente a capacidade do indivíduo de regular os outros domínios da AR (ESSEX ET AL., 2011).

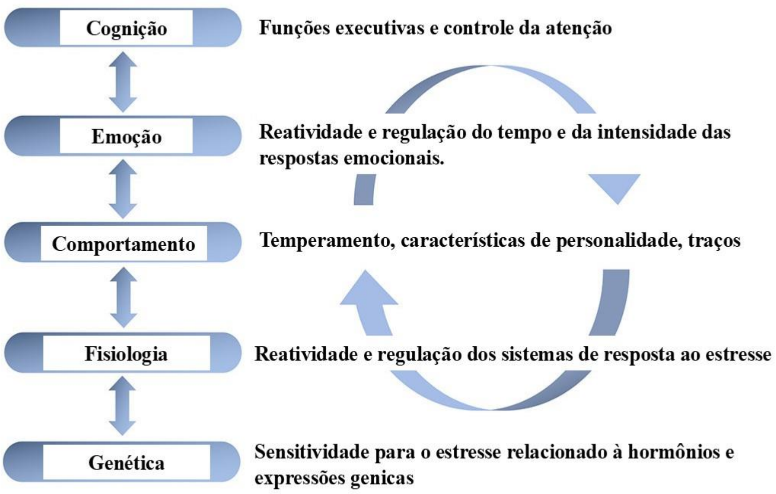


Figura 2. Modelo Hierárquico Integrado da Autorregulação (Traduzido de Blair; Ku, 2022): Modelo hierárquico integrado da Autorregulação, em que níveis cognitivos, emocionais, comportamentais, fisiológicos e genéticos da Autorregulação são reciprocamente e recursivamente relacionados. Nesta visão, Função Executiva é o componente do nível mais superior do modelo integrado.

A primeira infância é um período crítico em que a plasticidade cerebral, moldada por experiências precoces, influencia o desenvolvimento da AR. Blair e Ku (2022) destacam que neste estágio da vida, FEs são predominantemente reguladas por mecanismos "bottom-up", mais automáticos e reativos. Contudo, o ambiente tem um papel crucial na modulação desses processos. Interações positivas podem fortalecer as FE "top-down", promovendo uma regulação mais consciente das respostas emocionais e comportamentais, equilibrando a predominância inicial dos mecanismos "bottom-up" (GARON, 2016). A interação desses processos influencia aspectos fundamentais do desenvolvimento infantil, como o sucesso acadêmico, a formação de relações interpessoais e a adoção de hábitos de vida saudáveis (MOFFITT et al., 2011; 2013; BLAIR & RAVER, 2015).

De fato, crianças que desenvolvem de maneira efetiva a AR apresentam melhor desempenho escolar devido à maior capacidade de manter a atenção, controlar impulsos e processar informações complexas (BLAIR & RAZZA, 2007; MCCLELLAND et al., 2006). Essas competências são essenciais em ambientes educacionais, onde gerenciar frustrações e adaptar-se a novas informações é fundamental para o aprendizado (MORRISON et al., 2010; DUCKWORTH & CARSON, 2013; MCCLELLAND etal., 2019). Por exemplo, o desenvolvimento das FE, habilidades centrais da ARCOG, é um forte preditor de sucesso acadêmico, superando o QI (BULL & SCERIF, 2001; ZELAZO, 2015). Além do impacto acadêmico, a AR é vital para relações interpessoais saudáveis, ajudando as crianças a formar e manter amizades, colaborar com os outros e resolver conflitos de forma construtiva (MCCLELLAND et al., 2007; EISENBERG et al., 2010). Concomitantemente, a AR está intimamente ligada à adoção de hábitos saudáveis, o que tem gerado um crescente interesse na investigação sobre como os comportamentos de movimento (AF, CS e sono) podem interagir e influenciar o desenvolvimento da AR na primeira infância. O estudo dessa interação é especialmente relevante na fase pré-escolar, já que os comportamentos de movimento são estabelecidos nesta fase da vida e diferentes ambientes, como o familiar, o social e o escolar, podem exercer um impacto significativo nessas possíveis relações (BRONFENBRENNER, 1994; THOMPSON, 2006).

2.2 Autorregulação e a relação com os comportamentos de movimento atividade física, comportamento sedentário e sono em pré-escolares

A AR está relacionada à adoção de hábitos saudáveis, influenciando o sono adequado, a limitação de CS e a prática regular de AF (TREMBLAY et al., 2016). Contudo, as evidências mostram que as associações entre estes comportamentos de movimento de forma independente com a AR em pré-escolares variam conforme as características de cada comportamento e o domínio da AR avaliado.

A qualidade do sono tem sido relatada como um fator mais determinante para a AR na infância do que a quantidade total de horas dormidas (THAM et al., 2017; CHAPUT et al., 2017). Um sono de alta qualidade, caracterizado por ser profundo e reparador, é essencial para o desenvolvimento da ARCOG, já que crianças que dormem adequadamente apresentam melhor desempenho em FE, habilidades linguísticas, memória declarativa e avaliações de desenvolvimento e inteligência (THAM et al., 2021). Além disso, o sono é crucial para AREM e ARCOM na infância. Estudos indicam que uma má qualidade do sono pode aumentar a reatividade emocional, dificultar o gerenciamento de emoções negativas e levar a comportamentos impulsivos e desafiadores (GRUBER et al., 2012; KAHN et al., 2014).

Além do sono, o CS, especialmente o tempo de tela passivo (por exemplo, assistir televisão), tem sido amplamente associado a efeitos negativos na AR, como o aumento da impulsividade e dificuldades de atenção, enquanto o tempo de tela ativo (com interação de movimento ou educacional, por exemplo video-games e aplicativos educativos) estão associados a desfechos positivos na ARCOG (POITRAS et al., 2017; CARSON et al., 2019b; BUSTAMANTE et al., 2023). Bezerra et al. (2024), relataram que o tempo sedentário nos finais de semana está negativamente associado à eficiência inversa em tarefas de CI, enfatizando a importância de limitar o tempo sedentário passivo para promover um melhor desenvolvimento cognitivo. Além disso, atividades sedentárias que estimulam a cognição, como leitura ou resolução de quebra-cabeças, parecem apresentar efeitos neutros ou até positivos na AR (PAGANI et al., 2010; CARSON et al., 2017).

Embora hipotetize-se que a AF desempenha um papel fundamental no desenvolvimento da AR, os achados sobre essas associações variam significativamente entre os diferentes domínios da AR (CARSON et al., 2016; VABO et al., 2022; D'CRUZ et al., 2024). D`Cruz et al. (2023) ao revisarem a literatura, com a distinção dos domínios da AR, reportaram que associações positivas entre AF e ARCOM são mais consistentes, enquanto relações com a ARCOG e a AREM são frequentemente menos claras e, em alguns casos, inexistentes. Além disso, questões sobre a bidirecionalidade da relação entre AF e AR, ou seja, a influência mútua ao considerar a AR como variável expositora ou desfecho, ainda requerem investigação mais aprofundada (D`CRUZ et al., 2023). Em adição, a diversidade de medidas empregadas para avaliação da ARCOG e da ARCOM, a exemplo do teste cabeça, ombro, joelho e pés (MCCLEAND et al., 2021), dificulta a comparação e interpretação dos resultados existentes (D`CRUZ et al., 2024).

Por outro lado, é crucial reconhecer que os comportamentos de movimento são co-dependentes, compondo um continuum de 24 horas onde o tempo alocado a uma atividade inevitavelmente afeta o tempo disponível para as demais (CHASTIN et al., 2015; PEDISIĆ et al., 2017). Seguindo esta abordagem epistemológica, um crescente número de estudos tem buscado entender o quanto atingir quantidades recomendadas nos diferentes comportamentos de movimento ao longo de 24 horas pode impactar na AR em pré-escolares.

2.3 Autorregulação e a composição dos comportamentos de movimento - 24 horas em pré-escolares

AF, CS e sono são comportamentos que mutuamente compõem uma composição de comportamentos de movimento ao longo de 24 horas (PEDIŠIĆ et al., 2017). O constructo representado por esta composição de comportamentos descreve os padrões de movimento corporal, em relação ao equivalente metabólico basal, que ocorre quando um indivíduo está acordado ou dormindo, e acontece num período diário de 24 horas (PEDIŠIĆ et al., 2017; DUMUID et al.,2018).

As recomendações existentes sugerem que crianças de 3 a 4 anos devem acumular pelo menos 180 minutos de AF ao longo do dia, dos quais pelo menos 60 minutos devem ser de intensidade moderada a vigorosa; devem acumular menos de uma hora de tempo de tela sedentário; além de acumular entre 10 e 13 horas de sono de boa qualidade por dia. Para crianças de 5 anos, as recomendações diárias incluem pelo menos 60 minutos diários de atividade física de intensidade moderada a vigorosa; menos de 2 horas de tempo de tela sedentário e entre 9 e 11 horas de sono de boa qualidade (WHO, 2019; TREMBLAY et al., 2016).

A adesão a estas recomendações de movimento - 24 horas têm sido associada a desfechos saudáveis, nomeadamente na AR em pré-escolares (CLIFF et al., 2017; KUZIK et al., 2017; CARSON et al., 2017; MCNEILL et al., 2020; TAYLOR et al., 2021 . Em uma investigação longitudinal, McNeill et al. (2020) observaram que a combinação de AF e sono adequados, ou seja, dentro do tempo recomendado, estava relacionada a avanços significativos na FC e no controle comportamental. Crianças que cumpriram essas diretrizes demonstraram um melhor controle de impulsos e uma maior capacidade de concentração. Contudo, a literatura também aponta para resultados mistos ou até nulos, especialmente ao se considerar diferentes domínios da AR. Por exemplo, Kuzik et al. (2017) relataram associações positivas entre a adesão às recomendações de AF e a redução de problemas comportamentais, mas os efeitos sobre a ARCOG foram menos consistentes. Esses achados indicam que, apesar dos benefícios claros, os efeitos da adesão às diretrizes de movimento – 24horas podem variar, a depender do domínio específico da AR avaliado.

De fato, evidências têm indicado como cada um destes componentes da composição afeta a saúde e o desenvolvimento, já em idades pré-escolares (KUZIK et al., 2017; TAYLOR et al., 2018; ROLLO et al., 2020; BOURKE et al., 2022). No entanto, é importante considerar que a análise dos comportamentos de maneira isolada é limitada, uma vez que todos os comportamentos de movimento coexistem como uma composição, sendo interdependentes e necessariamente limitados aos 1440 minutos por dia (CHEN et al., 2019; DUMUID et al., 2020). Assim, o tempo gasto em um comportamento afeta, e é afetado pelos outros comportamentos durante o restante do dia.

Recentemente, Bianconi et al. (2024) levantaram questionamentos sobre a robustez das evidências que sustentam as recomendações. A análise realizada pelos autores indica que muitas das diretrizes foram baseadas em evidências de baixa qualidade, predominantemente derivadas de estudos observacionais, com poucas associações significativas em desfechos clínicos relevantes. Estudos sugerem que futuras pesquisas deveriam se concentrar em análises composicionais e ensaios clínicos randomizados para validar ou ajustar as diretrizes atuais, a fim de garantir uma aplicação mais precisa dessas recomendações na prática de saúde pública (CARSON et al., 2023; BIANCONI et al., 2024; TREMBLAY et al., 2024).

De fato, apesar de alguns estudos já terem explorado as associações entre a composição dos comportamentos de movimento – 24horas e a saúde de pré-escolares em diferentes domínios do desenvolvimento (MOTA et al., 2020; BEZERRA et al., 2020; LEMOS et al., 2021; DE SOUZA et al., 2023), o estudo da AR em pré-escolares continua sendo uma lacuna de investigação importante. Kuzik et al. (2017) evidenciaram uma associação positiva entre a composição dos comportamentos de movimento - 24 horas e a MT, embora não tenha sido observada nenhuma associação significativa com o nível comportamental da AR. De maneira semelhante, Bezerra et al. (2021) encontraram que a composição dos comportamentos de movimento - 24 horas estava positivamente associada ao CI em pré-escolares brasileiros. Em adição, recentes estudos buscaram predizer hipoteticamente como substituição do tempo despendido em um comportamento por outro pode indicar mudanças efetivas na AR, com enfoque no domínio cognitivo. O estudo de Bezerra et al. (2020) reportou que a realocação de 5 a 20 minutos de sono e AF leve (AFL) para AF moderada a vigorosa (AFMV) levou a melhorias significativas no CI em pré-escolares brasileiros. De maneira semelhante, Lu et al. (2023) reportaram que a substituição de sono e CS por AFMV foi associada a mudanças positivas na FC em pré-escolares chineses. Em outra pesquisa, também com pré-escolares chineses, Lau et al. (2024) observaram que a substituição de CS e sono por AFMV resultou em melhorias no CI, enquanto as realocações de AFL para sono, CS e AFMV foram associadas a um melhor desempenho na MT. Contudo, até o momento, não são conhecidos estudos que tenham avaliado os efeitos das mudanças teóricas entre os comportamentos de movimento nos domínios comportamentais e emocionais da AR.

2.4 Intervenções de AF e efeitos na autorregulação e nos comportamentos de movimento em pré-escolares

Além da investigação das relações transversais, intervenções específicas com AF como estratégia promissora para potencializar o desenvolvimento da AR em pré-escolares parece ser um campo emergente de investigação científica (VASILOPOULOS et al., 2023), devido à sua potencial capacidade de influenciar positivamente os domínios da AR (D`CRUZ et al., 2024; MUIR et al., 2023; KANAYAMA et al. 2024; WEI et al., 2024).

Estudos que exploraram como a AF pode influenciar a AR em pré-escolares (TOMPOROWSKI et al., 2011; DIAMOND; LING, 2016) têm sido propostos para explicar a possível conexão entre AF e mudanças na estrutura cerebral relacionadas ao desenvolvimento da AR na infância (BECKER et al., 2014; MCCLELLAND; CAMERON, 2019). A exemplo, a perspectiva neurofisiológica destaca que a AF está relacionada a aumentos nos níveis de fatores neurotróficos derivados do cérebro (BDNF) e que pode facilitar o aprendizado e manter a capacidade cognitiva, melhorando a plasticidade sináptica (WALSH *et al.*, 2020), porém esta abordagem tem sido proposta principalmente em pesquisas que envolvem crianças em idade escolar (HILLMAN; BIGGAN, 2017; ZHAO, G. *et al.*, 2017; WALSH *et al.*, 2020).

Outra perspectiva pauta-se na íntima relação entre o desenvolvimento de habilidades motoras fundamentais (HMF) e o desenvolvimento da AR na primeira infância (DIAMOND et al., 2000; MCCLELLAND & CAMERON, 2019). As HMF são entendidas como padrões básicos de movimento que servem de base para AF e esportivas mais avançadas e complexas (STODDEN et al., 2008; HULTEEN et al., 2020). Essas habilidades são classificadas em três categorias principais: habilidades locomotoras ou grossas (como saltar e correr), habilidades de controle de objetos, também conhecidas como habilidades motoras finas (como lançar e chutar uma bola), e habilidades de estabilização (como o equilíbrio corporal) (STODDEN et al., 2008; BARNETT et al., 2016). Pesquisas indicam que a proficiência em HMF, combinada com o desenvolvimento das funções cognitivas relacionadas à AR durante a pré-escola, influencia diretamente a prontidão para a alfabetização (MCCLELLAND; CAMERON, 2019; WILLOUGHBY et al., 2021) e o engajamento das crianças em AF e esportivas ao longo da infância (HULTEEN et al., 2020).

Nesse contexto, o aumento significativo de revisões sistemáticas publicadas nos últimos anos evidencia o crescente interesse da comunidade científica em investigar o impacto das intervenções de AF na AR de pré-escolares (VASILOPOULOS et al., 2023; D`CRUZ et al., 2024; MUIR et al., 2023; MARTINEZ-MERINO; MARKEL RICO-GONZÁLEZ et al., 2024).

D'CRUZ et al. (2024) ao revisarem a literatura considerando os domínios distintos da AR evidenciaram que em comparação com os domínios cognitivo e emocional, a AF foi mais consistentemente associada de forma positiva à ARCOM. Isso sugere que a AF pode ter um impacto mais direto em comportamentos como controle de esforço, comportamento orientado a objetivos e capacidade de adiar a gratificação. Os estudos de intervenção, em menor número na revisao, apoiaram a ideia de que programas estruturados de AF poderiam influenciar positivamente vários domínios da AR em crianças pequenas. Essas intervenções variaram em conteúdo, duração e intensidade, mas, em geral, mostraram resultados positivos para a AR, particularmente nos domínios cognitivo e comportamental.

Intervenções aplicadas ao contexto real da pré-escola têm sido recentemente sistematizadas e demonstram efeitos positivos nos níveis de AF e na AR em pré-escolares (MUIR et al., 2023; MARTINEZ-MERINO, 2024). Intervenções que combinam desafios cognitivos e movimento, com prática frequente e feedback contínuo, são mais eficazes no ambiente pré-escolar. Além disso, sessões regulares de Educação Física (EF), realizadas duas a três vezes por semana, mostraram-se eficazes para aumentar os níveis de AF em crianças dessa faixa etária. No entanto, há controvérsias sobre a eficácia do "jogo livre" em comparação com sessões de EF estruturadas. Intervenções que incluem elementos criativos, como a dança, também se mostraram particularmente eficazes.

Recentemente, Kanayama et al. (2024) relataram que as intervenções publicadas, em sua maioria, apresentam características coordenativas com foco no engajamento cognitivo. Essas intervenções variam significativamente em termos de conteúdo, incluindo brincadeiras livres, jogos e atividades cognitivamente engajadoras, música e ritmo, habilidades esportivas e atividades que envolvem as HMF. Além disso, a variabilidade metodológica dessas intervenções é notável, abrangendo desde a diversidade de atividades até as abordagens pedagógicas utilizadas para estimular o engajamento e a motivação das crianças. A heterogeneidade também se manifesta na dose das intervenções, que variam de quatro semanas a seis meses, com frequência de três a cinco dias por semana e duração entre 20 e 60 minutos por sessão.

Gutiérrez-Capotea et al. (2024) reportaram que esportes com habilidades abertas, como os coletivos, apresentaram maiores benefícios cognitivos, em comparação aos esportes de habilidades fechadas, como a corrida. Esses benefícios são mais evidentes em crianças e adolescentes, destacando a relevância de esportes que exigem rápida tomada de decisão para o desenvolvimento cognitivo.

Conforme exposto até momento, percebe-se que as intervenções publicadas tentam contemplar a combinação entre engajamento motor e cognitivo. A literatura reforça que as intervenções devem ser pensadas considerando uma perspectiva holística, que tenha como foco atividades de desafio motor e cognitivo (fatores específicos), e que envolvam o incremento de fatores contextuais não específicos, tais como suporte social, alegria e motivação, além de indiretamente diminuírem a influência de fatores principais, a exemplo do fracasso e da tristeza (PESCE et al., 2021).

Dentre as diferentes atividades que poderiam integrar as características supracitadas, destaca-se a modalidade Ginástica a qual pode ser praticada em nível educacional, a partir da experimentação de movimentos gímnicos baseados nas HMF.

2.5 Ginástica Educacional

A ginástica é considerada uma área ampla, que engloba muitas formas de movimento, podendo ser conceituada como exercícios físicos realizados com ou sem aparelhos, que envolvem a promoção da coordenação e controle corporal, bem como capacidades físicas, como força e agilidade (CAINE & RUSSELL, 2013; RUSSELL, 2013). A figura 4 expressa as diversas formas de expressão gímnicas existentes, cada uma com suas características e propósitos distintos.

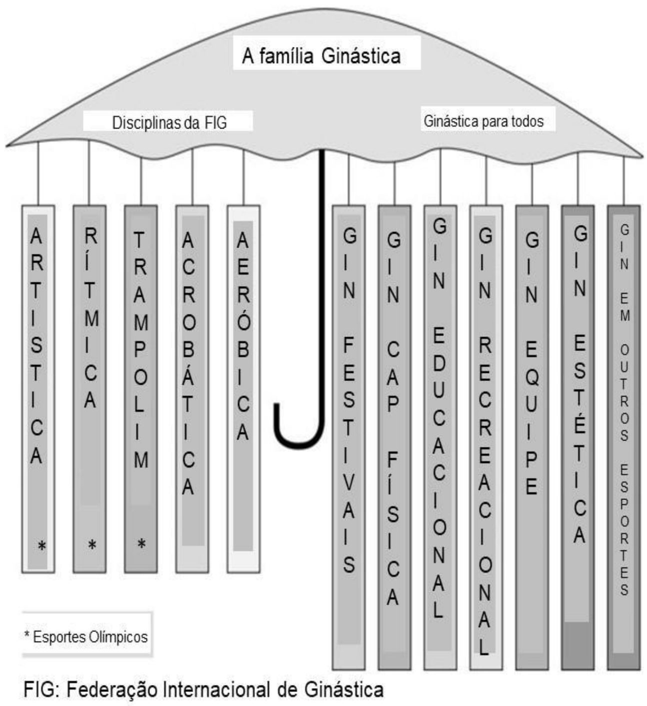


Figura 3: A família da Ginástica (traduzido de Russel (2013)). GIN – Ginástica; CAP FíSICA – Capacidade Física

Uma das formas de ginástica associada à prática no contexto escolar é a ginástica educacional. A ginástica educacional é distinguida das outras formas de ginástica tradicional (também conhecidas como "formal", “olímpicas” ou de “rendimento”) porque não visa a competição e nem o seguimento dos códigos de pontuação oficial, mas sim o prazer pela experiência do movimento gímnico (NILGES, 1997; 2008; BAUMGARTEN; PAGNANO-RICHARDSON, 2010;). A ginástica educacional proporciona a vivência de diferentes padrões de movimento, a partir de habilidades como saltar, equilibrar, balancear, rotacionar, rolar, girar e manipular objetos (NILGES, 1997, 2008; RUDD et al., 2017a).

Autores reportam que a ginástica educacional apresenta semelhanças às outras formas de ginástica no que tange ao conteúdo (nas formas básicas de movimento), porém apresenta grandes diferenças metodológicas referentes à estrutura necessária para sua prática (sem necessidade de aparelhos oficiais) e no objetivo proposto, que é desenvolver habilidades baseadas nas potencialidades e motivação de cada criança (NILGES, 1999; BAUMGARTEN; PAGNANO-RICHARDSON, 2010). A Austrália é um exemplo de país que incorporou programas de ginástica educacional em seus currículos escolares, chamado de *Lauch Pad*, que engloba objetivos específicos que vão desde a pré-escola (*Kindergym)* até 12 anos (*GymSkills)* (RUDD et al., 2017a; 2017b).

Apesar de diversos autores relatarem a importância da ginástica educacional ser inserida nos currículos desde a pré-escola (DONHAM-FOUTCH, 2007; RUDD, 2016; RUDD et al., 2020), até o momento não são conhecidos estudos que tenham investigado os efeitos da ginástica educacional na AR e nos comportamentos de movimento – 24 horas em pré-escolares.

3. PROCEDIMENTOS METODOLÓGICOS

3.1 Aspectos Éticos

O presente projeto de tese faz parte de um projeto maior intitulado "RELAÇÕES TRANSVERSAIS E LONGITUDINAIS ENTRE COMPORTAMENTOS DE MOVIMENTO EM 24 HORAS E DESFECHOS EM SAÚDE DE PRÉ-ESCOLARES DA CIDADE DE PETROLINA (PE) - PROJETO MOVEMENT´S COOL".

Este projeto seguiu a resolução 466/12 e a resolução 510/16 organizada pelo Conselho Nacional de Saúde e foi aprovado pelo Comitê de Ética e Pesquisa de Seres Humanos (CEP) – CAEE 47542921.7.0000.8267. Para a participação das crianças no estudo, todos os pais e/ou cuidadores primários assinaram o Termo de Consentimento Livre e Esclarecido (TCLE – Apêndice I e II).

3.2 População e Amostra

3.2.1 Local de Realização do Estudo

O presente projeto foi desenvolvido entre os anos de 2022 e 2023, no município de Petrolina, localizado no Vale do São Francisco, região sertão do estado de Pernambuco, Brasil. Conforme dados do Instituto Brasileiro de Geografia e Estatística (IBGE, 2022), Petrolina é uma cidade de aproximadamente 386.791habitantes, situada a 712 km deRecife (capital), sendo a quarta maior cidade do interior nordestino. Apresenta uma área territorial de 4.561,870 km², sendo 244,8 km² perímetro urbano e 4.317,072 km²zona rural, e um índice de desenvolvimento humano municipal (IDHM- 2010) de 0,697 (considerado alto - sexta posição em Pernambuco), com uma renda de 2,1 salários mínimos médios mensais para os trabalhadores formais.

Este projeto envolveu a participação dos Centros Municipais de Educação Infantil (CMEIS) de Petrolina. O ensino infantil no município de Petrolina é de responsabilidade da secretaria executiva da primeira infância, órgão incumbido do planejamento político-pedagógico, organização de vagas, implementação de novas unidades e fiscalização. A secretaria é responsável pelas unidades do Nova Semente (0 a 3 anos), pelos CMEIs e turmas de Pré-Escola,ambos para crianças de 3 a 5 anos. Todos os testes previstos no presente projeto de pesquisa foram realizados no espaço físico disponível nos CMEIs.

3.2.2 Critérios de Inclusão, Exclusão e não Inclusão

Critérios de inclusão

- Ter idade entre 4 e 5 anos no ano de 2022;
- Estar matriculado(a) em um CMEI para cursar o nível Pré-1;
- Não ser participante de atividade física regular e estruturada, como escolinhas esportivas ou projetos sociais esportivos;
- Apresentar o TCLE devidamente assinado pelo responsável;

Critérios de não-inclusão

- Apresentar transtornos específicos de desenvolvimento neuropsicomotor(dificuldades de aprendizagem, deficiências físicas, sensoriais, transtornos comportamentais e intelectuais.

Critérios de exclusão

- Apresentar laudo de transtornos neuropsicomotor (dificuldades de aprendizagem, deficiências físicas, sensoriais, transtornos comportamentais e intelectuais) no transcorrer do estudo.
- Não assentimento da criança, mesmo após assinatura do TCLE.

As crianças incluídas no estudo que obtiveram laudos de transtornos do neurodesenvolvimento no decorrer do estudo, continuaram participando de todas as etapas, mas seus resultados não foram considerados nas análises da pesquisa.

3.2.3 Recrutamento da amostra

De acordo com dados da Secretaria de Educação, Petrolina contava com 45 CMEIs, considerando zona urbana (n=30) e rural (n=15), no ano de 2022. Contudo, devido às diferentes estruturas dos CMEIs, existiam locais que apresentavam somente duas turmas de pré - 1, e CMEIs que apresentavam até quatro turmas que comportavam de 15 a 25 crianças. Além disso, alguns CMEIs apresentavam difícil acesso ou não permitiam a realização de pesquisas por acolherem crianças em situação de risco social.

Nesse sentido, foi realizada uma triagem dos CMEIs com maior número de alunos em cada zona da parte urbana da cidade (Norte, Sul e Central, Oeste e Leste), bem como da parte rural, em que fosse acessível o acesso dos pesquisadores. Após esta etapa, foram convidadas a participar do estudo sete Cmeis, sendo seis da zona urbana (três zona leste, um zona norte, um zona sul e um zona oeste) e um CMEI da zona rural. Nestas unidades, foram convidadas a participar do estudo todas as crianças matriculadas nas turmas pré-1 (4 e 5 anos). Esta etapa caracterizou a composição da amostra dos estudos II e III. Em adição, dentre os seis CMEIs elegíveis da zona urbana, dois foram randomizados para o desenvolvimento do estudo IV da presente tese.

3.3 Variáveis do Estudo

Abaixo é apresentada uma breve descrição das variáveis estudadas e analisadas nesta tese. Informações detalhadas sobre os procedimentos de coleta e análise de cada uma das variáveis do estudo estão descritas no capítulo de resultados.

3.3.1 Autorregulaçao

Autorregulação Cognitiva – Medida Direta

As habilidades centrais da ARCOG foram avaliadas de maneira direta nas crianças a partir dos escores de desempenho dos três componentes centrais, sendo estes Controle Inibitório (CI), Memória de Trabalho Viso-Espacial (MTVS) e Flexibilidade Cognitiva (FC) (DIAMOND, 2013). Para avaliação destes construtos foram utilizados os testes disponíveis na bateria Early Years Toolbox (EYT), instrumento validado para avaliação das habilidades de FE em pré-escolares (HOWARD; MELHUISH, 2017). A EYT funciona em Ipad, podendo ser realizada em campo, não necessitando de conexão com internet. O tempo médio para avaliação dos testes é de 40 minutos.

Autorregulação Comportamental – Medida Direta

A ARCOM foi avaliado de maneira direta nas crianças por meio do teste cabeça, ombro, joelho e pés revisado (GONZALES et al., 2021). Este teste vem sendo amplamente utilizado como uma medida confiável e válida da ARCOM para crianças de quatro a oito anos (KENNY et al., 2023), mostrando forte consistência interna (alfa de Cronbach < 0,90). O teste foi administrado por assistentes de pesquisa certificados em um espaço fornecido dentro dos centros. A avaliação não excedeu 10 minutos.

Autorregulação – Medida Indireta

A AR também foi avaliada subjetivamente através dos relatórios dos pais ou cuidadores primários, utilizando a versão brasileira do Questionário de Autorregulação e Comportamento Infantil (CSBQ) (LEMOS et al., 2024 - APÊNDICE I). Este estudo utilizou três subescalas: Autorregulação Cognitiva (CSR-CSBQ) (cinco itens, por exemplo, “persiste com tarefas difíceis”), Autorregulação Comportamental (BSR-CSBQ) (cinco itens, por exemplo, “espera sua vez nas atividades”) e Autorregulação Emocional (ESR-CSBQ) (três itens, por exemplo, “supera rapidamente a irritação”).

3.3.2 Habilidades Motoras Fundamentais

Para avaliação das habilidades motoras fundamentais (HMF) foi utilizada a bateria de testes Test of Gross Motor Development-Second Edition (TGMD-3) que avalia o processo das HMF através da qualidade dos movimentos realizados pelas crianças proposto por Ulrich (2018) e validado para crianças brasileiras (VALENTINI; RUDISILL, 2006). Esta bateria consiste em avaliar as habilidades de locomoção e controle de objetos, a partir das quais se calcula os escores de HMF, podendo ser aplicado em crianças de três a dez anos.

3.3.3 Comportamentos de Movimento

Os níveis de atividade física e comportamento sedentário foram avaliados por meio do acelerômetro Actgraph®, modelo Wgt3x (ACTGRAPH, 2018). O acelerômetro foi utilizado na cintura da criança por um período de oito dias. Para validação dos dados foram considerados um mínimo de 6 horas de uso, sem exigência de um dia de fim de semana válido, durante pelo menos 1 dia, entre 6h e 22h (BINGHAM et al., 2016).

Para medida de comportamento sedentário baseado em tempo de tela, os pais foram solicitados a relembrar a duração média total que seus filhos assistem TV, usamcomputador, smartphones e videogames. As perguntas foram feitas separadamente para dias de semana e dias de fim de semana (MARTINS et al.,2021).

Para medida do Sono adotou-se dois procedimentos distintos para os estudos transversais e longitudinal. Para os estudos transversais, os pais/cuidadores primários foram solicitados a lembrar o número total de horas de sono noturno e de sonecas de seus filhos da seguinte forma: "Nos dias de semana, quantas horas de sono seu filho costuma ter durante o dia (por exemplo, soneca) e à noite?" e "Nos finais de semana, quantas horas de sono seu filho costuma ter durante o dia (por exemplo, soneca) e à noite?" O Sono Total foi calculado como a soma do sono noturno (diferença entre a hora de dormir e a hora de acordar) e a duração das sonecas. Já para o estudo lonigitudinal, os pais/cuidadores primários foram solicitados a preencher um diário de sono durante a semana de uso do acelerômetro e regitrar o horário em que a criança foi dormir a noite, horário em que a criança acordou e o tempo dos cochilos. A duração total semanal do sono foi calculada somando as durações diárias do sono e dividindo o total por 7.

3.3.4 Medidas da Composição Corporal

A estatura foi determinada com o auxílio do estadiômetro (Holtain Stadiometer) pelo milímetro mais próximo acima da cabeça, estando o participante em pé, descalço, com os pés unidos. A massa corporal será avaliada através de umabalança (Seca 708 portable digital beam scale), estando o participante levemente vestido e descalço. Posteriormente será calculado o índice de massa corporal (IMC),relação entre massa de corpo (Kg) e estatura ao quadrado (m2). O perímetro da cintura, abdômen e quadril será mensurado com uma fita métrica não-elástica

(Seca;variação de 0 a 150 cm e precisão de 1 mm). A mensuração foi realizada no final de uma expiração normal, sem que a fita comprima a pele.

3.3.5 Correlatos Sociodemográficos

Foram coletadas informações acerca do estrato socioeconômico, nível de escolaridade do cuidador primário, sexo e idade dos avaliados, por meio de uma entrevista.

4. PLANO DE ANÁLISE ESTATÍSTICA

O tratamento dos dados e análises estatísticas foram realizados de acordo com o objetivo determinado para cada estudo, conforme Tabela 1.

Tabela I. Operacionalização das variáveis e tratamento estatístico dos estudos realizados na tese doutoral.

Estudo	Variáveis	Variáveis de Ajuste	Análise Estatística
1	Artigos originais	Padronização de nomes de autores, periódicos e instituições	Análise bibliométrica
2	CI, MTVE, FC, ARCOM, AF, CS, SONO	Sexo: 1) masculino x 2) feminino; Idade (meses); IMC (contínuo);	Teste T independente para variáveis contínuas, Teste Qui-Quadrado para variáveis categóricas e Modelos Lineares Generalizados
3	CI, MTVE, FC, ARCOM, AF, TT, SONO	Sexo: 1) masculino x 2) feminino; Idade (meses); IMC (contínuo);	Análise composicional e isotemporal
4	CI, MTVE, FC, ARCOM, ARSUBJ, TGMD, LOC, HB, AF, CS, SONO	Sexo: 1) masculino x 2) feminino; Idade (meses); IMC (contínuo);	Modelos Lineares Generalizados Mistos

CI: Controle Inibitório, MTVS: Memória de Trabalho Visoespacial, FC: Flexibilidade Cognitiva, AR: Autorregulação, ARCGOG: Autorregulação Cognitiva; ARCOM: Autorregulação Comportamental; ARSUBJ: Autorregulação Subjetiva; LOC: Locomoção, HB: Habilidades com Bola, AF: Atividade Física; TT: Tempo de Tela; CS: Comportamento Sedentário.

5. RESULTADOS

A execução desta tese visou responder pelo menos quatro questões problema principais que nortearam a construção do documento em questão. A primeira delas foi: como se apresenta o estado da arte em relação às intervenções com AF e desfechos na cognição de crianças e adolescentes? Quais as redes de publicação em relação a este tema, os principais desfechos investigados e o número de publicações em relação a faixa etária? Para responder a esta questão foi delimitado o objetivo específico 1 de explorar e sumarizar as publicações relativas aos efeitos das intervenções de AF e desfechos cognitivos em crianças e adolescentes, por meio de uma análise bibliométrica, que resultou na elaboração e publicação do artigo "A bibliometric analysis of physical activity interventions and cognition in children and adolescentes".

A segunda questão problema remeteu à pergunta: existe associação entre aderir às recomendações de comportamentos de movimento – 24 horas e ARCOG e ARCOM em pré-escolares? Para responder a esta questão foi definido o objetivo específico 2 da tese, no intuito de investigar as associações entre aderir às recomendações de comportamentos de movimento -24 horas e os domínios cognitivos e comportamentais da AR em pré-escolares. Neste sentido, foi elaborado o estudo 2 "Adherence to the 24-hour Movement Behaviors Guidelines and Associations with Cognitive and Behavioral Self-Regulation among Brazilian Preschoolers", submetido para apreciação por pares no American Journal of Human Biology.

A terceira questão problema definida para esta tese foi: as associações entre comportamentos de movimento – 24 horas e ARCOG e ARCOM se comportam de maneira diferente quando se considera os comportamentos como uma composição? Se sim, mudanças teóricas no tempo entre os comportamentos de movimento se associam positivamente com a ARCOG e a ARCOM em pré-escolares? Esta questão foi respondida a partir do objetivo específico 3, que diz respeito a investigar a associação entre a composição dos comportamentos de movimento -24h e a ARCOG e a ARCOM em pré-escolares; e investigar as mudanças teóricas na ARCOG e ARCOM quando diferentes tempos nos comportamentos de movimento são realocados. Para tal, foi elaborado o artigo "24-hour Movement Behaviors and Self-Regulation in Preschoolers: Cross-sectional associations using compositional and isotemporal analyses".

Por fim, as questões problema: uma intervenção de AF, a partir de um protocolo com foco na ginástica educacional, é capaz de gerar efeitos positivos na AR, nas HMF e nos comportamentos de movimento – 24horas em pré-escolares? E os efeitos desta intervenção são mantidos 12 semanas após o final da intervenção? foram respondidas com base no objetivo 4 investigar os efeitos de uma intervenção com AF, a partir de um protocolo com foco na ginástica educacional, na AR, HMF e comportamentos de movimento – 24 horas em pré-escolares; e investigar a manutenção dos efeitos desta intervenção após um período de 12 semanas pós-intervenção. Neste sentido, o artigo "Effects of an Educational Gymnastics Intervention on Self-Regulation, Motor Skills and Movement Behaviors in Preschoolers: A Cluster Randomized Control Trial" foi elaborado. Para tanto, neste último artigo foi contemplada também medidas da AR subjetiva avaliada pelos pais e/ou cuidadores primários a partir da publicação do artigo Evidence of the validity of the child self-regulation & behaviour questionnaire for the Brazilian context (Apêndice III).

5.1 ARTIGO I

Science & Sports 38 (2023) 582—592

Disponible en ligne sur
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com

ELSEVIER

SCIENCE & SPORTS

ORIGINAL ARTICLE

A bibliometric analysis of physical activity interventions and cognition in children and adolescents

Analyse bibliométrique des interventions d'activité physique et de la cognition chez les enfants et les adolescents

N. Lemos[a,b,*], **N. Sobral**[c], **M. Duncan**[d], **J. Mota**[e], **R. dos Santos**[f], **C. Martins**[g,b]

[a] *Department of Physical Education, Federal University of Vale do São Francisco, Petrolina, Brazil*
[b] *Associate Post-Graduate Program in Physical Education UPE/UFPB, João Pessoa, Brazil*
[c] *Institute of Information Science, Federal University of Bahia, Salvador, Brazil*
[d] *Centre for Applied Biological and Exercise Sciences, Coventry University, Priory Street, Coventry, CV1 5FB, UK*
[e] *Research Centre of Physical Activity, Health and Leisure, Faculty of Sport Sciences, University of Porto, 4500 Porto, Portugal*
[f] *Information Science Post-Graduate Program, Federal University of Pernambuco, Recife, Brazil*
[g] *Department of Physical Education, Federal University of Paraíba, João Pessoa, Brazil*

Received 26 October 2020; accepted 10 March 2022
Available online 9 March 2023

KEYWORDS
Exercise;
Cognitive development;
Childhood;
Quantitative approach;
Web of Science

Summary
Aim. — This study analyzed the scientific publications about Physical Activity (PA) interventions and cognition in children and adolescents between 2009 and 2019, indexed in the Web of Science database, by conducting a bibliometric analysis.
Methods. — The co-occurrence analysis between journals, authors, countries, institutes, co- cited references, and keywords was considered.
Results. — One hundred seventy-two studies, published in 90 journals, were identified.Active collaborations between high-income countries were observed, mainly U.S researchers,which also have the largest international network. ''Physical Activity,'' ''Exercise'', ''Cognition,'' ''Executive Function,'' ''Academic Performance, ''Aerobic Fitness'' ''Children'' and ''Adolescents'' were the most common keywords seen in the studies. Most of the publications target school children and preadolescents, followed by adolescents. This bibliometric

* Corresponding author. Department of Physical Education, Federal University of Vale do São Francisco, Petrolina, Brazil.
E-mail address: natalia.goulart@univasf.edu.br (N. Lemos).

https://doi.org/10.1016/j.scispo.2022.03.016

Science & Sports 38 (2023) 582—592

analysis allows a broader understanding of the current state of the art on the relationship between PA intervention and cognition in children and adolescents, and can support future researches, which should cover gaps as collaboration between low-middle income countries, and further evidence in early childhood.

MOTS CLÉS
Exercice ;
Développement cognitif ;
Enfance ;
Approche quantitative ;
Web of Science

Résumé
Objectifs. — Cette étude visait à analyser les publications scientifiques sur les interventions d'activité physique (AP) et la cognition chez les enfants et les adolescents entre 2009 et 2019, indexées dans la base de données Web of Science, en réalisant une analyse bibliométrique.
Méthodes. — L'analyse de cooccurrence entre les revues, les auteurs, les pays, les instituts, les références co-citées et les mots-clés a été réalisée.
Résultats. — Cent soixante-douze études ont été identifiées comme étant publiées dans90 revues. Les collaborations actives ont été observées entre les pays à revenu élevé, principalement des chercheurs aux États-Unis, qui disposent également du plus grand réseau international. « Activité physique», « Exercice », « Cognition », « Fonction exécutive », « Rendement scolaire », « Forme aérobique », « Enfants » et «Adolescents » étaient les mots clés les plus courants dans les études. La plupart des publications ciblent les écoliers et les préadolescents, suivis par les adolescents. Cette analyse bibliométrique permet une meilleure compréhension de l'état de l'art actuel sur la relation entre les interventions l'AP et la cognition chez les enfants et les adolescents. Bien qu'il y ait eu une augmentation de la production scientifique dans ce domaine, les travaux futurs devraient inclure collaboration entre des chercheurs de pays à revenu faible et intermédiaire et davantage d'études axées sur la petite enfance.

1. Introduction

The potential effect of physical activity (PA) interventions on cognition in children and adolescents is an emerging research field [1—3]. Several systematic reviews and meta-analyses have shown that acute and chronic PA have a positive influence on cognitive function [4,5], as well as on structural and functional brain health in youth [6—8]. Nonetheless, some studies have reported that certain types of PA, such as aerobic exercise, had a small [2,9,10] or even no effect on cognition, instead of activities with cognitive engagement [11,12]. Due to the lack of consensus on the PA exposure-cognition relationship in children and adolescents, many aspects of this relationship remain unclear, it is key to have a complete overview of the area, to understand what issues of PA and cognition future studies need to target [2,13].

It is possible to identify researchers that have been investigating different PA aspects, as type, intensity and duration, and its association with cognition outcomes, brain function and structure in youth [2,7]. However, due to the increasing number of academic publications on PA interventions and cognition in children and youth in the last decades, it is challenging to keep pace with the current state of the art related to this topic.

To addresses this increase in publications, and to synthesize findings in a specific area, the bibliometric analysis is an efficient tool for qualitative and quantitatively assist the development of a science field [14,15]. In this process, bibliometric indicators are used to measure productivity by analyzing the number of publications (quantitative indicators); to measure the impact of an author's or a research group's publication concerning the number of citations (quality or performance indicators); and to measure connections between papers, authors and research fields (structural indicators) [16]. Unlike the systematic review that analyzes the conceptual/methodological structure of a part of a body scientific literature, bibliometric analysis represents a broad synthesis that allows mapping the state of the art, identifying gaps and trends of research, as well as being as a tool for research evaluation [15,17,18]. Thus, bibliometric approaches may support the knowledge on this specific area, and guide future research interests [19]. Bibliometric approaches are well-established in several research areas, such as information sciences, and have been increasing in other areas, including PA, during the last years [19—22]. However, to date, no study has focusedon specific aspects of PA interventions and cognition in children and adolescents using the bibliometrics.

Thus, the present study aimed to explore and summarize the publications concerning the effects of PA interven- tions on cognitive outcomes in typically developed childrenand adolescents, which were published between 2009 and 2019. Bibliometric analysis focusing on the most prominent publications, journals, authors, and networks is a useful step in providing important support for future studies and researchers.

2. Material and methods

2.1. Eligibility criteria

The following inclusion criteria were adopted: (1) original articles, including experimental and quasi-experimental design, systematic reviews, meta-analysis, and editorials;

(2) articles investigating the effects of PA (acute and chronic) on cognition (cognitive function, brain function, and brain structure) in target populations from preschool to high-school age (3—18 years); (3) full texts (publishedor accepted for publication in a peer-reviewed journal)in English or Spanish from January 2009 until December 2019. Studies were excluded when including children and adolescents with mental or coordinative disorders; cross-sectional studies, systematic reviews, and meta-analyses that evaluated only the relationship between physical fitness and cognition (not acute or chronic PA intervention); cross-sectional studies that evaluated the relationship between physical activity levels (measurement by accelerometers or questionnaires) and cognition (not the acute or chronic effect of PA intervention); when the study's assessments involved only data concerning the association betweenPA intervention and academic performance outcomes (not cognitive function or brain function or brain structure outcomes).

2.2. Search criteria

The bibliometric data were derived from Web of Science (WOS) Core Collection citation indexes databases (a multidisciplinary database, 12,000 periodicals). The last search was conducted on January 31, 2020, to ensure the inclu- sion of all relevant papers published between January 1, 2009, and December 31, 2019. The WOS has been used in bibliometric studies and has been reported as the most pop-ular citation database for calculating bibliometric statistics[14,23,24].

The electronic search strategy was developed in collaboration with a PhD information science, with experience in bibliometric analysis. Firstly, we have chosen to mesh terms and keywords related to (1) physical activity (2) cognition and (3) children and adolescents, included search terms obtained from several systematic reviews [2,4,5]. The combination search # 1 and #2 and #3 retrieved more than 2000 registers. Despite not being the central theme of interest in this study, to refine the search, we have included the terms (4) ''academic performance'' OR ''academic achievement'', since academic performance has been one of the most prominent terms related to the study of the effects of physical activity interventions on cognition in children and adolescents [2,13]. Complete search strategies are provided in Appendix A.

One researcher (NL) selected the studies according to titles, abstracts, and inclusion criteria. Besides, the list of references from systematic reviews published from 2009 onwards was checked to identify other articles not captured in our search strategy. Four co-authors (NL; NS; MD; CM) checked the recovered studies with the screening of title and abstract or optional screening full-text to ensure the inclusion of all essential articles or exclude papers.

2.3. Data analysis

The extracted bibliographic data from WOS were exported to an Excel document (Microsoft Office®, Microsoft Corporation, USA) and saved in a plain text format. Then, the spreadsheet was standardized in the VantagePoint® software (Search Technology). This tool has been used in important bibliometric studies in the scientific community and published in prestigious journals [25].

One of the major problems in bibliometric studies is the standardization of authors' names, institutions, and keywords. Therefore, similarly to Zhao [26], standardization was carried out in three stages: (1) cleaned-up in VantagePoint® software, with the support of a predefined thesaurus that integrates terms based on syntactic similarity and standardization by the VOSviewer thesaurus file; (2) manual integration of terms, with the purpose of making the standards not considered by the software; (3) expert review, drawing on the knowledge of the co-authors of the article, especially for semantic normalization involving keywords and institutions. These steps were designed to handle issues of misspellings, alternative hyphenations and capitalizations, and differing conventions for listing the names of institutions and keywords. Finally, processed data were reviewed by experts to maintain the meaning of authors' keywords and keep the names of their affiliations standardized [26].

With normalized data, binary mathematical matrices of co-occurrence were generated, establishing zero for absence and one for the presence of relationships with the objective of crossing data, and therefore, generating rankings. For the analysis, of the results the following categories were defined: (a) the number of articles published by year, top journal of publications; (b) the number of authors and their collaboration networks, the population included in the author's studies; (c) top-countries and institutions; (d) top-cited references and top-cited authors; (e) main issues were identified through the analysis of the keywords used by the authors. The bibliometric maps were made in VOSviewer program version 1.6.9 (Leiden University, the Netherlands) [27].

3. Results

The WOS database search retrieved 813 articles, and ten additional records were identified through other sources, which were screened in detail based on the title and abstract. Of these, 185 were read in full, and 172 studies met the inclusion criteria (Fig. 1). All included studies may be found in Appendix B.

3.1. Publications

Publications focusing on the effects of PA interventions on cognition in children and adolescents increased between 2009 and 2019, and the highest number of publications was seen in 2018 (Fig. 2). Among the 172 included studies, 121 were experimental and quasi-experimental articles, 47 included narrative reviews, systematic reviews and meta-analysis, and four commentaries/editorials.

A total of 90 journals have published articles related to the effects of PA interventions on cognition in children and adolescents. Appendix C presents the top 10 journals, with at least four publications on this topic. The journal with the largest number of publications was Frontiers in Psychology (nine documents), followed by BMC Public Health (eight documents), Medicine and Science in Sports and Exercises and

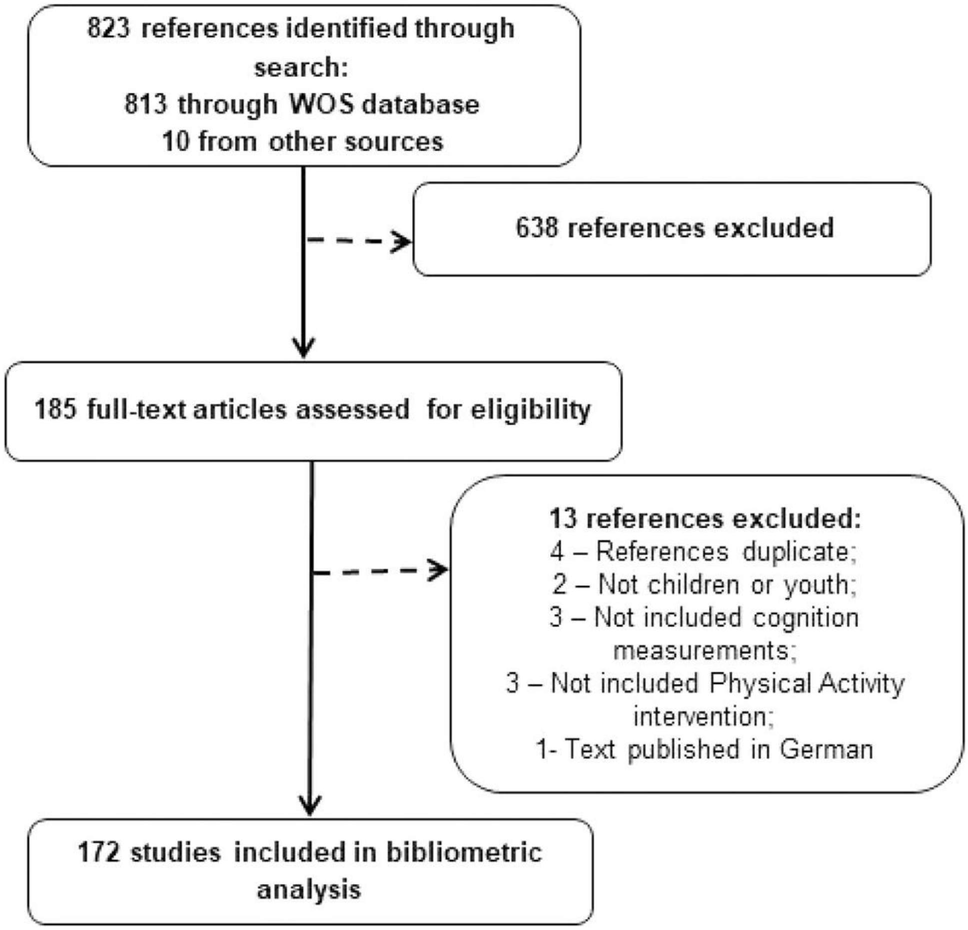


Figure 1 Literature research and selection process.

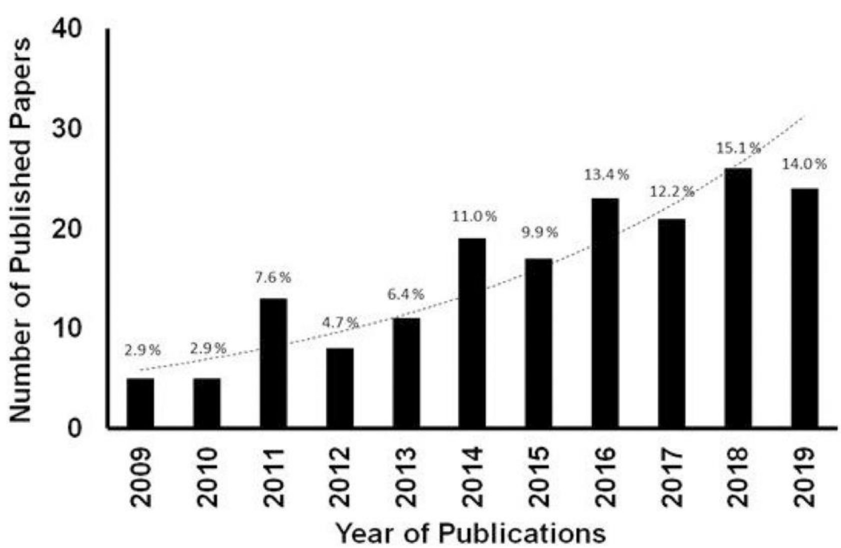


Figure 2 Number of publications per year.

Science & Sports 38 (2023) 582—592

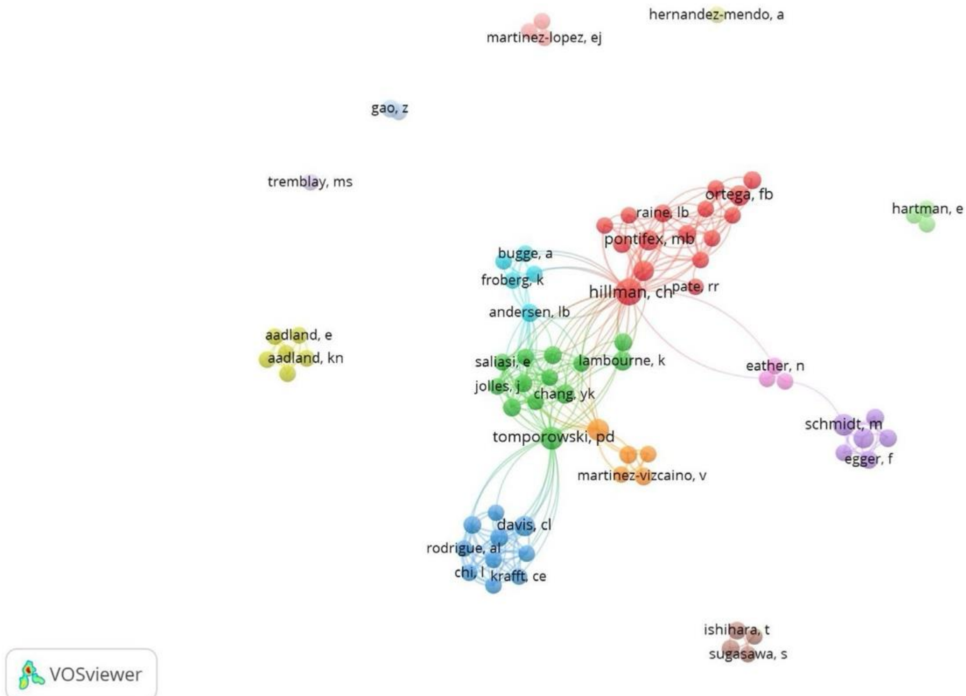


Figure 3 Authors and network collaborations (at least three publications). Circle — researcher; Clusters with the same color represent the network of collaborators. Circles of different colors represent different networks. The thickness of the line represents the number of co-authorship publications.

Mental Health and Physical Activity (both with seven documents). The impact factors ranged between 1.70 (lower value) to 11.64 (higher value).

3.2. Authors: networks of collaborators

A total of 649 authors and their network collaborations were identified. To identify the most productive authors in the research area, we considered authors with at least three publications. Seventy-eight researchers (12.01%) were in at least three publications from 14 different collaboration clusters (Fig. 3). The Top 10 authors with the highest number of publications concerning PA interventions and cognition in children and adolescents were Hillman, CH (*n* = 20 and 98 links), Tomporowski, PD (*n* = 10 and 53 links), Pesce, C (*n* = 8 and 45 links) and Schmidt, M (*n* = 8 and 13 links), followed by Castelli, DR (*n* = 6 and 13 links); Pontifex, MB (*n* = 6 and 9 links); Conzemann, A (*n* = 6 and 5 links); Davis, CL (*n* = 6 and 10 links); Ortega, FB (*n* = 6 and 9 links); Lambourne, K (*n* = 5 and 5 links) and Chang, YK (*n* = 5 and 13 links).

Among all the authors, the strongest collaborative networks were seen between Castelli, DM; Hillman, CH; Pontifex, MB; and between Schmidt, M; Conzelmann, A. (at least six documents in collaboration). In the Appendix D, can be found the research clusters.

The four institutions with the highest number of publications were the University of Illinois at Urbana-Champaign (18 publications, 10.46%), the University of Georgia (13 publications, 7.55%), followed by the University of Granada and the University of Bern (both with 10 papers, 5.81%).

We analyzed the age range of the author's interest by checking the abstract and/or full texts. The analysis showed the authors' target interest (Fig. 4). From 172 papers, 98 studies (56.97%) assessed children and preadolescents (6—12 years), 27 studies (15.69%) were developed with adolescents (older than 12 years) and 20 (11.62%) included both children and adolescents in the same study. Sixteen articles (9.30%) reported preschool children ($\geq$ 5 years), and six systematic review/and meta-analysis studies (3.48%) involved a broad age-group (3—18 years). Finally, five studies (2.90%) involving both preschool and school children were observed.

3.3. Countries and institutions

Several research groups from 32 countries have published studies on PA interventions and cognition in children and adolescents. The top 10 countries published at least ten papers, and all these countries have international collaborations (Appendix E). Most of the documents were published by authors from the USA (71 publications; 41.27%), followed by Spain, Switzerland, Australia, the Netherlands, Italy, Canada, Germany, England, and Norway (more than ten papers). The USA and Switzerland lead the number of international collaborations (seventeen and sixteen collaborations, respectively).

3.4. Top — references and top-cited authors

Regarding the co-citation of references, a total of 5655 cited references was observed. From those, the top 10 references were cited at least 40 times (Table 1). Among the most cited references, five experimental studies and five litera-

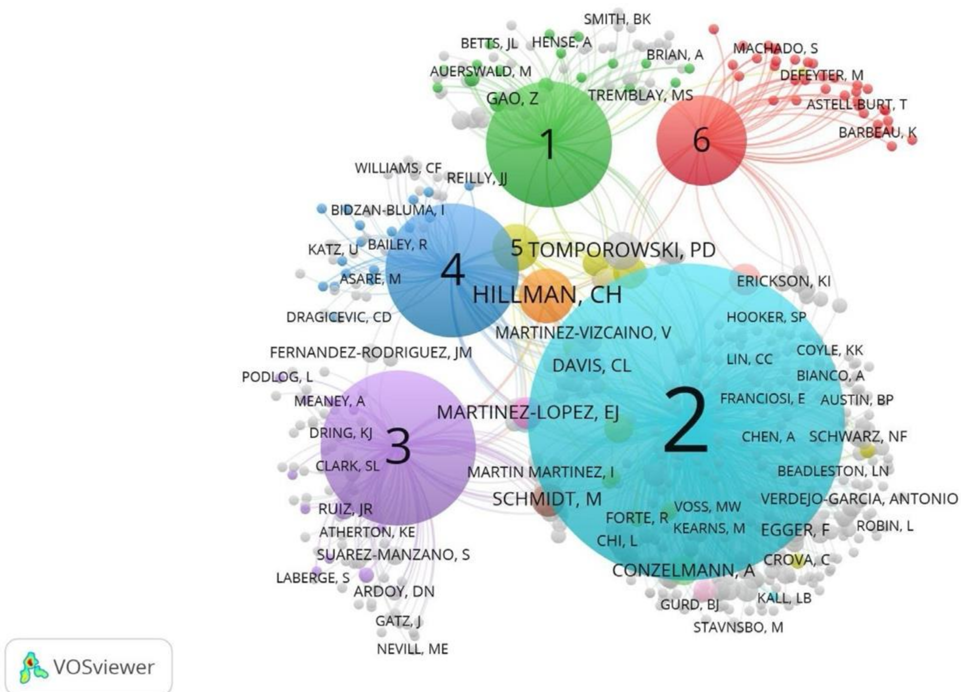


Figure 4 Authors × population network. 1: preschool children (5 years or young); 2: school children and pre-adolescents (6—12 years); 3: youth/adolescents (older than 12 years); 4: studies that included both children and adolescents (in the same study); 5:studies that included both preschool children and school children (in the same study); 6: studies that included a wide age group (3—18 years).

ture reviews, including one meta-analysis, were identified, and published between 2003 and 2014.

In addition, the most cited authors in the references were analyzed, using co-citation analysis in the VOSviewer, which includes the first author of a cited document. In these 5655 references, 4016 authors were observed. Among the authors, the top 10 authors received at least 77 citations. The top 10 cited authors were Hillman, CH (< 200 citations), following by Tomporowski, PH; Diamond, A; Pesce, C; Best, JR; Davis, CL; Chaddock, L; Donnelly, JE; Kamijo, K; Budde, H (range 77—200 citations).

3.5. Co-occurrence keywords

Fig. 5 illustrates the main terms investigated by the author's keywords. For better data analysis; some words were standardized (i.e.: ''working-memory'' = ''working memory''; ''academic achievement'' = ''academic performance''; ''cognitive control'' = ''executive function''). A total of 278 keywords were used; and 23 appeared at least 20 times. Keywords were related to the generaltopic (''Physical Activity'' — 76 times; ''Exercise'' — 27 times; ''Cognition''; 57 times); predominate population (''Children'' — 32 times; ''Adolescents'' — 21 times) and cognition outcome (''Executive Function'' — 44 times) and others outcomes (''Academic Performance'' — 29 times and ''Aerobic Fitness'' — 20 times).

4. Discussion

This study presents new data, via bibliometric analysis, focusing on studies examining the relationship between PA interventions and cognition in children and adoles-cents, between 2009 and 2019. Such information is critical in understanding the literature development, providing evidence that academic journals, research groups, and individual authors focus on understanding this research topic.

The current study showed a growing research interest in the effects of PA intervention on cognition in pediatric populations, which may be related to the methodological advances in assessing brain structure, function and activity, such as the use of neuroimaging devices (magnetic resonance imaging [MRI], electroencephalography [EEG]) and methods for assessing and capturing key aspects of cognitive development, providing valid and reliable measures in this populations [28—30].

The top 10 journals had published at least four articles. Although a higher number has been published in psychology journal (*Frontiers in Psychology* — 5.23%), it was also identified in public health, sports medicine, and exercise science journals. Most of these journals published only one article (61 journals), showing that many journals have contributed to the area. Recent reviews reported that there is a lack of high-quality studies in this field [2,13]. Since high-impact journals have greater dissemination on social

Table 1 Top-10 references cited.

Authors	Year	Title	Reference	Number of citations received in the network
Davis CL et al.	2011	Exercise improves executive function and achievement and alters brain activation in overweight children: a randomized controlled trial	*Health Psychol*, v. 30, p. 91, DOI 10.1037/a0021766	65
Hillman CH et al.	2009	The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children	*Neuroscience*, v. 159, p. 1044, DOI 10.1016/j.neuroscience.2009.01.057	62
Sibley BA & Etnier J	2003	The relationship between physical activity and cognition in children: a meta-analysis	*Pediatric Exerc Sci*, v. 15, p. 243, DOI 10.1515/ijsl.2000.143.183	61
Hillman CH et al.	2008	Be smart, exercise your heart: exercise effects on brain and cognition	*Nat Rev Neurosci*, v. 9, p. 58, DOI 10.1038/nrn2298	56
Best JR	2010	Effects of physical activity on children's executive function: contributions of experimental research on aerobic exercise	*Dev Rev*, v. 30, p. 331, DOI 10.1016/j.dr.2010.08.001	53
Budde H et al.	2008	Acute coordinative exercise improves attentional performance in adolescents	*Neurosci Lett*, v. 441, p. 219, DOI 10.1016/j.neulet.2008.06.024	50
Tomporowski PD et al.	2008	Exercise and children's intelligence, cognition, and academic achievement	*Edu Psychol Rev*, v. 20, p. 111, DOI 10.1007/s10648-007-9057-0	46
Diamond A	2013	Executive functions	*Annu Rev Psychol*, v. 64, p. 135, DOI 10.1146/113011-143750	43
Hillman CH et al.	2014	Effects of the FITKids randomized controlled trial on executive control and brain function	*Pediatrics*, v. 134, p. 239, DOI 10.1542/peds.2013-3219	42
Kamijo K, et al.	2011	The effects of an afterschool physical activity program on working memory in preadolescent children	*Developmental Science*, v. 14, p. 1046, DOI 10.1111/j.1467-7687.2011.01054.x	40

media and more often attract the attention of researchers, improving the quality of studies may strengthen the dissemination of knowledge about the effects of PA interventions and cognition in children and adolescents.

Co-authorship may be an effective scientific collaboration, and this is one of the most used bibliometric indicators [31,32]. The researcher who has the largest number of publications is Hillman, CH (Northeastern University/USA — expertise: Cognitive Neuroscience, Kinesiology, and Neurocognitive Kinesiology). The number of publications may be related to researchers with more experience, who have a more effective network that might act in favor of their publication activity [14]. This author has an average of 20 years of research experience with a broad international collaboration. On the other hand, the top 10 author's group in the number of publications are also composed of researchers with an average of 10 years of research experience, which shows a group of senior and junior researchers [2], who have contributed to the scientific production in this science field.

Several studies have been carried out mainly by U.S authors who have the largest network in several continents (Spain, Japan, England and Australia). High-income countries have influenced the knowledge on this topic, with closer cooperation. The high costs associated to intervention studies that involve brain measures, as well as the greater financial support to research in these countries, may partially justify these results [33]. Nonetheless, future studies should expand collaborations with researchers from different socio-cultural contexts, such as middle/low-income

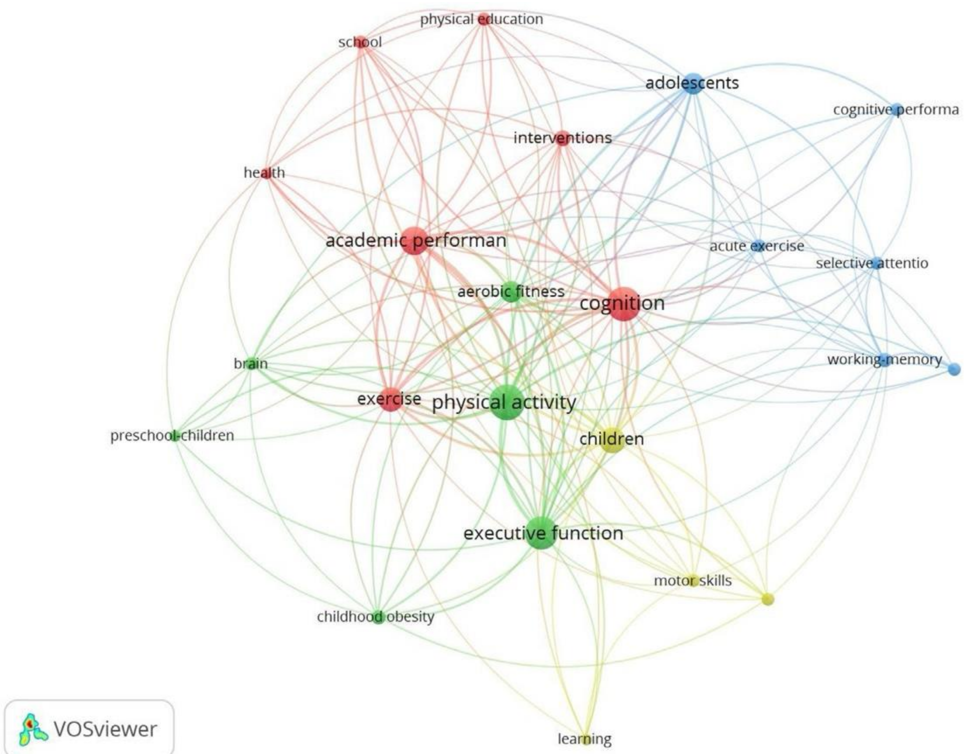


Figure 5 Most author keywords occur (at least six times). *keywords co-occurrence: the number of documents in which a keyword occurs. Item density is proportional to the number of occurrences.

countries, especially due to the direct influence of income and vulnerability correlates in children's brain development [33—35].

The co-citation analyses allow the identification of the relation between publications cited by the same papers and could be used as a tool methodological reference for academics and researchers interested in the research field [36]. The current results highlighted the ten most cited articles, published mostly from 2008. Among the referenced articles, the oldest cited study is from 2003 (Sibley & Etnier), a meta-analysis focusing on the relationship between PA and cognitive functioning in children. The most cited article is from Davis et al. (2011), and the most current report is from 2014 (Hillman et al., 2014), both randomized controlled trials, that evaluated the benefits of exercise on executive and brain functions in overweight children and preadolescents, respectively.

Seven of the top ten cited authors were authors or co-authors of the ten most cited references. Hillman, CH was the most cited author in the network. This American researcher has investigated the effects of interventions, such as aerobic exercise, on cognitive performance, brain function and brain structure in children and adolescents [6,37,38]. Other researchers with a higher number of citations in the network were the American researcher Tomporowski, PD who have developed research about the PA interventions and mental engagement, skill acquisition and learning [12,39,40], and the Canadian researcher Diamond, A who has investigated how and what physical activities can improve executive function in children (e.g., sports, coordination activities, mindfulness) [41—43].

The keyword analysis is an important aspect to consider when using a bibliometric approach, as besides providing information about the main trends of the research area, it may help researchers on the access to relevant papers in databases [44,45]. The keyword analysis showed that ''executive function'' is the widely explored cognitive outcome. Executive function is the cognitive control function associated with core executive function (ie, working memory, cognitive flexibility, selective attention-inhibition, higher-order thinking processes, and behaviour regulation), that plays an essential role in mental and physical health, success in academic and professional skills [1,46,47]. The keyword analysis also showed others relevant topics, such ''Academic performance'' [2,13] — typically rated through the assessment of core academic aspects, such as language skills (ie. spelling, language, vocabulary, writing, and reading) and mathematics (i.e., numeracy and arithmetic), and ''aerobic fitness'' [48] — related to maximal capacity of the cardiorespiratory system to use oxygen. These researches explored the effects of PA intervention strategies on executive function and academic performance in children and adolescents [2,13,41], and how PA interventions may influence the association between childhood aerobic fitness and cognition outcomes, including the executive function [38,48,49].

Moreover, when exploring the relationship between authors and the target population, data showed therehas been a few amount of publications developed with preschoolers, which have been corroborated in recent systematic reviews [2,8,13]. Indeed, assessing PA and cognitive outcomes in early childhood is additionally challenging, due to the validity and feasibility of measurement protocols that cover this specific developmental period [30,42]. Nonetheless, several studies reinforce that early childhood is an important stage for brain and cognitive development, being a critical period in the development of school readiness skills that influence children's performance and progress in school [43,46,50]. Given the greater number of studies about the effects of PA on cognitive performance (especially executive function) and academic performance in older children (above 6 yrs, and adolescents), it seems reasonable to suggest that further research should focus on this critical early childhood period.

Despite the increasing scientific interest in PA interventions-cognition relationship in children and adolescents, to the best of our knowledge, this is the first bibliometric analysis in this field. So, this study provides a broader understanding of the current state of research on the relationship between PA and cognition in children and adolescents. The active collaborations were observed between high-income countries. While research from these geographical areas is undoubted of use, there are cultural and environmental influences on both PA and cognitive performance during childhood and adolescence. Thus, collaborations with researchers from different sociocultural contexts, such as low/middle-income countries, could explore this literature gap.

Nonetheless, the current study has some limitations. Firstly, we explored studies indexed in WoS Core Collection, the most used in bibliometric studies. Future studies should focus on other databases that may have potential publications. Second, the stipulated period has been limited to 2009 and 2019. Thus, pioneer researchers in this area were not contemplated in the analysis. Furthermore, we used the co-citation analysis that included the first author of a cited document. So, co-authorship documents were not considered in this analysis. Finally, future studies should explore the rate of scientific production by the leading authors, as well as the normalized citation impact as a metric comparison.

5. Conclusions

This study summarized the publication focused on the relationship between PA intervention and cognition in pediatric populations between 2009 and 2019, using a bibliometric approach. The current findings highlighted researchgaps, as collaborative investigation with low/middle income countries, and evidence on the relationship between PA interventions and cognition in early childhood. These results may assist researchers, sports scientists, and clinicians in accessing this topic, supporting the development of new insights in the research field.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Disclosure of interest

The authors declare that they have no competing interest.

Appendix A. Supplementary data

Supplementary data associated with this arti-cle can be found, in the online version, at https://doi.org/10.1016/j.scispo.2022.03.016.

References

[1] Donnelly JE, Hillman CH, Castelli D, Etnier JL, Lee S, Tomporowski P, et al. Physical activity, fit- ness, cognitive function, and academic achievement in children. Med Sci Sport Exerc 2016;48:1197—222 https://www.journals.lww.com/00005768-201606000-00027.

[2] Singh AS, Saliasi E, van den Berg V, Uijtdewilligen L,de Groot RHM, Jolles J, et al. Effects of physical activity interventions on cognitive and academic perfor- mance in children and adolescents: a novel combination of a systematic review and recommendations from an expert panel. Br J Sports Med 2019;53:640—7 https://www.bjsm.bmj.com/lookup/doi/10.1136/bjsports-2017-098136.

[3] Erickson Ki, Hillman C, Stillman CM, Ballard RM, Blood- good B, Conroy DE, et al. Physical activity, cognition, and brain outcomes. Med Sci Sport Exerc 2019;51:1242—51 https://www.journals.lww.com/00005768-201906000-00019.

[4] Álvarez-Bueno C, Pesce C, Cavero-Redondo I, Sánchez- López M, Martínez-Hortelano JA, Martínez-Vizcaíno V. The Effect of physical activity interventions on children's cognition and metacognition: a systematic review and meta- analysis. J Am Acad Child Adolesc Psychiatry 2017;56:729—38 https://www.linkinghub.elsevier.com/retrieve/pii/S0890856717303180.

[5] Gunnell KE, Poitras VJ, LeBlanc A, Schibli K, Bar- beau K, Hedayati N, et al. Physical activity and brain structure, brain function, and cognition in children and youth: a systematic review of randomized con- trolled trials. Ment Health Phys Act 2019;16:105—27 https://www.linkinghub.elsevier.com/retrieve/pii/S1755296618300528.

[6] Hillman CH, Biggan JR. A Review of childhood physi-cal activity, brain, and cognition: perspectives on the future. Pediatr Exerc Sci 2017;29:170—6 https://www.journals.humankinetics.com/view/journals/pes/29/2/article-p170.xml.

[7] Vazou S, Pesce C, Lakes K, Smiley-Oyen A. More than one road leads to Rome: a narrative review and meta-analysisof physical activity intervention effects on cognition in youth. Int F Sport Exerc Psychol 2019;17:153—78 https://www.www.tandfonline.com/doi/full/10.1080/1612197X.2016.1223423.

[8] Stillman CM, Esteban-Cornejo I, Brown B, Bender CM, Erickson KI. Effects of exercise on brain and cognition across age groups and health states. Trends Neurosci 2020;43:533—43 https://www.linkinghub.elsevier.com/retrieve/pii/S0166223620301016.

[9] Bidzan-Bluma I, Lipowska M. Physical Activity andcognitive functioning of children: a systematic review. Int J Environ Res Public Health 2018;15:800 https://www.www.mdpi.com/1660-4601/15/4/800.

[10] Schmidt M, Jäger K, Egger F, Roebers CM, Conzel- mann A. Cognitively engaging chronic physical activity, but not aerobic exercise, affects executive functions

Science & Sports 38 (2023) 582—592

in primary school children: a group-randomized controlled trial. J Sport Exerc Psychol 2015;37:575—91 https://www.journals.humankinetics.com/view/journals/jsep/37/6/article-p575.xml.

[11] Diamond A, Ling DS. Conclusions about interventions, programs, and approaches for improving executive func- tions that appear justified and those that, despite much hype, do not. Dev Cogn Neurosci 2016;18:34—48 https://www.linkinghub.elsevier.com/retrieve/pii/S1878929315300517.

[12] Tomporowski PD, Lambourne K, Okumura MS. Physical activity interventions and children's mental function: an introduction and overview. Prev Med (Baltim) 2011;52:S3—9 https://www.linkinghub.elsevier.com/retrieve/pii/S0091743511000569.

[13] Wassenaar TM, Williamson W, Johansen-Berg H, DawesH, Roberts N, Foster C, et al. A critical evaluationof systematic reviews assessing the effect of chronic physical activity on academic achievement, cognition and the brain in children and adolescents: a system-atic review. Int J Behav Nutr Phys Act 2020;17:1—18 https://www.doi.org/10.1186/s12966-020-00959-y.

[14] Glänzel W. Bibliometrics as a research field: a course on theory and application of bibliometric indicators. Researchgate; 2003.

[15] Diem A, Wolter SC. The use of bibliometricsto measure research performance in educa- tion sciences. Res High Educ 2013;54:86—114 https://www.link.springer.com/10.1007/s11162-012-9264-5.

[16] Durieux V, Gevenois PA. Bibliometric indicators:quality measurements of scientific publication. Radiology 2010;255:342—51 https://www.pubs.rsna.org/doi/10.1148/radiol.09090626.

[17] Cobo MJ, López-Herrera AG, Herrera-Viedma E, Herrera F. Science mapping software tools: review, analysis, and cooperative study among tools. J Am Soc Inf Sci Technol 2011;62:1382—402 https://www.doi.wiley.com/10.1002/asi.21525.

[18] Bornmann L, Leydesdorff L. Scientometrics in a changing research landscape. EMBO Rep 2014;15:1228—32 https://www.onlinelibrary.wiley.com/doi/abs/10.15252/embr.201439608.

[19] Shi J, Gao Y, Ming L, Yang K, Sun Y, Chen J, et al. A bibliometric analysis of global research output on network meta-analysis. BMC Med Inform Decis Mak 2021;21:1—12 https://www.bmcmedinformdecismak.biomedcentral.com/articles/10.1186/s12911-021-01470-5.

[20] Müller AM, Maher CA, Vandelanotte C, Hingle M, Middel-weerd A, Lopez ML, et al. Physical activity, sedentary behavior, and diet-related eHealth and mHealth research: Bibliometric Analysis. J Med Internet Res 2018;20:1—18 https://www.www.jmir.org/2018/4/e122/.

[21] Memon AR, Vandelanotte C, Olds T, Duncan MJ, Vicent GE. Research combining physical activity and sleep: a bibliometric analysis. Percept Mot Ski 2020;127:154—81 https://www.journals.sagepub.com/doi/10.1177/0031512519889780.

[22] Memon AR, To QG, Vandelanotte C. Vigorously cited: a bibliometric analysis of the 500 most cited physical activity articles. J Phys Act Health 2021;18:904—19 https://www.journals.humankinetics.com/view/journals/jpah/18/8/article-p904.xml.

[23] Khoo S, Li C, Ansari P. The top 50 most cited publications in disability sport: a bibliometric analysis. Percept Mot Skills 2018;125:525—45 https://www.journals.sagepub.com/doi/10.1177/0031512518760350.

[24] Huertas González-Serrano M, Jones P, Llanos-Contrera O.An overview of sport entrepreneurship field: a biblio- metric analysis of the articles published in the Web of Science. Sport Soc 2020;23:296—314 https://www.www.tandfonline.com/doi/full/10.1080/17430437.2019.1607307.

[25] Liu X, Porter AL. A 3-dimensional analysis for evaluating technology emergence indicators. Scientometrics 2020;124:27—55 https://www.link.springer.com/10.1007/s11192-020-03432-6.

[26] Zhao Q. Electromobility research in Germany and China: structural differences. Scientometrics 2018;117:473—93 https://www.link.springer.com/10.1007/s11192-018-2873-9.

[27] Van Eck N, Waltman L. Software survey: VOSviewer,a computer program for bibliometric mapping. Scien-tometrics 2010;84:523—38 https://www.link.springer.com/article/10.1007/s11192-009-0146-3.

[28] Davidson MC, Amsoa D, Anderson LC, Diamond A. Development of cognitive control and executive functions from 4 to 13 years: evidence from manipulations of memory, inhibition, and task switching. Neuropsychologia 2006;44:2037—78 https://www.www.ncbi.nlm.nih.gov/pmc/articles/PMC1513793/.

[29] Hillman CH, Erickson KI, Kramer AF. Be smart, exercise your heart: exercise effects on brainand cognition. Nat Rev Neurosci 2008;9:58—65 https://www.www.nature.com/articles/nrn2298.

[30] Howard SJ, Melhuish E. An early years toolbox for assessing early executive function, language, self-regulation, and social development: validity, reliability, and preliminary norms. J Psychoeduc Assess 2017;35:255—75 https://www.www.ncbi.nlm.nih.gov/pmc/articles/PMC5424850/.

[31] Glänzel W. Analysis of co-authorship patterns at theindividual level. Transinformação 2014;26:229—38 https://www.www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-37862014000300229&lng=en&tlng=em.

[32] Wagner CS, Park HW, Leydesdorff L. The contin- uing growth of global cooperation networks in research: a conundrum for national governments. Glanzel W, editor. PLoS One 2015;10:e0131816 https://www.dx.plos.org/10.1371/journal.pone.0131816.

[33] The UK Collaborative on Development Sciences (UKCDS). Rapid mapping of international funders' research capac- ity strengthening priorities; 2015. https://www.www.ukcdr.org.uk/wp- content/uploads/2017/11/UKCDS-rapid-RCS-mapping-for-DFID.pdf.

[34] Farah M. The neuroscience of socioeconomic status: correlates, causes, and consequences. Neuron 2017;96:56—71 https://www.dx.doi.org/10.1016/j.neuron.2017.08.034.

[35] Tomasi D, Volkow ND. Associations of family income with cognition and brain structure in USA children: prevention implications. Mol Psychiatry 2021;26:6619—29 https://www.www.nature.com/articles/s41380-021-01130-0#citeas.

[36] Boyack KW, Klavans R. Co-citation analysis, biblio- graphic coupling, and direct citation: Which citation approach represents the research front most accu- rately? J Am Soc Inf Sci Technol 2010;61:2389—404 https://www.doi.wiley.com/10.1002/asi.21419.

[37] Hillman CH, Pontifex MB, Raine LB, Castelli DM, Hall EE, Kramer AF. The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. Neuroscience 2009;159:1044—54 https://www.linkinghub.elsevier.com/retrieve/pii/S0306452209001171.

[38] Chaddock L, Hillman CH, Pontifex MB, Johnson CR, Raine LB, Kramer AF. Childhood aerobic fitness predicts cognitive performance one year later. J Sports Sci 2012;30:421—30 https://www.www.tandfonline.com/doi/abs/10.1080/02640414.2011.647706.

[39] Tomporowski PD, Davis CL, Miller PH, Naglieri JA. Exercise and children's intelligence, cognition, and

academic achievement. Educ Psychol Rev 2008;20:111—31 https://www.link.springer.com/10.1007/s10648-007-9057-0.

[40] Tomporowski PD, McCullick B, Pendleton DM, Pesce C. Exercise and children's cognition: the role of exercise characteristics and a place for metacognition. J Sport Heal Sci 2015;4:47—55 https://www.linkinghub.elsevier.com/retrieve/pii/S2095254614001203.

[41] Diamond A, Barnett WS, Thomas J, Munro S. The early years: preschool program improves cognitive con- trol. Science (80-) 2007;318:1387—8 https://www.www.sciencemag.org/lookup/doi/10.1126/science.1151148.

[42] Diamond A, Lee K. Interventions shown to aid exec- utive function development in children 4 to 12 yearsold. Science (80-) 2011;333:959—64 https://www.www.sciencemag.org/lookup/doi/10.1126/science.1204529.

[43] Diamond A. Activities and programs that improve children's executive functions. Curr Dir Psychol Sci 2012;21:335—41 https://www.journals.sagepub.com/doi/10.1177/0963721412453722.

[44] Blank I, Rokach L, Shani G. Leveraging meta- data to recommend keywords for academic papers. J Assoc Inf Sci Technol 2016;67:3073—91 https://www.doi.wiley.com/10.1002/asi.23571.

[45] Chen G, Xiao L. Selecting publication keywords for domain analysis in bibliometrics: a compari- son of three methods. J Informetr 2016;10:212—23 https://www.linkinghub.elsevier.com/retrieve/pii/S175115771600002X.

[46] Diamond A. Executive function. Annu Rev Psychol 2013;64:135—68 https://www.www.annualreviews.org/doi/abs/10.1146/annurev-psych-113011-143750.

[47] Xue Y, Yang Y, Huang T. Effects of chronic exer- cise interventions on executive function among children and adolescents: a systematic review withmeta-analysis. Br J Sports Med 2019;53:1397—404 https://www.bjsm.bmj.com/lookup/doi/10.1136/bjsports-2018-099825.

[48] Chaddock L, Pontifex MB, Hillman CH, Kramer AF.A review of the relation of aerobic fitness and physical activity to brain structure and function in children. J Int Neuropsychol Soc 2011;17:975—85, http://dx.doi.org/10.1017/S1355617711000567.

[49] Khan NA, Hillman CH. The relation of childhood phys- ical activity and aerobic fitness to brain function and cognition: a review. Pediatr Exerc Sci 2014;26:138—46 https://www.journals.humankinetics.com/view/journals/pes/26/2/article-p138.xml.

[50] Laurent CWSt, Burkart S, Andre C, Spencer RMC. Physical activity, fitness, school readiness, and cognition in early child-hood: a systematic review. J Phys Act Health 2021;18:1004—13 https://www.journals.humankinetics.com/view/journals/jpah/18/8/article-p1004.xml.

Appendix A: Search Strategy

Web of Science Core Collection - January, 31 2020

Table A.1 Advanced Search

#1. TS=("physical activit*" OR "exercise*" OR "acute exercise*" OR "motor activit*" OR "chronic exercise*" OR "isometric exercise*" OR "aerobic exercise*" OR "exercise training*" OR "sport*" OR "athletic*" OR "exercise movement technique*" OR "activity school program*" OR "physical activity intervention*" OR "afterschool physical activit*" OR "afterschool exercise program*" OR "outdoor activit*")
#2. TS=("cognit*" OR "cognitive function*" OR "executive function*" OR "executive control" OR "Brain" OR "Brain function*" OR "Brain sctructur*" OR "Attetion" OR "memory" OR "Problem Solving" OR "Behavior*" OR "Self-control" OR "self-regulation" OR "Event Related Potential*" OR "Event-related Potencial*" OR "P300" OR "P3" OR "evoked potential*" OR "P300 Component*" OR "gray matter*" OR "white matter*" OR "cognitive performance*" OR "inhibition" OR "inhibitory control" OR "working" OR "Working memory" OR "cognitive flexibility")
3. TS=("child*" OR "preschool*" OR "adolescen*" OR "teen*" OR "Youth*" OR "infan*" OR "pediatric*" OR "prepube*" OR "pube*" OR "kindergart*" OR "Kid*" OR "young*" OR "highschool*") NOT TS= "birth" NOT TS= "preterm" NOT TS= "adult" NOT TS= "elderly" NOT TI= "disorder*" NOT TI= "disability*" NOT TS= "university student*" NOT TS= "men" NOT TS= "women")
4. TS=("academic performance" OR "academic achievement")
#5 = #4 And #3 And #2 And #1; limit 2009-2019; document type: Article OR Review OR Early access OR Editorial material OR Meeting abstract
#5 = (813 documents)

Appendix B

Table B.1 Top 10 Journals with publications about Physical Activity Interventions and Cognition in Children and Adolescents (at least four publications)

Journal	Impact Factor *	Year (number of documents published)
Frontiers in Psychology	2.12	2014 (2); 2016 (1); 2017 (3); 2018 (2); 2019 (1) Totally: 9 documents
BMC Public Health	2.56	2013 (1); 2014(1); 2016 (2); 2018 (1); 2019 (3) Totally: 8 documents
Medicine and Science in Sports and Exercise	4.47	2012 (2); 2016 (3); 2017 (1); 2019 (1) Totally: 7 documents
Mental Health and Physical Activity	1.79	2013 (2); 2014 (1); 2015 (1); 2018 (1); 2019 (2) Totally: 7 documents
Journal of Sport & Exercise Psychology	2.43	2013 (1); 2014 (1); 2015 (1); 2017 (1); 2018 (1) Totally: 5 documents
Journal of Science and Medicine in Sport	3.62	2015 (2); 2016 (1); 2017 (1); 2018 (1) Totally: 5 documents
Pediatric Exercise Science	1.70	2014 (1); 2015 (1); 2016 (1); 2017 (2) Totally: 5 documents
British Journal of Sports Medicine	11.64	2011 (1); 2014 (1); 2018 (1); 2019 (1)

		Totally: 4 documents
Preventive Medicine	3.44	2011 (4) Totally: 4 documents
Psychology of Sport and Exercise	2.71	2010 (1); 2014 (1); 2015 (1); 2019 (1) Totally: 4 documents

*According to Journal of Citation Reports (JCR) year: 2018

Appendix C

Table C.1 Clusters of networks researcher's collaboration (at least three documents published for the analyzed period - January 1, 2009 until December 31, 2019)

Cluster	N	Researchers
1	16	Cadenas-Sanchez, C; Castelli, DM; Chaddock-Heyman, I; Drollette, ES; Erickson, KI; Esteban-Cornejo, I; Hillman, C; Khan, NA; Mora-Gonzalez, J; Ortega, FB; Pate, RR; Pontifex, MB; Raine, LB; Ruiz, JR; Scudder, MR
2	13	Chang, YK; Chinapaw, MJM; de Groot, RHM; Diamond, A; Donnelly, JE; Etnier, JL; Fedewa, AL; Jolles, J; Lambourne, K; Saliasi, E; Singh, AS; Tomporowski, PD; Van Den Berg, V.
3	10	Allison, JD; Chi, L; Davis, CL; Krafft, CE; Mcdowell, JE; Pierce, JE; Rodrigue, AL; Schaeffer, DJ; Schwarz, NF; Yanasak, NE.
4	6	Aadland, E; Aadland, KN; Bronnick, KS; Moe, VF; Ommundsen, Y; Resaland, GK.
5	6	Benzing, V; Conzelmann, A; Egger, F; Jaeger, K; Roebers, CM; Schmidt, M.
6	5	Andersen, LB; Bugge, A; Domazet, SL; Froberg, K; Tarp, J.
7	5	Alvarez-Bueno, C; Cavero-Redondo, I; Martinez-Vizcaino, V; Pesce, C; Sanchez-Lopez, M.
8	4	Ishihara, T; Matsuda, Y; Mizuno, M; Sugasawa, S.
9	3	Eather, N; Lubans, DR; Mavilidi, MF.
10	3	Martinez-Lopez, EJ; Ruiz-Ariza, A; Suarez-Manzano, S.
11	3	Hartman, E; Oosterlaan, J; Visscher, C.
12	2	Gao, Z; Wen, X
13	1	Hernandez-Mendo, A
14	1	Tremblay, MS

Appendix D

Top 10 Countries that published studies about Physical Activity Intervention and Cognition in Children and Adolescents and Collaborations between Countries

1. **USA (70 documents and 17 collaborations):** Spain, Italy, Scotland, Taiwan, Denmark, Norway, Germany, Canada, Singapore, Switzerland, the Netherlands, England, Sweden, Australia, Israel, Japan, and China.

2. **Spain (18 documents and 7 collaborations):** USA, Mexico, Chile, Italy, Sweden, Australia, and the Netherlands.

3. **Switzerland (13 documents and 16 collaborations):** USA, Lithuania, Iceland, South Africa, Iran, Germany, Italy, Australia, the Netherlands, Sweden, Canada, Singapore, Taiwan, Norway, Denmark, and England.

4. **Australia (13 documents and 7 collaborations):** Switzerland, Germany, the Netherlands, Sweden, Canada, USA, and Spain.

5. **Netherlands (12 documents and 12 collaborations):** USA, Spain, Italy, Sweden, Australia, Canada, Norway, Singapore, England, Taiwan, Germany, and Switzerland.

6. **Italy (11 documents and 13 collaborations):** Spain, Chile, Brazil, USA, Norway, Canada, Sweden, the Netherlands, Taiwan, Singapore, Australia, Germany, and Switzerland.

7. **Canada (11 documents and 11 collaborations):** Italy, USA, Sweden, Australia, the Netherlands, Norway, Taiwan, Singapore, Germany, Switzerland, and England.

8. **Germany (10 documents and 14 collaborations):** USA, Italy, Sweden, Australia, the Netherlands, Singapore, Canada, Taiwan, Norway, England, Switzerland, Iceland, Lithuania, and South Africa.

9. **England (10 documents and 13 collaborations):** USA, Italy, Switzerland, New Zealand, Denmark, Norway, Canada, Taiwan, Singapore, the Netherlands, Sweden, Scotland, and Germany.

10. **Norway (10 documents and 11 collaborations):** USA, Italy, Sweden, the Netherlands, Singapore, England, Denmark, Germany, Switzerland, Taiwan, and Canada.

Ranking created from documents recovered in WOS from Jan 2009 until Dec 31, 2020.

5.2 ARTIGO 2

Adherence to the 24h Movement Behaviors Guidelines and Associations with Cognitive and Behavioral Self-Regulation among Brazilian Preschoolers

Natalia Batista Albuquerque Goulart Lemos[1,2], Pablo Gabriel da Silva Santos[1], Valerie Carson[3], Fernando de Aguiar Lemos[1], Michael Duncan[4], Clarice Maria de Lucena Martins[5,6]

Article submited

[1] Department of Physical Education, Federal University of Vale do São Francisco, Petrolina, Brazil

[2] Associate Graduate Program in Physical Education, Federal University of Paraiba, João Pessoa, Brazil

[3] Faculty of Kinesiology, Sport, and Recreation, University of Alberta, Edmonton, Alberta, Canada

[4] Centre for Applied Biological and Exercise Sciences, Coventry University, Priory Street, Coventry, CV1 5FB, UK

[5] Research Centre of Physical Activity, Health and Leisure, Faculty of Sports; Laboratory for Integrative and Translational Research in Population Health (ITR), University of Porto, Porto, Portugal

[6] Department of Physical Education, Federal University of Paraíba, João Pessoa, Brazil

Abstract

Background: Adherence to 24-hour movement guidelines has been associated with early health benefits, including neurodevelopmental outcomes. However, the associations between these guidelines and Cognitive (CSR) and Behavioral (BSR) self-regulation in preschoolers are underexplored. This study investigated the associations between adherence to 24-hour movement guidelines and CSR and BSR in Brazilian preschoolers. Methods: A total of 223 preschoolers (4.76 ± 0.32 years old; 50.67% boys) participated. Physical activity (PA) was assessed with Actigraph wGT3X. Parents reported children's sleep and screen time. CSR was evaluated through iPad games, and BSR was assessed using the Head, Toes, Knees, Shoulders test revised. Results: Boys showed higher adherence to the PA recommendation than girls (52.2% vs. 32.7%, X2 = 0.003), while a higher percentage of girls did not adhere to any recommendations (23.6% vs. 12.4%, X2 = 0.029). Positive association was found between adherence to combined PA and screen time with cognitive flexibility [β = 4.091 (95% CI:

0.699, 7.754)]. Adherence to PA was associated with lower BSR scores [β = -7.104 (-13.52, -0.623)], as was adherence to combined PA and sleep duration [β = -8.813 (-15.794, -1.397)]. Conclusion: This study highlighted differences in adherence to movement behavior guidelines between boys and girls, as well as demonstrated that different combinations of these behaviors can affect preschoolers` cognitive and behavioral levels of self-regulation in distinct ways.
Keywords: Movement behaviors, Self-regulation, Preschoolers

1. Introduction

Early childhood represents a critical period in human development, characterized by significant neurobiological changes (Diamond, 2013; Miguel et al., 2019). This phase establishes the foundation for several brain processes, including self-regulation, which is essential for adaptive functioning throughout life (Perry, 2019). Self-regulation entails the ability to manage one's thoughts, emotions, and behaviors in alignment with internal goals and external demands (Blair & Ku, 2022). The cognitive level of self-regulation is termed executive function, which comprises three core abilities: i) working memory, characterized by the capacity of holding and manipulating information in mind; ii), inhibitory control, related to the ability of suppressing irrelevant or automatic responses; and iii) cognitive flexibility, operationalized by the capacity of switching between different tasks or strategies in response to changing demands (Garon et al., 2008; Hofmann et al., 2012; Diamond, 2013). These three cognitive abilities undergo distinct developmental trajectories in early childhood and manifest overtly in behavioral self-regulation, reflecting the ability to manage and control one's actions, emotions, and thoughts to achieve desired goals or adapt to various situations (Mccleand et al., 2007; Burke et al., 2023).

The preschool-age years are crucial for the development of cognitive and behavioral self-regulation, which are predictors of success in pre-academic skills and social-emotional competence (Howard & Vasseleu, 2020; Sezgin & Ulus, 2020; Korucu et al., 2022; Schmidt et al., 2022). In this perspective, studies have explored how the adoption of healthy habits might correlate with self-regulation in preschoolers (Moffitt et al., 2011). For instance, the impact of adhering to the recommendations of 24-h movement behaviors (Tremblay et al., 2017; WHO, 2019; 2020), namely physical activity, sedentary behavior, and sleep, on early cognitive and behavioral development have been investigated (Cliff et al., 2017; McNeill et al., 2020; Taylor et al., 2021; Kuzik et al., 2022; McGowan et al., 2023). Systematic reviews have focused on summarizing these studies, and the results have shown that adhering 24-h movement behaviors guidelines, whether in isolation or combination, yielded mixed results, depending on the level of self-regulation investigated (Rollo et al., 2020; Feng et al., 2021). On the other hand, children who adhere to the 24-h movement guidelines, specifically more than one recommendation, tend to have lower behavioral problems (Carson et al., 2019; Zhu et al., 2023).

Objective self-regulation measures have been used to assess cognitive and behavior self-regulation in preschool age. In this regard, McNeil et al. used computational objective measure tasks to assess preschoolers´ cognitive self-regulation (McNeill et al., 2020). Their results highlighted that those preschoolers who adhere to physical activity and sleep recommendations showed higher phonological working memory and cognitive flexibility scores while adhering to overall 24-h movement guidelines was associated with higher cognitive flexibility. Moreover, adherence to physical activity recommendations was linked to higher shifting performance even after 12 months. Other studies did not find significant associations between adhering to movement behaviors and cognitive scores in preschoolers (Kuzik et al., 2022; McGowan et al., 2023).

The core cognitive abilities of self-regulation (i.e., working memory, inhibitory control, and cognitive flexibility) exhibit different trajectories of maturation, and these abilities are mutually related to behavioral self-regulation (McClelland et al., 2007a; Garon et al., 2008; Blair & Raver, 2012; Diamond, 2013). Consequently, some tasks of behavioral self-regulation are often treated as executive function tasks, leading to conceptual biases when comparing results. For instance, when children aged 1 to 5 years were investigated using the Head, Toes, Knee, Shoulder task, Taylor et al. (Taylor et al., 2021) reported that those at 3.5 years of age who adhered to physical activity recommendations had higher inhibitory control score compared to their non-adherer peers (HTKS; McClelland et al., 2007b; Cameron Ponitz et al., 2008; Ponitz et al., 2009b). Nonetheless, while the authors classified this task as a measure of inhibitory control and behavior regulation, other studies solely define it as a measure of behavioral self-regulation, leading to inconsistencies in the literature and consequently, in comparisons across studies. Therefore, the employment of latent measurement protocols to assess cognitive and behavioral self-regulation levels warrants careful consideration, ensuring consistent interpretation across studies, especially when considering children at the end of early childhood (i.e. 4-to-5 years-old) where other executive function skills, such as cognitive flexibility, are emerging (Diamond et al., 2013). The present study aimed to investigate the associations between adherence to 24-h movement guidelines with cognitive and behavioural self-regulation in Brazilian preschoolers. It is hypothesized that (1) There will be differences in adherence to 24-hour movement behaviors between boys and girls; (2) adherence to the 24-

h movement guidelines will be favorably associated with higher scores on the three core cognitive abilities, as well as with a higher score on the behavioral level of self-regulation in preschoolers.

2. Methods

2.1 Setting and population characteristics

Participants included preschoolers enrolled in public early childhood educational centers (ECEC), located in median-low-income neighborhoods in Petrolina, in hinterlands of the state of Pernambuco, Brazil. Petrolina is divided into five areas, in with seven ECEC were randomly selected, including two centers from the most populated areas (north and east). Children spend part-time at the institutions (from 7.30 a.m. to 11.30 a.m. or from 1.00 p.m. to 5.30 p.m.). For consistency across the data collection, only children registered for the morning period were included in the study. All parents of registered children aged 4 and 5 years (420 children) were invited, and 283 agreed to participate. The average month family income was 1.5 minimum Brazilian wage (approximately $275.00 American Dollar).

2.2 Procedures

An introductory meeting with the administration of each ECEC was conducted to obtain consent to conduct the study. During this meeting, information regarding the number of enrolled children aged 4 and 5, as well as families' contact information were obtained. Parents/primary caregivers were briefed on the research's aims and procedures during meetings with the research team (one session in each ECEC). Then, the research team collected sociodemographic data (including children's age, date of birth and household income). information concerning the children's sleep routine, and screen time. Interviews were conducted either in person at the ECEC for parents who submitted their written consent forms during the initial meeting or via telephone for those who provided consent on subsequent days.

Measurements were performed between February and September, 2022. Anthropometric data, cognitive and behavioural self-regulation tests were conducted by a trained research team of PE teachers at ECEC, during two consecutive days. The cognitive and behavior self-regulation test were performed on different random days. An accelerometer was given to each child, and were asked to wear it for 7 consecutive days.

2.3 Measurements

2.3.1 Anthropometric measures

Height (cm) and body mass (kg) were assessed using a Holtain stadiometer and a digitized weighing scale (Seca, Hamburg, model 708) respectively, with the participant lightly dressed and barefoot. Two measurements were taken, and if they differed, the average value was adopted. For height, if the second measurement differed by more than 0.5 cm, a third measurement was recorded. The same procedure was followed if the second weight measurement differed by more than 0.25 kg. Body mass index (BMI) was calculated by dividing body weight by the square of the height in meters (kg/m2) (Cadenas-Sanchez et al., 2016). Children were classified according to WHO cut-offs – normal weight, overweight and obese (de Onis et al., 2009).

2.3.2 Physical activity (PA)

PA was objectively assessed using an accelerometer (Actigraph, model WGT3-X, Florida), a valid instrument for measuring PA in preschoolers (Bornstein et al., 2011). The preschool teachers and parents/ primary caregivers received training (verbal and written instructions) on the correct use of the accelerometer, including placement and proper positioning (worn on an elasticized belt around the waist, positioned on the right side, and capable of being worn underneath clothing). The same procedures were explained to the children in a playful manner through the storytelling of a children's story about the use of a belt with superpowers, emphasizing that they couldn't share their belt with other friends or classmates. The participants were instructed to wear the accelerometer 24 h/day for seven consecutive days (Wednesday morning to Tuesday afternoon). Children were allowed to remove the device during water-based activities and while sleeping (at night), if necessary. Throughout the week, parents received phone messages to be remind them about the accelerometer wear.

The device initialization, data reduction, and analysis were performed using the ActiLife software (Version 6.13.3). Accelerometers were analyzed as ActiGraph counts considering vector magnitude, using a 15-s epoch length and data were reintegrated in 60-s epochs for analysis (Cliff et al., 2009). Periods of ≥20 min of consecutive zero counts were defined as non-wear time and removed from the analysis (Esliger et al., 2005) The first day of accelerometer data was omitted from analysis to avoid subject reactivity. Valid data were considered for a minimum of 6 h of wear time, without requirement for a valid weekend day, during at least 1 day, between 6 am to 10 pm (Bingham et al., 2016). Time spent in the commonly defined intensity domains light, moderate and vigorous was estimated using the cutpoints proposed by Buttle for vector magnitude, with light-intensity defined as 820–3.907 counts, moderate intensity defined as 3.908–6.111 counts and vigorous intensity as ≥6.112 counts (Butte et al., 2014). The amount of time spent sedentary was set at <820 counts. These cut-points were validated against double labeled water, room calorimetry and using a triaxial accelerometer. Minutes per day in total physical activity (TPA), light physical activity (LPA), moderate physical activity (MPA), vigorous physical activity (VPA) and MVPA were calculated (Martins et al., 2021; Martins et al., 2024).

2.3.3 Sleep time (SL)

Parents were asked to recall the total number of hours their child sleeps at night and during the data (i.e., naps). They were asked to recall the total average hours their child sleeps as follows: “On weekdays, how many hours of sleep does your child usually have during the day (e.g., nap) and night?” and “On weekend days, how many hours of sleep does your child usually have during the day (e.g., nap) and night?” SL was calculated as the sum of nighttime sleep (difference between bedtime and wake-up time) and nap duration. Overall sleep hours were calculated as follows: ((Sleep on weekdays, including naps) × 5) + (Sleep on weekend days, including naps × 2))/7. The results were multiplied by 60 to represent minutes per day. This approach has been previously used in similar population (Vale & Mota, 2020; Okely et al., 2021; Martins et al., 2024), and validated against estimates from sleep logs and objective actigraphy in young children (Goodlin-Jones et al., 2008).

2.3.4 Screen time (ST)

Parents asked to recall the total amount of time, on average, their child watched TV, used the computer and played videogames (Martins et al., 2024). The questions addressed weekdays and weekend days separately and were combined in the analysis (Cronbach’s α = 0.87). For ST, the questions were as follows: “How many hours during a week day does your child usually watch TV, use the computer, smartphones or electronic games?” and “How many hours during a weekend day does your child usually watch TV, use the computer, smartphones or electronics games?” The same procedure used for sleep hours was applied to calculate the average daily ST.

2.3.5 Cognitive Self-Regulation (CSR)

CSR was assessed using the Early Years Toolbox (Howard & Melhuish, 2017), and comprised three tasks: the Mr. Ant task for Visual-Spatial Working Memory (VSWM) the Go/No-Go task for Inhibitory Control (IC), and Rabbits and Boats for Cognitive Flexibility (CF).

For the Mr. Ant task, children observed Mr. Ant with stickers on different parts of his body for 5 seconds, followed by a 4-second blank screen, and then Mr. Ant reappeared with an auditory prompt to replace the stickers. The task had 8 levels (1-8 stickers), with three trials per level. Each level increased in complexity with the number of features to remember. It ended if all three trials within a level failed or after completing all eight levels. Instructions were followed in order, with auditory cues and delays before presenting shapes to match the instructions. Performance was assessed by a point score, starting from level 1, points were awarded with 1 point for each level where at least 2/3 of the trials were correct. If a level had 1/3 of the trials correct, that level and all subsequent levels were scored based on the number of correct trials, with 1/3 of a point for each correct trial. A score of 8 represents the ceiling value for this task.

In the Go/No-Go task, children tapped the screen for fish (GO - 80% occurrence) but not for sharks (NO GO - 20% occurrence) in three trials. For each trial, 75 stimuli were presented in a semi-random order, lasting 1,500 milliseconds, followed by a 1,000-millisecond of no stimulus. IC was determined by multiplying the proportion of accuracy of Go and accuracy of No-Go, where a score of 1 represents the ceiling value for this task.

In the Rabbits and Boats task, children sorted cards (e.g., red rabbits, blue boats) based on either color or shape into locations identified by a blue rabbit or a red boat. They switch sorting rules after a demonstration and two practice trials, sorting by one dimension for six trials, then switching to the other dimension. Each trial starts with a reminder of the sorting rule, followed by sorting stimuli. Participants advancing to the border phase must sort by color for cards with a black border and by shape for cards without a black border. Cards are arranged to avoid presenting the same stimulus more than twice consecutively. Scores reflect correct sorts after the initial sorting phase (Switch phase). A score of 12 represents the ceiling value for this task.

The Early Years Toolbox has previously shown excellent reliability (Cronbach's α = 0.92) and good convergent validity (r: 0.40–0.46) for inhibition, VSWM, and CF with established measures, and has been widely used in several countries to assess CSR in early childhood (Cliff et al., 2017; Kuzik et al., 2020; Bezerra et al., 2020; COOK et al., 2023).

2.3.6 Behavior Self-Regulation (BRS)

BSR was directly assessed using Head, Toes, Knee, Shoulder test – Revised (HTKS-R) (Gonzales et al., 2021). The HTKS-R is a validated children's behavioral self-regulation task that requires the cognitive abilities (working memory, inhibitory control, and cognitive flexibility) manifested in real situations such as paying attention, remembering instructions, and adapting to changing demands. The HTKS-R is an updated version of the HTKS test that includes a Part 0 (Opposites), where children are instructed to say the opposite response (e.g., "if I say toes, you say head"). The remaining sections incorporating gross motor tasks. Part 1 focusing on single pair commands (e.g., "if I say touch your toes, touch your head"), Part 2 introducing an additional pair (e.g., "if I say touch your knees, touch your shoulders"), and Part 3 switching pairs (e.g., "toes go with shoulders, and knees go with head"). The HTKS-R comprises 59 items, scored 0 for incorrect, 1 for self-corrected, and 2 for correct responses. A score of 118 represents the ceiling value for this task. HTKS-R is indicated as a reliable and valid assessment of BSR for children aged four to eight, showing strong internal consistency (Cronbach's alpha < .90). The HTKS-R was administered by certified research assistants in a space provided within the centers. Children were recorded for subsequent score checking if necessary. The assessment did not exceed 10 minutes.

4. Statistical analysis

As a preliminary analytical step, the data were examined for data entry accuracy and missing values. Children with missing items in more than three key variables (ie. Anthropometric, PA, ST, SL, CSR, BSR) were excluded from the analysis. This criterion was applied since some children had missing values for ST and SL, as these two variables were collected in the same protocol. No missing values were identified for the anthropometric and cognitive variables. Little's test was applied to the missing data indicating that these data were completely at random ($p = 0.129$, using SPSS v 28.0) and supporting expectation maximization (EM) imputation. The percentage of missing imputation were 12,6%, 13,9% and 14,8% for PA, ST/SL and BSR, respectively (Lin & Tsai, 2020).

All variables were checked for normality using Kolmogorov–Smirnov tests. Descriptive analyses were performed for continuous variables and the prevalence of adhering to the single and combined recommendations. Children were classified as adhering to the movement behaviors guidelines by age, when: (a) PA: TPA ≥180 min/day, including MVPA ≥60 min/day; (b) screen time: ≤ 60 min/day for 4-years-old children, and ≤120 min/day for 5-

years-old children; and (c) sleep time: 10 - 13 h/day for 4-years-old children, and 9 - 11 h/day for 5-years-old children (Tremblay et al., 2016; WHO, 2019; 2020). The descriptive statistics of the outcome measures are presented as mean and SD. Sex differences were tested through the independent t-test for continuous variables, and the Chi-square test for categorical variables. Generalized linear models were used to examine the associations among adhering to the single or combined 24-h Movement Behavior and self-regulation (cognitive and behavior) controlling for sex, age and BMI. The level of significance was set at alpha level of 0.05. Data were analyzed using Jamovi 2.3.21.

5. Ethical aspects

All procedures were approved by the university committee and the board of education. The Helsinki Declarations' ethical aspects were followed (Association, 2013). The Research Ethics Committee of the Health Science Center and the local board of education approved the Study (protocol n. 4.933.291).

6. Results

After applying the criterion for missing values, data of 60 children were excluded from the analysis (21%), and the final analytical sample comprised 223 preschoolers (50.67% boys) of similar age and BMI. On average, the children were classified as normal weight. The mean wear time was 13 h per day. A total of 7,73% of the sample had <3 valid days. Participants spent more than the recommended 180 min/day physically active but spent less that the recommended 60 min/day on MVPA. Boys were more active in MPA, VPA and MVPA than girls (MPA = 50.00 ± 19.39 *vs* 42.02 ± 18.34 min/day, *P* = 0.002; VPA = 13.17 ± 8.10 *vs* 9.60 ± 7.00 min/day, *P*< 0,001; MVPA = 62.46 ± 24.36 *vs* 51.63 ± 23.76 min/day, *P*< 0,001). No significant difference was observed in ST nor SL between sexes. On average, participants spent more than two hours (175.96 ± 101.96 min/day) in screen-based activities and slept for approximately 10 hours, (604.90 ± 79.16 min/day), with 42.15% napping for 1 to 3 hours. There was no statistically significant difference between sex in their CSR abilities (VSWM, IC and CF) (*P* >0,05), but girls had significantly higher BSR score than boys (39.98 ± 26.52 *vs* 32.68 ± 23.99, *P* = 0.032) (Table 1).

Insert Table 1

Overall, the majority of children adhered to the SL recommendations (57.8%) (Fig. 1). The prevalence of adherence to the combined recommendations of the 24-h movement guidelines was higher for children compliant with PA and SL recommendations (21.5%), while the lowest adherence was observed for PA + ST (2,2%). Only 3.1% of participants adhered to the overall guidelines, while 17.9 % did not adhere any of the recommendations.

Males had higher adherence to PA recommendation, compared to girls (52.2 % *vs* 32.7 %, X^2 = 0.003), while a higher percentage of girls did not adhere to any of the recommendations, when compared to boys (23,6 % *vs* 12,4%, X^2 = 0.029) (Supplementary Table 2).

Insert Figure 1

Table 3 presents the relationships between adherence to single and combined 24h movement behavior recommendations, with CSR (i.e., VSWM, IC, CF) and BSR. Positive associations were observed between adherence to combined PA + ST and CF [β = 4.091 (95% CI: 0.699, 7.754)]. Adhering to PA recommendation was associated with a significantly lower BSR score [β = -7.104 (-13.52, -0.623)], as was with adhering to combined PA + SL recommendations [β = -8.813 (-15.794, -1.397)]. All other associations were not significant.

Insert Table 3

7. Discussion

This study investigated the associations between preschoolers´ adherence to individual and combined 24h-movement behaviours recommendations and CSR and BSR. Three important findings were highlighted: (1) differences between sexes were observed for continuous PA and BSR variables - boys spent higher min/day in MPA, VPA and MVPA, while girls had higher BSR scores; (2) only 3.1% of the preschoolers adhered the 24h movement behaviours guidelines, being a higher prevalence of boys compliant with the PA recommendations, and a high proportion of girls do not adhere to any recommendation; (3) adhering to PA + ST recommendations was positively associated with CF, while adhering to the single PA recommendation, and the combined PA + SL recommendations were negatively associated with BSR, after adjustments for sex, age and BMI.

The present study identified that boys spent more time per day in MVPA compared to girls. While there are a body of evidence showing that boys are more engaged in MVPA than girls, other studies do not report such differences (Kippe & Lagestad, 2018; Meredith-Jones et al., 2018; Ruiz et al., 2018). Preschool settings and family factors play a significant role in determining overall PA levels during early childhood (Määttä et al., 2019). The children who participated in the current study spent one school period of their day (i.e., morning) in the ECECs, and the remaining time at home. It is therefore important to consider the types of PA available to children when they are not at school, particularly for those who attend school for only one session.

In the present study it was also observed that girls had higher BRS scores than boys. Corroborating with the current results, Vabo et al., when assessing Norwegian preschoolers, reported lower levels of BSR for boys, when compared to girls (Vabø et al., 2022). These results may potentially indicate a sex-associated developmental delay in favor of girls and denote a unique trajectory in BSR during preschool-age (Montroy et al., 2016). Understanding sex differences in the development of BSR is crucial for comprehending its potential impact on multiple outcomes, such as academic performance, as well as for designing appropriate interventions (Kırkıç & Demir, 2020). Although our results corroborate with Vabo et al findings in a completely different cultural and social background, longitudinal studies supporting this potential sex-related different trajectories are scarce.

The results showed that only 3.1% of the preschoolers adhered with the overall guidelines. This prevalence is in accordance with a previous studies conducted in Brazilian preschoolers (Martins et al., 2021; Martins et al., 2024). A higher adherence to PA recommendations was observed for boys (52.2%), whereas a higher percentage of girls did not adhere to any of the recommendations (23.6%). In this regard, higher adherence to PA recommendations has been previously observed in boys, while girls have shown higher adherence to sleep, PA and ST recommendations (Chen et al., 2019; Martins et al., 2021; Christian et al., 2022). Important to state that there are also evidence showing no difference between sexes, what reinforce the inconsistent findings in this research topic, which may be partly due to different methodological procedures used in the several studies (Cliff et al., 2017; Santos et al., 2017; Kim et al., 2020; Taylor et al., 2021).

The discrepancy in PA engagement between sexes may also be related to various factors, including cultural aspects, movement preference, gender socialization, the environmental affordances, and the opportunities for structured physical activities (Kretschmer et al., 2023; Telford et al., 2016). Culturally, boys tend to be more active than girls (Telford et al., 2016). Although we could expect to see a cultural discrepancy in stimulusfor being active according to sex, especially in older children and adolescents (Aubert et al., 2021), our results highlighted that girl exhibited a higher percentage of non-adherence to any recommendation, suggesting that sex-related inequality could be presented in all movement behaviours from a young age.

Adherence to movement recommendations, whether isolated or in combination, did not associate with any CSR abilities, except when combining PA + ST, which was associated with a higher score in CF. Data from a systematic review comprising 10 studies yielded mixed results, suggesting that adherence to movement behaviours guidelines may provide varying effects on children´s cognitive function abilities (Kuzik et al., 2017; McNeill et al., 2020; Rollo et al., 2020; Feng et al., 2021). Similar to our findings, in a 12-month longitudinal study with Australian children, McNeill observed positive associations for CF, although with different combinations (i.e., PA + SL, and the overall adherence to the guidelines) (McNeill et al., 2020). Additionally, children adhering to the PA recommendations at baseline exhibited better CF performance 12 months later compared to those who did not adhere to the PA recommendation. In this sense, although incipient, it seems plausible to encourage the adherence to PA and ST recommendations among children, to enhancing their cognitive abilities, potentially with greater sensitivity for CF than IC and VSWM, since CF develops later in early childhood (Diamond, 2013).

Conversely, adherence to PA recommendations and to the combined adherence of PA + SL were negatively associated with BSR. Few studies have investigated the associations between adherence to 24-h movement guidelines and BSR in preschoolers, particularly considering its scores. Taylor et al. found that children aged 3.5 years who adhered to PA recommendation had higher scores on the HTKS task compared to those non-adherers, despite the use of this task as a measure of inhibitory control (Taylor et al., 2021). McGowan et al. observed that adherence to more than one recommendation was linked to increased BSR in preschoolers, assessed by off-task behavior (McGowan et al., 2023). When considering SL recommendations, Kuzik et al. identified a positive association between adherence to the recommendations and BSR scores assessed through a parental report (Kuzik et al., 2022).

In this regard, the wide variety of measures to assess BSR thwarts direct comparisons with the current results. We selected the HTKS-R task as a valid measure of BSR. According to McClelland et al., the HTKS-R appears to capture various aspects of executive function in real contexts (McClelland et al., 2021). The abovementioned authors also reinforce the need for further studies to examine how the HTKS-R is related to aspects of executive function and self-regulation (Gonzales et al., 2021; McClelland et al., 2021). Notwithstanding the existence of literature indicating that the interaction among all core abilities of CSR (Working Memory, Inhibitory Control and Cognitive Flexibility) operates in an integrated manner for behavioral regulation, forming a unitary construct in young children (Garon et al., 2008), the results of this study, which assessed the core abilities individually, suggest that adherence to health behaviors may have differential effects on cognitive and behavior levels of self-regulation in preschoolers.

The results of the current study add critical information for early years professionals, childcare stakeholders, and parents, by demonstrating how the isolate and combined adherence to movement behaviors guidelines may positive or negatively associate with different aspects of children´s self-regulation.

As practical implications, these results seem to suggest that movement behaviors associate differently on both cognitive and behavioral self-regulation, and it is urgent to identify which aspects of self-regulation would be focused on future interventions. To the best of the authors´ knowledge, this is the first study to explore the association of movement behaviours with the cognitive and the behavioral levels of preschoolers´ self-regulation, especially when considering objectively protocols. Moreover, it covers an important geographical gap in the literature, by assessing understudied low-middle income children. Although the current findings may pave the way for new insights in the research area, it is key to state the study´s limitations. Considering the difficulty in assessing a fluctuating latent construct in such young children, the combination of both objective and parent-reported subjective measures should be considered. Finally, longitudinal designs should be conducted to explore the stability of these association along the preschool years.

8. Conclusions

The results of the current study suggested sex differences for PA in favor of boys, and for BSR in favor of girls. Only 3.1% of the assessed children adhered to the 24-h movement behaviours guidelines, being more than a half of the boys compliant with PA recommendations (52.2%), while 23.6% of the girls do not adhere to any recommendation. Moreover, adhering to PA + ST recommendations was positively associated with CF, while adhering to the single PA recommendation, and the combined PA + SL recommendations were negatively associated with BSR, suggesting that adherence to health behaviors may have differential effects on cognitive and behavior levels of self-regulation in preschoolers.

9. References

Aubert, S., Brazo-Sayavera, J., González, S. A., Janssen, I., Manyanga, T., Oyeyemi, A. L., Picard, P., Sherar, L. B., Turner, E., & Tremblay, M. S. (2021). Global prevalence of physical activity for children and adolescents; inconsistencies, research gaps, and recommendations: a narrative review. In *International Journal of Behavioral Nutrition and Physical Activity* (Vol. 18, Issue 1). BioMed Central Ltd. https://doi.org/10.1186/s12966-021-01155-2

Bezerra, T. A., Clark, C. C. T., de Souza Filho, A. N., de Souza Fortes, L., Silva Mota, J. A. P., Duncan, M. J., & de Lucena Martins, C. M. (2020). 24-hour movement behaviour and executive function in preschoolers: a compositional and isotemporal reallocation analysis. *European Journal of Sport Science*, 1–18. https://doi.org/10.1080/17461391.2020.1795274

Bingham, D. D., Costa, S., Clemes, S. A., Routen, A. C., Moore, H. J., & Barber, S. E. (2016). Accelerometer data requirements for reliable estimation of habitual physical activity and sedentary time of children during the early years - a worked example following a stepped approach. *Journal of Sports Sciences*, *34*(20), 2005–2010. https://doi.org/10.1080/02640414.2016.1149605

Blair, C., & Ku, S. (2022). A Hierarchical Integrated Model of Self-Regulation. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.725828

Blair, C., & Raver, C. C. (2012). Individual development and evolution: Experiential canalization of self-regulation. *Developmental Psychology*, *48*(3), 647–657. https://doi.org/10.1037/a0026472

Bornstein, D. B., Beets, M. W., Byun, W., & McIver, K. (2011). Accelerometer-derived physical activity levels of preschoolers: A meta-analysis. In *Journal of Science and Medicine in Sport* (Vol. 14, Issue 6, pp. 504–511). https://doi.org/10.1016/j.jsams.2011.05.007

Burke, K. N., Zatto, B. R. L., & Hoglund, W. L. G. (2023). Developmental patterns of behavioural self-regulation and peer relations in early childhood. *Early Childhood Research Quarterly*, *65*, 179–194. https://doi.org/10.1016/j.ecresq.2023.06.001

Butte, N. F., Wong, W. W., Lee, J. S., Adolph, A. L., Puyau, M. R., & Zakeri, I. F. (2014). Prediction of energy expenditure and physical activity in preschoolers. *Medicine and Science in Sports and Exercise*, *46*(6), 1216–1226. https://doi.org/10.1249/MSS.0000000000000209

Cadenas-Sanchez, C., Martinez-Tellez, B., Sanchez-Delgado, G., Mora-Gonzalez, J., Castro-Piñero, J., Löf, M., Ruiz, J. R., & Ortega, F. B. (2016). Assessing physical fitness in preschool children: Feasibility, reliability and practical recommendations for the PREFIT battery. *Journal of Science and Medicine in Sport*, *19*(11), 910–915. https://doi.org/10.1016/j.jsams.2016.02.003

Cameron Ponitz, C. E., McClelland, M. M., Jewkes, A. M., Connor, C. M. D., Farris, C. L., & Morrison, F. J. (2008). Touch your toes! Developing a direct measure of behavioral regulation in early childhood. *Early Childhood Research Quarterly*, *23*(2), 141–158. https://doi.org/10.1016/j.ecresq.2007.01.004

Carson, V., Ezeugwu, V. E., Tamana, S. K., Chikuma, J., Lefebvre, D. L., Azad, M. B., Moraes, T. J., Subbarao, P., Becker, A. B., Turvey, S. E., Sears, M. R., & Mandhane, P. J. (2019). Associations between meeting the Canadian 24-Hour Movement Guidelines for the Early Years and behavioral and emotional problems among 3-year-olds. *Journal of Science and Medicine in Sport*, *22*(7), 797–802. https://doi.org/10.1016/j.jsams.2019.01.003

Chen, B., Bernard, J. Y., Padmapriya, N., Yao, J., Goh, C., Tan, K. H., Yap, F., Chong, Y. S., Shek, L., Godfrey, K. M., Chan, S. Y., Eriksson, J. G., & Müller-Riemenschneider, F. (2019). Socio-demographic and maternal predictors of adherence to 24-hour movement guidelines in Singaporean children. *International Journal of Behavioral Nutrition and Physical Activity*, *16*(1). https://doi.org/10.1186/s12966-019-0834-1

Christian, H., Murray, K., Trost, S. G., Schipperijn, J., Trapp, G., Maitland, C., & Divitini, M.

(2022). Meeting the Australian 24-Hour Movement Guidelines for the Early Years is associated with better social-emotional development in preschool boys. *Preventive Medicine Reports*, *27*. https://doi.org/10.1016/j.pmedr.2022.101770

Cliff, D. P., McNeill, J., Vella, S. A., Howard, S. J., Santos, R., Batterham, M., Melhuish, E., Okely, A. D., & De Rosnay, M. (2017). Adherence to 24-Hour Movement Guidelines for the Early Years and associations with social-cognitive development among Australian preschool children. *BMC Public Health*, *17*. https://doi.org/10.1186/s12889-017-4858-7

Cliff, D. P., Reilly, J. J., & Okely, A. D. (2009). Methodological considerations in using accelerometers to assess habitual physical activity in children aged 0-5 years. In *Journal of Science and Medicine in Sport* (Vol. 12, Issue 5, pp. 557–567). https://doi.org/10.1016/j.jsams.2008.10.008

Cook, C. J., Howard, S., Scerif, G., Twine, R., Kahn, K., Norris, S., & Draper, C. (2023). Executive function and pre-academic skills in preschoolers from South Africa. *South African Journal of Childhood Education*, 13(1), 1-11.

Martins, C. M. de lucena, Lemos, L. F. G. B. P., de Souza Filho, A. N., Bezerra, T. A., Soares, I. A. A., Mota, J. G., Bandeira, P. F. R., Mota, J. A. P. S., Tassitano, R. M., & Duncan, M. J. (2021). Adherence to 24-hour movement guidelines in low-income Brazilian preschoolers and associations with demographic correlates. *American Journal of Human Biology*, *33*(4). https://doi.org/10.1002/ajhb.23519

de Onis, M., Garza, C., Onyango, A. W., & Rolland-Cachera, M. F. (2009). WHO growth standards for infants and young children. Archives de Pédiatrie, 16(1), 47–53. https://doi.org/10.1016/j.arcped.2008.10.010

Diamond, A. (2013). Executive functions. In *Annual Review of Psychology* (Vol. 64, pp. 135–168). Annual Reviews Inc. https://doi.org/10.1146/annurev-psych-113011-143750

Esliger, D. W., Copeland, J. L., Barnes, J. D., & Tremblay, M. S. (2005). Standardizing and Optimizing the Use of Accelerometer Data for Free-Living Physical Activity Monitoring. In *Journal of Physical Activity and Health* (Vol. 3).

Feng, J., Zheng, C., Sit, C. H. P., Reilly, J. J., & Huang, W. Y. (2021). Associations between meeting 24-hour movement guidelines and health in the early years: A systematic review and meta-analysis. *Journal of Sports Sciences*, *39*(22), 2545–2557. https://doi.org/10.1080/02640414.2021.1945183

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive Function in Preschoolers: A Review Using an Integrative Framework. *Psychological Bulletin*, *134*(1), 31–60. https://doi.org/10.1037/0033-2909.134.1.31

Gonzales, C. R., Bowles, R., Geldhof, G. J., Cameron, C. E., Tracy, A., & McClelland, M. M. (2021). The Head-Toes-Knees-Shoulders Revised (HTKS-R): Development and psychometric properties of a revision to reduce floor effects. *Early Childhood Research Quarterly*, *56*, 320–332. https://doi.org/10.1016/j.ecresq.2021.03.008

Goodlin-Jones, B. L., Sitnick, S. L., Tang, K., Liu, J., & Anders, T. F. (2008). *The Children's Sleep Habits Questionnaire in Toddlers and Preschool Children*.

Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. In *Trends in Cognitive Sciences* (Vol. 16, Issue 3, pp. 174–180). https://doi.org/10.1016/j.tics.2012.01.006

Howard, S. J., & Melhuish, E. (2017). An Early Years Toolbox for Assessing Early Executive Function, Language, Self-Regulation, and Social Development: Validity, Reliability, and Preliminary Norms. *Journal of Psychoeducational Assessment*, *35*(3), 255–275. https://doi.org/10.1177/0734282916633009

Howard, S. J., & Vasseleu, E. (2020). Self-Regulation and Executive Function Longitudinally Predict Advanced Learning in Preschool. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.00049

Kim, H., Ma, J., Harada, K., Lee, S., & Gu, Y. (2020). Associations between adherence to combinations of 24-h movement guidelines and overweight and obesity in Japanese preschool children. *International Journal of Environmental Research and Public Health*, *17*(24), 1–11. https://doi.org/10.3390/ijerph17249320

Kippe, K. O., & Lagestad, P. A. (2018). Kindergarten: Producer or reducer of inequality regarding physical activity levels of preschool children. *Frontiers in Public Health*, *6*(DEC). https://doi.org/10.3389/fpubh.2018.00361

Kırkıç, K. A., & Demir, B. (2020). Examination of Pre-School Students' Self-Regulation Skills. *Problems of Education in the 21st Century*, *78*(6), 967–982. https://doi.org/10.33225/pec/20.78.967

Korucu, I., Ayturk, E., Finders, J. K., Schnur, G., Bailey, C. S., Tominey, S. L., & Schmitt, S. A. (2022). Self-Regulation in Preschool: Examining Its Factor Structure and Associations with Pre-academic Skills and Social-Emotional Competence. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.717317

Kretschmer, L., Salali, G. D., Andersen, L. B., Hallal, P. C., Northstone, K., Sardinha, L. B., Dyble, M., & Bann, D. (2023). Gender differences in the distribution of children's physical activity: evidence from nine countries. *International Journal of Behavioral Nutrition and Physical Activity*, *20*(1). https://doi.org/10.1186/s12966-023-01496-0

Kuzik, N., Naylor, P. J., Spence, J. C., & Carson, V. (2020). Movement behaviours and physical, cognitive, and social-emotional development in preschool-aged children: Cross-sectional associations using compositional analyses. *PLoS ONE*, *15*(8 August). https://doi.org/10.1371/journal.pone.0237945

Kuzik, N., Poitras, V. J., Tremblay, M. S., Lee, E. Y., Hunter, S., & Carson, V. (2017). Systematic review of the relationships between combinations of movement behaviours and health indicators in the early years (0-4 years). *BMC Public Health*, *17*. https://doi.org/10.1186/s12889-017-4851-1

Kuzik, N., Spence, J. C., Arkko, K., Blye, C.-J., Davie, J., Duddridge, R., Ekeli, T., English, A., Etruw, E., Hunter, S., Lamboglia, C. G., Nesdoly, A., Predy, M., Rubuliak, R., Wohlers, B., Wright, K., & Carson, V. (2022). Associations between meeting the Canadian 24-hour movement guidelines and physical, cognitive, social-emotional, and overall development in early childhood. *Journal of Activity, Sedentary and Sleep Behaviors*, *1*(1). https://doi.org/10.1186/s44167-022-00002-4

Lin, W. C., & Tsai, C. F. (2020). Missing value imputation: a review and analysis of the literature (2006–2017). *Artificial Intelligence Review*, *53*(2), 1487–1509. https://doi.org/10.1007/s10462-019-09709-4

Määttä, S., Gubbels, J., Ray, C., Koivusilta, L., Nislin, M., Sajaniemi, N., Erkkola, M., & Roos, E. (2019). Children's physical activity and the preschool physical environment: The moderating role of gender. *Early Childhood Research Quarterly*, *47*, 39–48. https://doi.org/10.1016/j.ecresq.2018.10.008

Martins, C., Mota, J., Goulart, N., Silva, M., Silva, T., Carvalho, F., Mota, J., Bandeira, P. F., & Lemos, L. (2024). Compliance with the 24-h movement behaviors guidelines among urban and rural Brazilian preschoolers. *American Journal of Human Biology*. https://doi.org/10.1002/ajhb.24045

McClelland, M. M., Cameron, C. E., Wanless, S. B., Murray, A., Saracho, O., & Spodek, B. (2007a). Executive function, behavioral self-regulation, and social-emotional competence. *Contemporary perspectives on social learning in early childhood education*, 1, 113-137.

McClelland, M. M., Cameron, C. E., Connor, C. M. D., Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007b). Links Between Behavioral Regulation and Preschoolers' Literacy, Vocabulary, and Math Skills. *Developmental Psychology*, *43*(4), 947–959. https://doi.org/10.1037/0012-1649.43.4.947

McClelland, M. M., Gonzales, C. R., Cameron, C. E., Geldhof, G. J., Bowles, R. P., Nancarrow, A. F., Merculief, A., & Tracy, A. (2021). The Head-Toes-Knees-Shoulders Revised: Links to Academic Outcomes and Measures of EF in Young Children. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.721846

McGowan, A. L., Gerde, H. K., Pfeiffer, K. A., & Pontifex, M. B. (2021). Physically active learning in preschoolers: Improved self-regulation, comparable quantity estimation. *Trends in Neuroscience and Education*, *22*. https://doi.org/10.1016/j.tine.2021.100150

McGowan, A. L., Gerde, H. K., Pfeiffer, K. A., & Pontifex, M. B. (2023). Meeting 24-hour movement behavior guidelines in young children: Improved quantity estimation and self-regulation. *Early Education and Development*, *34*(3), 762–789. https://doi.org/10.1080/10409289.2022.2056694

McNeill, J., Howard, S. J., Vella, S. A., & Cliff, D. P. (2020). Compliance with the 24-Hour movement guidelines for the early years: Cross-sectional and longitudinal associations with executive function and psychosocial health in preschool children. *Journal of Science and Medicine in Sport*, *23*(9), 846–853. https://doi.org/10.1016/j.jsams.2020.02.011

Meredith-Jones, K., Haszard, J., Moir, C., Heath, A. L., Lawrence, J., Galland, B., Taylor, B., Gray, A., Sayers, R., & Taylor, R. (2018). Physical activity and inactivity trajectories associated with body composition in pre-schoolers. *International Journal of Obesity*, *42*(9), 1621–1630. https://doi.org/10.1038/s41366-018-0058-5

Miguel, P. M., Pereira, L. O., Silveira, P. P., & Meaney, M. J. (2019). Early environmental influences on the development of children's brain structure and function. In *Developmental Medicine and Child Neurology* (Vol. 61, Issue 10, pp. 1127–1133). Blackwell Publishing Ltd. https://doi.org/10.1111/dmcn.14182

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H. L., Houts, R., Poulton, R., Roberts, B. W., Ross, S., Sears, M. R., Thomson, W. M., & Caspi, A. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(7), 2693–2698. https://doi.org/10.1073/pnas.1010076108

Montroy, J. J., Bowles, R. P., Skibbe, L. E., McClelland, M. M., & Morrison, F. J. (2016). The development of self-regulation across early childhood. *Developmental Psychology*, *52*(11), 1744–1762. https://doi.org/10.1037/dev0000159

Okely, T., Reilly, J. J., Tremblay, M. S., Kariippanon, K. E., Draper, C. E., El Hamdouchi, A., Florindo, A. A., Green, J. P., Guan, H., Katzmarzyk, P. T., Lubree, H., Pham, B. N., Suesse, T., Willumsen, J., Basheer, M., Calleia, R., Chong, K. H., Cross, P. L., Nacher, M., … Widyastari, D. A. (2021). Cross-sectional examination of 24-hour movement behaviours among 3- And 4-year-old children in urban and rural settings in low-income, middle-income and high-income countries- And SUNRISE study protocol. *BMJ Open*, *11*(10). https://doi.org/10.1136/bmjopen-2021-049267

Perry, N. E. (2019). Recognizing early childhood as a critical time for developing and supporting self-regulation. *Metacognition and Learning*, *14*(3), 327–334. https://doi.org/10.1007/s11409-019-09213-8

Ponitz, C. C., McClelland, M. M., Matthews, J. S., & Morrison, F. J. (2009). A Structured Observation of Behavioral Self-Regulation and Its Contribution to Kindergarten Outcomes. *Developmental Psychology*, *45*(3), 605–619. https://doi.org/10.1037/a0015365

Rollo, S., Antsygina, O., & Tremblay, M. S. (2020). The whole day matters: Understanding 24-hour movement guideline adherence and relationships with health indicators across the lifespan. In *Journal of Sport and Health Science* (Vol. 9, Issue 6, pp. 493–510). Elsevier B.V. https://doi.org/10.1016/j.jshs.2020.07.004

Ruiz, R. M., Sommer, E. C., Tracy, D., Banda, J. A., Economos, C. D., Jaka, M. M., Evenson, K. R., Buchowski, M. S., & Barkin, S. L. (2018). Novel patterns of physical activity in a large

sample of preschool-aged children. *BMC Public Health*, *18*(1). https://doi.org/10.1186/s12889-018-5135-0
Santos, R., Zhang, Z., Pereira, J. R., Sousa-Sá, E., Cliff, D. P., & Okely, A. D. (2017). Compliance with the Australian 24-hour movement guidelines for the early years: Associations with weight status. *BMC Public Health*, *17*. https://doi.org/10.1186/s12889-017-4857-8
Schmidt, H., Daseking, M., Gawrilow, C., Karbach, J., & Kerner auch Koerner, J. (2022). Self-regulation in preschool: Are executive function and effortful control overlapping constructs? *Developmental Science*, *25*(6). https://doi.org/10.1111/desc.13272
Sezgin, E., & Ulus, L. (2020). An Examination of Self-Regulation and Higher-Order Cognitive Skills as Predictors of Preschool Children's Early Academic Skills. *International Education Studies*, *13*(7), 65. https://doi.org/10.5539/ies.v13n7p65
Taylor, R. W., Haszard, J. J., Healey, D., Meredith-Jones, K. A., Taylor, B. J., & Galland, B. C. (2021). Adherence to 24-h movement behavior guidelines and psychosocial functioning in young children: a longitudinal analysis. *International Journal of Behavioral Nutrition and Physical Activity*, *18*(1). https://doi.org/10.1186/s12966-021-01185-w
Telford, R. M., Telford, R. D., Olive, L. S., Cochrane, T., & Davey, R. (2016). Why are girls less physically active than boys? Findings from the LOOK longitudinal study. *PLoS ONE*, *11*(3). https://doi.org/10.1371/journal.pone.0150041
Tremblay, M. S., Carson, V., Chaput, J. P., Connor Gorber, S., Dinh, T., Duggan, M., Faulkner, G., Gray, C. E., Grube, R., Janson, K., Janssen, I., Katzmarzyk, P. T., Kho, M. E., Latimer-Cheung, A. E., LeBlanc, C., Okely, A. D., Olds, T., Pate, R. R., Phillips, A., … Zehr, L. (2016). Canadian 24-hour movement guidelines for children and youth: An integration of physical activity, sedentary behaviour, and sleep. *Applied Physiology, Nutrition and Metabolism*, *41*(6), S311–S327. https://doi.org/10.1139/apnm-2016-0151
Vabø, K. B., Aadland, K. N., Howard, S. J., & Aadland, E. (2022). The Multivariate Physical Activity Signatures Associated With Self-Regulation, Executive Function, and Early Academic Learning in 3–5-Year-Old Children. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.842271
Vale, S., & Mota, J. (2020). Adherence to 24-hour movement guidelines among Portuguese preschool children: the prestyle study. *Journal of Sports Sciences*, *38*(18), 2149–2154. https://doi.org/10.1080/02640414.2020.1775385
Zhu, N., Guo, H., Ma, D., Wang, Q., Ma, J., & Kim, H. (2023). The Association between 24 h Movement Guidelines and Internalising and Externalising Behaviour Problems among Chinese Preschool Children. *Children*, *10*(7). https://doi.org/10.3390/children10071146
WHO. (2019). Guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age. World Health Organization.
WHO. (2020). WHO guidelines on physical activity and sedentary behaviour. World Health Organization.

Acknowledgments: The authors wish to thank the Municipality Educational Bord from Petrolina, and all the preschools, children, parents and staff direct and indirectly involved in the study.

Table 1. Descriptive characteristics of the participants

	Boys	Girls	Total	
	(n= 113)	**(n= 110)**	**(n= 223)**	***p***
Age (month)	56.78 ± 3.97	57.40 ± 3.71	57.09 ± 3.85	0.236
BMI	15.75 ± 1.69	15.86 ± 2.01	15.81 ± 1.86	0.656
TPA (min/day)	409.00 ± 77.80	407.00 ± 93.40	408.00 ± 85.66	0.894
LPA (min/day)	345.58 ± 65.74	355.58 ± 81.85	350.52 ± 74.13	0.250
MPA (min/day)	50.00 ± 19.39	42.02 ± 18.34*	46.07 ± 19.26	0.002
VPA (min/day)	13.17 ± 8.10	9.60 ± 7.00*	11.42 ± 7.78	<0.001
MVPA (min/day)	62.46 ± 24.36	51.63 ± 23.76*	57.12 ± 24.62	<0.001
Screen time (min/day)	186.72 ± 103.46	164.89 ± 99.65	175.96 ± 101.96	0.110
Sleep time (min/day)	603.82 ± 83.10	606.00 ± 75.26	604.90 ± 79.16	0.838
VSWM	1.408 ± 0.70	1.346 ± 0.63	1.378 ± 0.67	0.491
IC	0.578 ± 0.19	0.609 ± 0.19	0.593 ± 0.20	0.228
CF	2.646 ± 3.58	3.482 ± 3.99	3.058 ± 3.81	0.285
BSR	32.68 ± 23.99	39.98 ± 26.52*	36.28 ± 25.48	0.032

* Significant differences between boys and girls; BMI =Body Mass Index; TPA = Total Physical Activity; LPA = Light Physical Activity; MPA = Moderate Physical Activity; VPA = Vigorous Physical Activity; MVPA = Moderate to Vigorous Physical Activity; Visual-Spatial Working Memory = VSWM; IC = Inhibitory Control; CF = Cognitive Flexibility; BRS = Behavioral Self-Regulation.

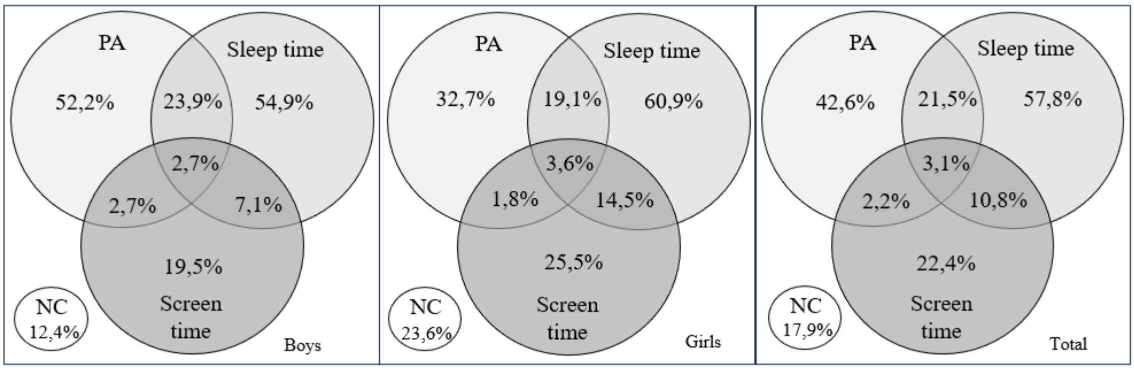


FIGURE 1 Venn diagrams showing the prevalence of adherence to the 24-hour movement guidelines by sex. NC: non-compliant; PA: Physical Activity.

Table 3. Associations between adhering to 24-hour movement behaviours guidelines and cognitive and behavioural self-regulation

Dependente Variable	Predictors	β (95%CI)	Z	p
VSWM	PA	0.107 (-0.073, 0.288)	1.163	0.246
	ST	-0.018 (-0.230, 0.194)	-0.170	0.865
	SL	-0.074 (-0.253, 0.104)	-0.813	0.417
	PA + ST	0.325 (-0.266, 0.925)	1.069	0.286
	PA + SL	0.114 (-0.098, 0.328)	1.050	0.295
	ST + SL	-0.092 (-0.378, 0.195)	-0.631	0.528
	PA + ST + SL	0.021 (-0.486, 0.532)	0.081	0.935
	NONE	0.107 (-0.128, 0.344)	0.894	0.372
IC	PA	-0.008 (-0.060, 0.044)	-0.301	0.764
	ST	0.019 (-0.040, 0.080)	0.642	0.522
	SL	0.004 (-0.046, 0.055)	0,171	0.865
	PA + ST	-0.007 (-0.177, 0.163)	-0.083	0.934
	PA + SL	0.030 (-0.030, 0.092)	0.989	0.324
	ST + SL	0.015 (-0.066, 0.098)	0.379	0.705
	PA + ST + SL	-0.039 (-0.185, 0.107)	-0.526	0.600
	NONE	0.011 (-0.056, 0.079)	0.336	0.738
CF	PA	-0.360 (-1.376, 0.697)	-0.695	0.488
	ST	-0.260 (-1.441, 0.940)	-0.428	0.669
	SL	-0.247 (-1.250, 0.752)	-0.484	0.629
	PA + ST	**4.091 (0.699, 7.754)**	**2.281**	**0.024***
	PA + SL	-0.180 (-1.366, 1.025)	-0.296	0.767
	ST + SL	-0.816 (-2.394, 0.809)	-0.999	0.319
	PA + ST + SL	-2.277 (-4.970, 0.586)	-1.609	0.109
	NONE	0.292 (-1.021, 1.632)	0.433	0.665
BSR	PA	**-7.104 (-13.52, -0.623)**	**-2.154**	**0.032***
	ST	-0.087 (-7.581, 7.930)	-0.022	0.982
	SL	-5.29 (-11.81, 1.131)	-1.61	0.108
	PA + ST	-9.533 (-25.852, 12.510)	-0.987	0.325
	PA + SL	**-8.813 (-15.794, -1.397)**	**-2.409**	**0.017***
	ST + SL	2.44 (-8.042, 14.287)	0.432	0.666
	PA + ST + SL	-15.220 (-30.509, 4.356)	-1.75	0.082
	NONE	5.002 (-3.456, 14.111)	1.123	0.263

Reference: Do not adhere (0)

* Statistical Difference $P<0.05$

PA = Physical Activity; ST = Screen Time; SL = Sleep time; Visual-Spatial Working Memory = VSWM; IC = Inhibitory Control; CF = Cognitive Flexibility; BRS = Behavior Self-Regulation

Table 2. Percentage of preschoolers compliant with the PA, ST and SLT guidelines by Sex

		Boys	Girls	X^2
		n (%)	n (%)	
PA	Compliant	52.2	32.7	.003*
	Non compliant	47.8	67.3	
ST	Compliant	19.5	25.5	.284
	Non compliant	80.5	74.5	
SLT	Compliant	54.9	60.9	.361
	Non compliant	45.1	39.1	

* Significant differences between boys and girls; PA = Total Physical Activity; ST = Screen Time; SLT = Sleep Time

5.3 ARTIGO 3

24h Movement Behaviors and Self-Regulation in Preschoolers: Cross-sectional associations using compositional and isotemporal analyses

Abstract

Introduction: Early childhood is a critical period for brain development, particularly in self-regulation (SR), which is essential for pre-academic success and socio-emotional competence. Recent studies have highlighted the role of 24-hour movement behaviors, including physical activity (PA), sedentary behavior (SB), and sleep, in influencing SR. Meeting recommended guidelines for these behaviors has been associated with positive cognitive and behavioral outcomes in preschoolers. However, the relationship between different combinations of these behaviors and various levels of SR remains unclear. Objective: This study aims to analyze the association between the compositional of 24-hour movement behaviors and cognitive and behavioral SR in preschoolers and to investigate the effects of reallocating time between different movement behaviors. Methods: The sample comprised 223 four- and five-year-old preschoolers enrolled in public early childhood education centers in Petrolina, Brazil. Movement behaviors were assessed using accelerometry, sleep was evaluated by parent report, while cognitive and behavioral self-regulation were measured using validated tools, including the Early Years Toolbox for cognitive self-regulation (CSR) and the Head, Toes, Knees, Shoulders–Revised test for behavioral self-regulation (BSR). Compositional data analysis was employed to examine the relationship between movement behaviors and self-regulation outcomes. Results: The findings revealed that the 24-hour movement composition predicted 6% of the variance in visual-spatial working memory and cognitive flexibility, and 13% in BSR. Isotemporal substitution analysis showed that reallocating time from moderate-to-vigorous PA to SB or light PA resulted in significant improvements in BSR. However, no significant association was observed between movement behaviors and inhibitory control. Conclusion: The results suggest that balanced daily movement behaviors are important for enhancing self-regulation in preschoolers, particularly BSR. Future research should explore longitudinal impacts and mechanisms underlying these relationships to inform public health interventions aimed at optimizing self-regulation development in early childhood.

Key-Words: Self-regulation, Movement Behaviors, Compositional Analysis, Preschoolers

1. Introduction

Early childhood is a critical period for the development of several brain processes, including self-regulation (PERRY, 2019), which is characterized by the ability to manage one's thoughts, emotions, and behaviors in alignment with internal goals and external demands (BLAIR; KU, 2022). This construct is an important predictor of success in pre-academic skills and social-emotional competence (SEZGIN; ULUS, 2020; HOWARD; VASSELEU, 2020; KORUCU et al., 2022; SCHMIDT et al., 2022), and is commonly operationalized by the study of three core levels: the cognitive, namely executive function (i.e., working memory, inhibitory control, and cognitive flexibility), behavioral, and emotional levels, respectively (MCCLELLAND et al., 2007).

In recent years, cross-sectional and longitudinal studies have focused on the association between compliance with the guidelines for movement behaviours and self-regulation in preschool age children (TAYLOR et al., 2021; KUZIK et al., 2022; MCGOWAN et al., 2023). Accruing adequate amounts of time spent on movement behaviors, namely physical activity (PA), sedentary behavior (SB), and sleep, in early childhood has been associated with positive socioemotional outcomes short and long-term health outcomes, including children´s self-regulation (CLIFF et al., 2017; TAYLOR et al., 2021; CARSON et al., 2022). The World Health Organization (WHO, 2019) recommends that, for preschoolers aged 3-4 years, a healthy 24-h during the day comprises: i) ≥180 minutes of PA, including at least 60 minutes of moderate-to-vigorous physical activity (PA), ii) ≤1 hour of sedentary screen time, and iii) between 10 and 13 hours of good quality sleep. For the 5 years-old children, the World Health Organization´s recommendations include 60 daily minutes of MVPA (WHO, 2020). Besides that, the Canadian and Australian guidelines for 5 years-old children recommends that a healthy 24-h day should include less than 2 hours of sedentary screen time, and between 9 and 11 hours of good quality sleep (TREMBLAY, CARSON, & CHAPUT, 2016; OKELI et al., 2017).

Although evidence has been produced focusing on the association between movement behaviours and preschoolers´ self-regulation has increased in the last decade special attention has been driven to the cognitive level of self-regulation. For instance, when assessing the physical, cognitive and social-emotional development of 3-5 years-old Canadian children, Kuzik et al observed that meeting sleep recommendations alone, as well as the combination of sleep and physical activity recommendations, were associated with better overall development, including the cognitive, and the behavioural levels of self-regulation (KUZIK et al., 2022). Moreover, in U.S. preschoolers, McGowan et al. reported that meeting more than one recommendation guidelines and accruing more moderate-to-vigorous physical activity daily related to better self-regulation (MCGOWAN et al., 2022). Nonethleless, a longitudinal study conducted in Australia, with 247 children followed for 12-months, showed no association, suggesting that meeting the guidelines may not be adequate for broad the cognitive level of self-regulation in preschoolers (MCNEILL et al., 2020). When longitudinally assessing both cognitive and behavioural levels of self- regulation in 528 children at 1, 2, 3.5 and then, at 5 years of age, Taylor and colleagues reported that although meeting some individual movement guidelines at certain ages was associated with several improved outcomes at 5 years of age, there was little consistency in these relationships, and suggested the use of a compositional 24-h time use approach (TAYLOR et al., 2021). Indeed, assessing movement behaviors in an isolated manner is a flawed approach, given that movement behaviors are co-dependent and necessarily bound to 1440 minutes per day, which may, at least partially, justify the contradictory observed results. All incumbent movement behaviors co-exist as a whole or composition. Thus, the time spent in one behavior effects, and is affected by the other behaviors during the remaining time of the day (CHEN et al., 2019; DUMUID et al., 2020).

Moreover, few studies have explored the association between the composition of movement behaviours and self-regulation, particularly when considering its behavioral level. To the best of the authors´ knowledge, only one study to date analyzed the association between the 24-hour composition with cognitive and behavioural levels of self-regulation in preschoolers (KUZIK et al., 2017). The results suggested a positive association between the 24-hour compositional and the working memory component of cognitive self-regulation, though no association has been seen for the behavioral level. The mixed findings observed between stationary time (i.e. sedentary time and sleep) and the two levels of self-regulation may indicate the need of further studies to elucidate these relationships in preschoolers. Although the abovementioned study suggested an important preliminary finding concerning the possible associations between the 24-hour movement behaviours composition and preschoolers´ self-regulation, a critical bias related to the parent-reported questionnaire used to assess self-regulation should be acknowledged. To date, no evidence exploring these associations via an objective measure of self-regulation is available. Moreover, no study has applied a compositional data analysis approach to estimate cognitive and behavioral self-regulation, considering the reallocation of fixed durations of time between movement behaviors, which is key for effective public health interventions. Thus, the aims of this study were: 1) to analyze the associations between the 24-hour movement composition behaviors and cognitive and behavioral self-regulation of preschoolers; and 2) to investigate predicted changes in self-regulation when time in different behaviors is reallocated.

2. Methods

2.1 Setting and population characteristics

Participants included four and five-year-old preschoolers enrolled in public early childhood educational centers (ECEC), located in median-low-income neighborhoods in Petrolina, in hinterlands of the state of Pernambuco, Brazil. Petrolina is divided into five areas, in which seven ECEC were randomly selected, including two centers from the most populated areas (north and east). All parents of registered children aged 4 and 5 years (420 children) were invited, and 283 agreed to participate. The average month family income was 1.5 x minimum Brazilian wage (approximately $275.00).

2.2 Procedures

An introductory meeting with the administration of each ECEC was conducted to obtain consent to conduct the study. During this meeting, information regarding the number of enrolled children aged 4 and 5, as well as families' contact were obtained. Parents/primary caregivers were briefed on the research's aims and procedures during meetings with the research team (one session in each ECEC). Then, the research team collected sociodemographic data (including children's age, date of birth and household income) and information concerning the children's sleep routine, and screen time. Interviews were conducted either in person at the ECEC for parents who submitted their consent forms during the initial meeting or via telephone for those who provided consent on subsequent days.

Measurements were performed between February and September/2022. Anthropometric data, cognitive and behavioural self-regulation tests were conducted by a trained research team of PE teachers at ECEC, during two consecutive days. The cognitive and behavior self-regulation test were performed on different random days. The accelerometer was given to each child, who used it during 7 consecutive days.

2.3 Measurements

2.3.1 Anthropometric measures

Height (cm) and body mass (kg) were assessed using a Holtain stadiometer and a digitized weighing scale (Seca, Hamburg, model 708) respectively, with the participant lightly dressed and barefoot. Two measurements were taken, and if they differed, the average value was adopted. For height, if the second measurement differed by more than 0.5 cm, a third measurement was recorded. The same procedure was followed if the second weight measurement differed by more than 0.25 kg. Body mass index (BMI) was calculated by dividing body weight by the square of the height in meters (kg/m2) (Cadenas-Sanchez et al., 2016). Children were classified according to WHO cut-offs (de Onis et al., 2009).

2.3.2 Sedentary Behavior (SB) and Physical activity (PA)

SB and PA were objectively assessed using an accelerometer (Actigraph, model WGT3-X, Florida), a valid instrument for measuring PA in preschoolers (Bornstein et al., 2011). The preschool teachers and parents/ primary caregivers received training (verbal and written instructions) on the correct use of the accelerometer, including placement and proper positioning (worn on an elasticized belt around the waist, positioned on the right side, and capable of being worn underneath clothing). The same procedures were explained to the children in a playful manner through the storytelling of a children's story about the use of a belt with superpowers, emphasizing that they couldn't share their belt with other friends or classmates. The participants were instructed to wear the accelerometer 24 h/day for seven consecutive days (Wednesday morning to Tuesday afternoon). Children were allowed to remove the device during water-based activities and while sleeping (at night), if necessary. Throughout the week, parents received phone messages to be remembered about the accelerometer used.

The device initialization, data reduction, and analysis were performed using the ActiLife software (Version 6.13.3). Accelerometers were analyzed as ActiGraph counts considering vector magnitude, using a 15-s epoch length and data were reintegrated in 60-s epochs for analysis (CLIFF et al., 2009). Periods of ≥20 min of consecutive zero counts were defined as non-wear time and removed from the analysis (ESLIGER et al., 2005) The first day of accelerometer data was omitted from analysis to avoid subject reactivity. Valid data were considered for a minimum of 6 h of wear time, without requirement for a valid weekend day, during at least 1 day, between 6 am to 10 pm (BINGHAM et al., 2016). The mean wear time was 13 h per day. A total of 7,73% of the sample had <3 valid days.

The amount of sedentary time was estimated as ≤ 819 counts, as proposed by Butte et al. (2014). These cutoff points were calculated based on data from triaxial accelerometers. Considering preschoolers’ short and intermittent bouts of PA, children’s movements may be more accurately assessed when considering different axes of motion. Time spent in the commonly defined intensity domains light, moderate and vigorous was estimated using the cutpoints proposed by Buttle for vector magnitude, with light-intensity defined as 820–3.907

counts, moderate intensity defined as 3.908–6.111 counts and vigorous intensity as ≥6.112 counts (BUTTE et al., 2014). The threshold for time spent sedentary was set at ≤819 counts. These cut-points were validated against doubly labeled water, room calorimetry, and using a triaxial accelerometer. For the statistical analysis, Total physical activity (TPA), Light physical activity (LPA) and MVPA was considered (MARTINS et al., 2021; MARTINS et al., 2024).

2.3.3 Sleep time (SL)

Parents were asked to recall the total number of hours their child's nighttime sleep and nap routines. They were asked to recall the total average hours their child sleep as follows: "On weekdays, how many hours of sleep does your child usually have during the day (e.g., nap) and night?" and "On weekend days, how many hours of sleep does your child usually have during the day (e.g., nap) and night?" SL was calculated as the sum of nighttime sleep (difference between bedtime and wake-up time) and nap duration. Overall sleep hours were calculated as follows: ((Sleep on weekdays, including naps) × 5) + (Sleep on weekend days, including naps × 2))/7. The results were multiplied by 60 to represent minutes per day. This approach has been previously used in similar population (VALE & MOTA, 2020; OKELY et al., 2021; MARTINS et al., 2024), and validated against estimates from sleep logs and objective actigraphy in young children (GOODLIN-JONES et al., 2008).

2.3.4 Cognitive Self-Regulation (CSR)

CSR was assessed using the Early Years Toolbox (HOWARD & MELHUISH, 2017), and comprised three tasks: the Mr. Ant task for Visual-Spatial Working Memory (VSWM) the Go/No-Go task for Inhibitory Control (IC), and Rabbits and Boats for Cognitive Flexibility (CF).

For the Mr. Ant task, children observed Mr. Ant with stickers on different parts of his body for 5 seconds, followed by a 4-second blank screen, and then Mr. Ant reappeared with an auditory prompt to replace the stickers. The task had 8 levels (1-8 stickers), with three trials per level. Each level increased in complexity with the number of features to remember. It ended if all three trials within a level failed or after completing all eight levels. Instructions were followed in order, with auditory cues and delays before presenting shapes to match the instructions. Performance was assessed by a point score, starting from level 1, points were awarded with 1 point for each level where at least 2/3 of the trials were correct. If a level had 1/3 of the trials correct, that level and all subsequent levels were scored based on the number of correct trials, with 1/3 of a point for each correct trial. The point score = 8 represents the ceiling value for this task.

In the Go/No-Go task, children tapped the screen for fish (GO - 80% occurrence) but not for sharks (NO GO - 20% occurrence) in three trials. For each trial, 75 stimuli were presented in a semi-random order, lasting 1,500 milliseconds, followed by a 1,000-millisecond of no stimulus. IC was determined by multiplying the proportion of accuracy of Go and accuracy of No-Go, where IC = 1 represents the ceiling value for this task.

In the Rabbits and Boats task, children sorted cards (e.g., red rabbits, blue boats) based on either color or shape into locations identified by a blue rabbit or a red boat. They switch sorting rules after a demonstration and two practice trials, sorting by one dimension for six trials, then switching to the other dimension. Each trial starts with a reminder of the sorting rule, followed by sorting stimuli. Participants advancing to the border phase must sort by color for cards with a black border and by shape for cards without a black border. Cards are arranged to avoid presenting the same stimulus more than twice consecutively. Scores reflect correct sorts after the initial sorting phase (Switch phase). Switch accuracy score = 12 represents the ceiling value for this task.

The Early Years Toolbox has previously shown excellent reliability (Cronbach's α = 0.92) and good convergent validity (r: 0.40–0.46) for inhibition, VSWM, and CF with established measures, and has been widely used in several countries to assess CSR in early childhood (CLIFF et al., 2017; KUZIK et al., 2020; BEZERRA et al., 2020; COOK et al., 2023).

2.3.5 Behavior Self-Regulation (BRS)

BSR was directly assessed using Head, Toes, Knee, Shoulder test – Revised (HTKS-R) (GONZALES et al., 2021). The HTKS-R is a validated children's behavioral self-regulation task that requires the cognitive abilities (working memory, inhibitory control, and cognitive flexibility) manifested in real situations such as paying attention, remembering instructions, and adapting to changing demands. The HTKS-R is an updated version of the HTKS test that includes a Part 0 (Opposites), where children are instructed to say the opposite response (e.g., "if I say toes, you say head"). The remaining sections incorporating gross motor tasks. Part 1 focusing on single pair commands (e.g., "if I say touch your toes, touch your head"), Part 2 introducing an additional pair (e.g., "if I say touch your knees, touch your shoulders"), and Part 3 switching pairs (e.g., "toes go with shoulders, and knees go with head"). The HTKS-R comprises 59 items, scored 0 for incorrect, 1 for self-corrected, and 2 for correct responses, with a total score range of 0 to 118. HTKS-R is indicated as a reliable and valid assessment of BSR for children aged four to eight, showing strong internal consistency (Cronbach's alpha < .90). The HTKS-R was administered by certified research assistants in a space provided within the centers. Children were recorded for subsequent score checking if necessary. The assessment did not exceed 10 minutes.

3. Statistical analysis

As a preliminary analytical step, the data were examined for data entry accuracy and missing values. Children with missing items in more than three key variables (i.e., Anthropometric, SB, PA, ST, SL, CSR, BSR) were excluded from the analysis. This criterion was applied since some children had missing values for SB and PA, as soon as ST and SL, since these pairs of variables were collected in the same protocol. No missing values were identified for the anthropometric and cognitive variables. Little's test was applied to the missing data indicating that these data were completely at random (p = 0.129, using SPSS v 28.0) and supporting expectation maximization (EM) imputation. The percentage of missing imputation were 12,6%, 13,9% and 14,8% for SB/PA, ST/SL and BSR, respectively (Lin & Tsai, 2020).

Compositional data analyses were conducted in R (http://cran.r-project.org) using the compositions (version 1.40-1) (VAN DEN BOOGAART & TOLOSANA-DELGADO, 2008), robCompositions (version 0.92-7) (PAWLOWSKY-GLAHN & BUCCIANTI, 2011; TEMPL, HRON, & FILZMOSER, 2011), and lmtest (version 0.9-35) packages (for prior examples, see BEZERRA et al., 2020; MOTA et al., 2020). The time-use composition (daily time spent in sleep, SB, LPA, and MVPA) was referred to in terms of central tendency, i.e. the geometric mean of time spent in each component, linearly adjusted so that all components summed to the total day, which for purposes of this study, was bound to 1,440 minutes. Multivariate dispersion of the school day composition was described using pairwise log-ratio variation (AITCHISON, 1982; DONTJE, & SKELTON, 2015).

Multiple linear regression models were used to investigate the relationship between the time-use composition (explanatory variable) and each fitness parameter (dependent variable). Prior to inclusion in the regression model, the composition was expressed as a set of three isometric log ratio (*ilr*) co-ordinates. Covariates (age, BMI, and sex) were additionally included as explanatory variables. The outcome variables were Behavior Self-Regulation, Visual-Spatial Working Memory, Inhibitory Control, and Cognitive Flexibility scores, respectively. The *ilr* multiple linear regression models were further checked for linearity, normality, homoscedasticity, and outlying observations to ensure assumptions were not violated. The significance of the time-use composition (i.e., the set of *ilr* coordinates) was examined with the '*car::Anova()*' function, which uses Wald Chi squared to calculate Type II tests, according to the principle of marginality, testing each covariate after all others (FOX & WEISBERG, 2018). The aforementioned *ilr* multiple linear regression models were subsequently used to predict differences in the outcome variables associated with the reallocation of a fixed duration of time (5 mins) between two activity behaviours, whilst the third and fourth remain unchanged. This was achieved by systematically creating a range of new activity compositions to mimic the reallocation of 5 min between all activity behaviour pairs, using the mean composition of the sample as the baseline, or starting composition. The new compositions were expressed as ilr coordinate sets, and each subtracted from the mean composition ilr coordinates, to generate ilr differences. These ilr differences (each representing a 5-minute reallocation between two behaviours) were used in the linear models to determine estimated differences (95% CI) in all outcomes. Predictions were repeated for pairwise reallocations of 5, 10, and 15 minutes, respectively. The decision was made to only go up to 15 minutes reallocation so as to reflect the viability of real or actual change in MVPA. Beyond 15 minutes, there is relatively high proportion of MVPA being reallocated, and thus, any inferences from reallocating such a high proportion of overall MVPA may yield distorted or unrealistic outputs.

4. Results

After applying the criterion for invalided, abnormal and missing values, data of 60 children were excluded from the analysis (21%), and the final analytical sample comprised 223 preschoolers (50.67% boys) of similar age and BMI.

Table 1. Descriptives Variables

Variable	Mean±SD
Age (months)	57.08±3.85
Age (years)	4.76±0.32
BMI (Kg/m^2)	15.81±1.86
SB	393.85±80.18
LPA	353.82±78.55
MPA	46.47±20.29
VPA	11.61±8.15
MVPA	57.12±24.62
TPA	408.00±85.66
VSWM	1.37±0.67
IC	0.593±0.20
CF	3.058±3.81
BSR	36.28±25.48

PA = Physical Activity; ST = Screen Time; SL = Sleep time; Visual-Spatial Working Memory = VSWM; IC = Inhibitory Control; CF = Cognitive Flexibility; BRS = Behavior Self-Regulation.

Table 2. Time-use, cognitive parameters, and participant characteristics data

	Mean(SD)/count	Arithmetic mean	Compositional mean
Time-use			
Sleep	604.9 (79.1)	0.43 (0.06) [43%]	0.44 [44%]
SB	393.5 (75.8)	0.28 (0.05) [28%]	0.28 [28%]
LPA	350.5 (74.1)	0.25 (0.05) [25%]	0.24 [24%]
MVPA	57.1 (24.6)	0.04 (0.01) [4%]	0.04 [4%]
Cognitive parameters			
VSWM	1.37 (0.67)	-	-
IC	0.59 (0.19)	-	-
CF	3.06 (3.81)	-	-
BSR	36.28 (25.48)	-	-
Participant characteristics			
Age (y)	4.75 (0.32)	-	-
BMI (kg·m^2)	15.81 (1.86)	-	-
Sex (M/F)	113/110	-	-

Notes: SB: sedentary behaviour; LPA: light physical activity; MVPA: moderate-to-vigorous phy sical activity; VSWM: visual-spatial working memory; IC: inhibitory control; CF: cognitive flex ibility; BSR: behavior self-regulation; BMI: body mass index. *Time-use* data are presented as lin early-adjusted mean(standard deviation (SD)); arithmetic mean (SD), compositional mean, and [%time per day]. *Cognitive parameters* and *participant characteristics* are presented as mean(SD)/count only. Please note; *"compositional mean"* cannot include SD. Data are rounded to two de cimal places.

The variability of the data was explored in a variation matrix containing all pair-wise log-ratio variances. A value approaching zero indicates that the time spent in the two respective behaviors are highly proportional. In this study, for example, the variance of log(Sleep/sedentary) is 0.05, which reflects the (proportional) relationship or co-dependence between the two behaviors. Conversely, the highest log-ratio variance involved MVPA and sedentary (0.4).

Table 3. Variation matrix

	Sleep	Sedentary	LPA	MVPA
Sleep	0.00	0.05	0.07	0.32
Sedentary	0.05	0.000	0.09	0.4
LPA	0.07	0.09	0.000	0.25
MVPA	0.32	0.4	0.25	0.000

LPA: light physical activity; MVPA: moderate-to-vigorous physical activity. A value approaching “0” indicates high proportionality between pairs of behaviors, whilst a value approaching “1” indicates the opposite.

The daily time-use composition, adjusted for BMI, sex, and age was significantly associated with, VSWM (P = 0.02; r^2 = 0.06), CF (P = 0.02; r^2 = 0.06) and BSR (P < 0.001; r^2 = 0.13), but not IC (P = 0.1; r^2 = 0.04) respectively. Thereafter, we conducted isotemporal substitution between all behavior-pairs, in time increments of 5-mins (ranging from 5-mins to 15-mins). Accordingly, we found that for BSR, the addition of LPA, at the expense of all other behaviors, was associated with notable increases. For VSWM, IC and CF, only negligible changes were observed when any one behavior was replaced and the reallocated to any other behavior.

Table 4. Isotemporal substitutions

Add	Remove	BSR	WM	IC	CF
5 minutes reallocated					
Sleep	Sedentary	**-0.33*(-0.46- -0.21)**	-0.01(-0.01 0.00)	0(0.00 0.00)	0.02(-0.03 0.06)
Sleep	Light	**-0.47*(-0.59- -0.34)**	-0.01(-0.01 0.00)	0(0.00 0.00)	-0.02(-0.06 0.02)
Sleep	MVPA	0.27(-0.03 0.57)	-0.02(-0.04 0.00)	0(-0.01 0.01)	0.02(-0.10 0.13)
Sedentary	Sleep	**0.33*(0.21 0.46)**	0.01(0.00 0.01)	0(0.00 0.00)	-0.02(-0.06 0.03)
Sedentary	Light	-0.13(-0.27 0.00)	0.00(-0.01 0.01)	0(0.00 0.00)	-0.04(-0.08 0.01)
Sedentary	MVPA	**0.60*(0.32 0.87)**	-0.01(-0.03 0.01)	0(0.00 0.01)	0.00(-0.10 0.10)
Light	Sleep	**0.46*(0.34 0.58)**	0.01(0.00 0.01)	0(0.00 0.00)	0.02(-0.02 0.06)
Light	Sedentary	**0.13*(0.00 0.26)**	0.00(-0.01 0.01)	0(0.00 0.00)	0.04(-0.01 0.08)
Light	MVPA	**0.73*(0.39 1.07)**	-0.01(-0.04 0.01)	0(-0.01 0.01)	0.03(-0.09 0.16)
MVPA	Sleep	0.23(-0.50 0.05)	0.02(0.00 0.04)	0(-0.01 0.00)	-0.01(-0.11 0.09)
MVPA	Sedentary	**-0.56*(-0.81- -0.31)**	0.01(-0.01 0.03)	0(-0.01 0.00)	0.00(-0.09 0.09)
MVPA	Light	**-0.69*(-1.01- -0.38)**	0.01(-0.01 0.03)	0(-0.01 0.00)	-0.03(-0.15 0.08)
10 minutes reallocated					
Sleep	Sedentary	**-0.66*(-0.92- -0.41)**	-0.01(-0.03 0.00)	0(0.00 0.00)	0.03(-0.06 0.12)
Sleep	Light	**-0.93*(-1.18- -0.69)**	-0.01(-0.03 0.01)	0(-0.01 0.00)	-0.04(-0.13 0.05)
Sleep	MVPA	0.59(-0.05 1.23)	-0.04(-0.08 0.00)	0(-0.01 0.00)	0.03(-0.20 0.26)
Sedentary	Sleep	**0.66*(0.41 0.91)**	0.01(0.00 0.03)	0(0.00 0.00)	-0.03(-0.12 0.06)
Sedentary	Light	**-0.27*(-0.54- -0.01)**	0.00(-0.01 0.02)	0(-0.01 0.00)	-0.07(-0.17 0.03)
Sedentary	MVPA	**1.25*(0.67 1.83)**	-0.03(-0.06 0.01)	0(-0.01 0.01)	0.00(-0.21 0.21)
Light	Sleep	**0.92*(0.68 1.16)**	0.01(0.00 0.03)	0(0.00 0.01)	0.04(-0.05 0.13)
Light	Sedentary	0.25(-0.01 0.52)	0.00(-0.02 0.01)	0(0.00 0.01)	0.07(-0.03 0.17)
Light	MVPA	**1.51*(0.80 2.21)**	-0.03(-0.07 0.02)	0(-0.01 0.02)	0.07(-0.18 0.33)
MVPA	Sleep	-0.41(-0.95 0.12)	0.03(0.00 0.07)	0(-0.01 0.01)	-0.03(-0.22 0.17)
MVPA	Sedentary	**-1.08*(-1.57- -0.60)**	0.03(-0.01 0.05)	0(-0.01 0.01)	0.00(-0.17 0.18)
MVPA	Light	**-1.35*(-1.96- -0.75)**	0.02(-0.02 0.06)	0(-0.01 0.01)	-0.07(-0.29 0.15)
15 minutes reallocated					
Sleep	Sedentary	**-1.00*(-1.38- -0.62)**	-0.02(-0.04 0.00)	0(-0.01 0.01)	0.05(-0.09 0.18)
Sleep	Light	**-1.40*(-1.77- -1.04)**	-0.02(-0.04 0.01)	0(-0.01 0.00)	-0.06(-0.19 0.07)
Sleep	MVPA	0.98(-0.03 1.99)	-0.06(-0.13 0.00)	0(-0.02 0.02)	0.05(-0.32 0.42)
Sedentary	Sleep	**1.00*(0.62 1.37)**	0.02(0.00 0.04)	0(-0.01 0.01)	-0.05(-0.18 0.09)
Sedentary	Light	**-0.42*(-0.82- -0.02)**	0.00(-0.02 0.03)	0(-0.01 0.01)	-0.11(-0.25 0.04)
Sedentary	MVPA	**1.96*(1.04 2.88)**	-0.04(-0.10 0.02)	0(-0.02 0.02)	0.01(-0.33 0.34)
Light	Sleep	**1.38*(1.03 1.74)**	0.02(-0.01 0.04)	0(0.00 0.01)	0.06(-0.07 0.19)
Light	Sedentary	0.37(-0.03 0.77)	-0.01(-0.03 0.02)	0(-0.01 0.01)	0.11(-0.04 0.25)
Light	MVPA	**2.35*(1.24 3.46)**	-0.05(-0.12 0.02)	0(-0.02 0.02)	0.11(-0.29 0.51)
MVPA	Sleep	-0.57(-1.35 0.20)	0.05(0.00 0.10)	0(-0.02 0.01)	-0.04(-0.32 0.24)
MVPA	Sedentary	**-1.58*(-2.28- -0.89)**	0.03(-0.02 0.07)	0(-0.01 0.01)	0.01(-0.24 0.26)
MVPA	Light	**-1.99*(-2.870- -1.11)**	0.03(-0.02 0.09)	0(-0.02 0.01)	-0.10(-0.42 0.22)

Note: Data reported as total (95% CI). * Significant at P<0.05, based on 95% CI.
Competence.

5. Discussion

This study investigated the association between 24-hour movement BSR at a cognitive and behavioral levels in preschoolers, while also exploring the effects of isotemporal substitution of movement behaviors. Although prior studies have examined the association between 24-h movement composition and CSR in preschool age (KUZIK et al., 2020; BEZERRA et al., 2020; LU et al., 2023; LAU et al., 2024), this study advances prior studies by assessing BSR through direct measures. Accordingly, the findings indicate that: a) the 24-hour movement composition predicts 6% of the variation in both VSWM and CF, and 13% of the variation in BSR; b) reallocating individual behaviors in favor of SB and LPA had positive effects on BSR; c) the greatest effects were observed when replacing MVPA with SB and LPA, respectively; and d) no significant associations has been highlighted between the 24-hour movement behaviours composition and IC.

The current findings align with previous research showing that the 24-hour movement composition may be positively associated with VSWM and CF (KUZIK et al., 2020; LU et al., 2023). VSWM benefits from activities requiring coordination, spatial awareness, and problem-solving, while CF is typically enhanced by tasks involving task-switching and rule adaptation. These cognitive functions are subtly developed through daily play and activities in preschoolers, stimulating relevant brain regions (DIAMOND, 2000; BEST; MILLER, 2010; WANLESS et al., 2011). Similarly, adequate sleep duration and quality also play a critical role in consolidating memory and supporting cognitive processes in early childhood (PELED et al., 2021; DAHAT et al., 2023; THAM et al., 2024; LIU et al., 2024). However, literature on sedentary behavior's influence on cognitive development in preschoolers shows mixed results, with activities like parent-child reading being beneficial, while screen time may have adverse effects (CARSON et al., 2016).

Additionally, the present study showed that the 24-hour movement composition explained 13% of the variation in BSR. To the best of the authors' knowledge, this is the first study to analyze the association between 24-hour compositional movement behaviors and BSR in preschool children, and therefore, direct comparisons with previous studies are not possible. When analyzing adherence to 24-hour movement behaviors, whether individually or in combination, mixed results have been observed (D`CRUZ et al., 2023). These outcomes are particularly influenced by the specific aspects of self-regulation assessed, besides the methodological approaches employed to assess children's self-regulation (ROLLO et al., 2020; ZHU et al., 2021; MCGOWAN et al., 2022). Indeed, children who adhere to the 24-hour movement guidelines, specifically meeting more than one recommendation, tend to exhibit fewer behavioral problems (CARSON et al., 2019a; ZHU et al., 2023). Our findings suggest that a balanced composition of these behaviors positively correlates with better BSR, highlighting the importance of considering the entire spectrum of daily activities. While the current study provides novel insights into the relationship between 24-hour movement behaviors and BSR in preschoolers, further research is needed to confirm these findings and explore the underlying mechanisms.

The present study also showed that isotemporal substitution models involving movement behaviors with CSR were minimal or non-existent. These findings contrast with recent research that primarily reported changes in CSR when behaviors were replaced by MVPA. For instance, Bezerra et al. have previously shown that reallocating 5-20 minutes (in 5-minute increments) of sleep and LPA to MVPA led to significant improvements in IC. Similarly, Lau et al. showed that reallocating time from sleep and SB to MVPA was linked to better IC, and reallocating time from LPA to sleep, SB, and MVPA improved performance in WM. Additionally, Lu et al. indicated that replacing sleep or SB with MVPA produced the most substantial positive changes in CF, whereas did not result in significant changes in IC and WM. Nonetheless, it is important to argue that the current study focused on exploring the effects of reallocating time from movement behaviors on each component of CSR (i.e., IC, VSWM, and CF) while also investigating how these reallocations impact BSR, which involves the integrated application of executive functions to maintain attention and regulate impulses in real-world situations (MCCLELLAND et al., 2012. This distinction is crucial because the context in which executive functions are applied can lead to different outcomes, depending on the nature of the behaviors that are being substituted. The results of the present study showed that reallocating time from different components of daily activities to SB and LPA was associated with changes in BSR. Specifically, findings indicated that increases in BSR were observed when shifting 5-15 minutes from MVPA to SB and LPA, respectively, which opens important discussion on the nature of LPA and SB to be executed.

BSR is likely to be more effectively stimulated through activities that foster sustained attention and cognitive engagement, such as structured play or academic tasks, rather than solely through high-intensity physical activities (DIAMOND et al., 2016; MUIR et al., 2021). For example, sedentary activities such as reading or puzzle-solving require children to concentrate and control their impulses, directly enhancing BSR (CARSON et al., 2015; KUZIK et al., 2020). Moreover, studies have shown that the quality of the PA is more important than its intensity for improving BSR. Studies have demonstrated that activities requiring coordination and focus, rather than high intensity, positively impacted on BSR (PESCE et al., 2012; DIAMOND; LEE, 2016; PESCE; SOUSSAN, 2016; MUIR et al., 2021). This suggests that while MVPA is beneficial for physical health, activities that combine cognitive and physical challenges are more effective for enhancing BSR. However, the positive impacts of MVPA on cognitive domains cannot be overlooked. Therefore, activities that simultaneously incorporate MVPA and cognitive challenges may be beneficial for enhancing both cognitive and behavioral aspects of self-regulation.

Finally, the present study did not find a significant association between 24-hour movement composition and IC, which diverges from those found by Bezerra et al. (2020) in a sample of Brazilian preschoolers. It is important to note that in Bezerra et al., children spent approximately 10 hours daily in childcare centers, including nap times, whereas the children involved in the current study are part-time attending the ECECs. It is plausible to argue that IC may be influenced by subtle factors such as the educational environment, family dynamics, as well as socioemotional aspects (CARSON et al., 2007; HOSOKAWA et al., 2019) Future research should delve deeper into these relationships, exploring potential moderators and mediators in the association between daily movement behaviors and IC (CARSON et al., 2007).

The primary strength of this study lies in its statistically robust compositional approach to investigate the relationship between movement behaviors and self-regulation in preschoolers. Additionally, the objective measurement of cognitive and behavioral self-regulation enhances the study's methodological rigor. However, it is crucial to acknowledge that this study is cross-sectional, which limits its ability to track the longitudinal consistency and stability of movement behaviors over time. To address these limitations, future research should incorporate longitudinal designs and interventions that manipulate daily movement behaviors. Such approaches would provide more robust evidence regarding the optimal strategies for promoting cognitive and behavioral self-regulation development through daily activity compositions. Furthermore, more detailed assessments of movement behaviors, including their intensity and context-specific activities, could offer deeper insights into the differential contributions of various physical activity and sedentary behaviors to self-regulation outcomes in preschoolers.

6. Conclusion

In conclusion, this study provides new insights into the association between 24-hour movement behaviors and self-regulation in preschoolers, particularly focusing on cognitive and behavioral aspects. The findings underscore the significant role of movement behaviors in influencing various facets of self-regulation, with notable impacts observed on VSWM, CF and BSR. The study showed that the composition of daily movement behaviors explained a substantial portion of the variance in VSWM, CF, and

BSR among preschoolers. Specifically, reallocating time from MVPA to SB and LPA was associated with improvements in BSR.

While this study advances our understanding of how movement behaviors influence self-regulation in preschool-aged children, further research is essential to validate these findings and elucidate the underlying mechanisms. These efforts are crucial for developing effective strategies to enhance self-regulation skills through targeted interventions and tailored activity recommendations in early childhood settings.

7. References

Aitchison J. The Statistical Analysis of Compositional Data. J R Stat Soc Ser B. 1982;44(2):139-77.

Aubert S, Brazo-Sayavera J, González SA, Janssen I, Manyanga T, Oyeyemi AL, et al. Global prevalence of physical activity for children and adolescents; inconsistencies, research gaps, and recommendations: a narrative review. Int J Behav Nutr Phys Act. 2021;18(1):81. doi:10.1186/s12966-021-01155-2.

Bezerra TA, Clark CCT, de Souza Filho AN, Fortes LS, Mota JAPS, Duncan MJ, Martins CM. 24-hour movement behaviour and executive function in preschoolers: A compositional and isotemporal reallocation analysis. J Sports Sci. 2020;38(18):2145-2153. doi:10.1080/02640414.2020.1776925.

Blair C, Ku S. A Hierarchical Integrated Model of Self-Regulation. Front Psychol. 2022;13:725828. doi:10.3389/fpsyg.2022.725828.

Bingham DD, Costa S, Clemes SA, Routen AC, Moore HJ, Barber SE. Accelerometer data requirements for reliable estimation of habitual physical activity and sedentary time of children during the early years - a worked example following a stepped approach. J Sports Sci. 2016; DOI: 10.1080/02640414.2016.1149605.

Bornstein DB, Beets MW, Byun W, McIver K. Accelerometer-derived physical activity levels of preschoolers: A meta-analysis. J Sci Med Sport. 2011 Jun;14(6):504-11. doi: 10.1016/j.jsams.2011.05.007.

Butte NF, Wong WW, Lee JS, Adolph AL, Puyau MR, Zakeri IF. Prediction of energy expenditure and physical activity in preschoolers. Med Sci Sports Exerc. 2014;46(6):1216-1226. doi:10.1249/MSS.0000000000000209.

Cadenas-Sanchez, C., Martinez-Tellez, B., Sanchez-Delgado, G., Mora-Gonzalez, J., Castro-Piñero, J., Löf, M., Ruiz, J. R., & Ortega, F. B. (2016). Assessing physical fitness in preschool children: Feasibility, reliability and practical recommendations for the PREFIT battery. *Journal of Science and Medicine in Sport, 19*(11), 910–915. https://doi.org/10.1016/j.jsams.2016.02.003

Carson SM, Carlson SM, Wang TS. Inhibitory control and emotion regulation in preschool children. Cogn Dev. 2007;22(4):489-510. doi:10.1016/j.cogdev.2007.08.002.

Carson V, Ezeugwu VE, Tamana SK, Chikuma J, Lefebvre DL, Azad MB, et al. Associations between meeting the Canadian 24-Hour Movement Guidelines for the Early Years and behavioral and emotional problems among 3-year-olds. J Sci Med Sport. 2019;22(7):797-802. doi:10.1016/j.jsams.2019.01.003.

Carson V, Hunter S, Kuzik N, Gray CE, Poitras VJ, Chaput JP, et al. Systematic review of sedentary behavior and health indicators in school-aged children and youth: an update. Appl Physiol Nutr Metab. 2016;41(6 Suppl 3). doi:10.1139/apnm-2015-0630.

Cliff DP, McNeill J, Vella SA, Howard SJ, Santos R, Batterham M, et al. Adherence to 24-Hour Movement Guidelines for the Early Years and associations with social-cognitive development among Australian preschool children. BMC Public Health. 2017;17:857. doi:10.1186/s12889-017-4858-7.

Cook CJ, Howard S, Scerif G, Twine R, Kahn K, Norris S, Draper C. Executive function and pre-academic skills in preschoolers from South Africa. S Afr J Child Educ. 2023;13(1):1-11. doi:10.4102/sajce.v13i1.1256.

Dahat H, Rathi P, Pande S, Sharma S, Rao S. Correlation of Various Sleep Patterns on Different Types of Memory Retention: A Systematic Review. Sleep Med Rev. 2023;67:101734. doi:10.1016/j.smrv.2023.101734.

de Onis, M., Garza, C., Onyango, A. W., & Rolland-Cachera, M. F. (2009). WHO growth standards for infants and young children. Archives de Pédiatrie, 16(1), 47–53. https://doi.org/10.1016/j. arcped.2008.10.010

Diamond A. Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. Child Dev. 2000;71(1):44-56. doi:10.1111/1467-8624.00117.

Diamond A, Lee K. Interventions shown to aid executive function development in children 4 to 12 years old. Science. 2011;333(6045):959-964. doi:10.1126/science.1204529.

D'Cruz M, Aw S, Koh W, Chua ML, Mahmud A, Wong CH, et al. Association between physical activity and self-regulation in early childhood: A systematic review. Early Child Res Q. 2023;64:50-64. doi:10.1016/j.ecresq.2023.03.002.

Dontje ML, Skelton DA, Chastin SF. The use of compositional data analysis to explore change in physical activity and sedentary behavior. Aging Clin Exp Res. 2015;27(5):519-27.

Dumuid D, Pedisic Z, Stanford TE, et al. The compositional isotemporal substitution model: A method for estimating changes in a health outcome for reallocation of time between sleep, physical activity and sedentary behaviour. Stat Methods Med Res. 2019;28(3):846-857. doi:10.1177/0962280217737805.

Esliger DW, Copeland JL, Barnes JD, Tremblay MS. Standardizing and optimizing the use of accelerometer data for free-living physical activity monitoring. J Phys Act Health. 2005;3:366-383.

Fox J, Weisberg S. An R Companion to Applied Regression. 3rd ed. Thousand Oaks: Sage Publications; 2018.

Gonzales CR, Bowles R, Geldhof GJ, Cameron CE, Tracy A, McClelland MM. The Head-Toes-Knees-Shoulders Revised (HTKS-R): Development and psychometric properties of a revision to reduce floor effects. Early Child Res Q. 2021;56:320-332. doi:10.1016/j.ecresq.2021.03.008.

Goodlin-Jones BL, Sitnick SL, Tang K, Liu J, Anders TF. The Children's Sleep Habits Questionnaire in toddlers and preschool children. J Dev Behav Pediatr. 2008;29(2):82-88. doi:10.1097/DBP.0b013e318163c39a.

Hosokawa R, Katsura T. Inhibitory Control Across the Preschool Years: Developmental Changes and Associations with Parenting. Child Dev. 2019;90(5). doi:10.1111/cdev.13426.

Howard SJ, Melhuish E. An Early Years Toolbox for assessing early executive function, language, self-regulation, and social development: Validity, reliability, and preliminary norms. J Psychoeduc Assess. 2017;35(3):255-275. doi:10.1177/0734282916633009.

Howard SJ, Vasseleu E. Self-Regulation and Executive Function Longitudinally Predict Advanced Learning in Preschool. Front Psychol. 2020;11:49. doi:10.3389/fpsyg.2020.00049.

Korucu I, Ayturk E, Finders JK, Schnur G, Bailey CS, Tominey SL, Schmitt SA. Self-Regulation in Preschool: Examining Its Factor Structure and Associations With Pre-academic Skills and Social-Emotional Competence. Front Psychol. 2022 Jan 18;12:717317. doi:10.3389/fpsyg.2021.717317.

Kuzik N, Naylor PJ, Spence JC, Carson V. Movement behaviours and physical, cognitive, and social-emotional development in preschool-aged children: cross-sectional associations using compositional analyses. PLoS One. 2020;15(8). doi:10.1371/journal.pone.0237945.

Kuzik N, Spence JC, Arkko K, Blye CJ, Davie J, Duddridge R, et al. Associations between meeting the Canadian 24-hour movement guidelines and physical, cognitive, social-emotional, and overall development in early childhood. J Act Sedent Sleep Behav. 2022;1(2). doi: 10.1186/s44167-022-00002-4.

Lau PWW, Song H, Song D, Wang JJ, Zhen S, Shi L, Yu R. 24-Hour movement behaviors and executive functions in preschoolers: A compositional and isotemporal reallocation analysis. J Sport Health Sci. 2023;12(1):104-113. doi:10.1016/j.jshs.2022.05.003.

Lin WC, Tsai CF. Missing value imputation: a review and analysis of the literature (2006–2017). Artif Intell Rev. 2020;53(2):1487-1509. doi:10.1007/s10462-019-09709-4.

Lu Z, Qu X, Chang J, Xu M, Song G, Wang X, et al. Reallocation of time between preschoolers' 24-h movement behaviours and executive functions: A compositional data analysis. J Sports Sci. 2023;41(6):678-686. doi:10.1080/02640414.2022.2161811.

Martins C, Mota J, Goulart N, Silva M, Silva T, Carvalho F, et al. Compliance with the 24-h movement behaviors guidelines among urban and rural Brazilian preschoolers. Am J Hum Biol. 2024;e24045. doi:10.1002/ajhb.24045.

Martins CM, Lemos LFBP, de Souza Filho AN, Bezerra TA, Soares IAA, Mota JG, et al. Adherence to 24-hour movement guidelines in low-income Brazilian preschoolers and associations with demographic correlates. Am J Hum Biol. 2021;33(4). doi:10.1002/ajhb.23519.

McClelland MM, Cameron CE. Self-regulation in early childhood: Improving conceptual clarity and developing ecologically valid measures. Child Dev Perspect. 2012;6(2):136-142. doi:10.1111/j.1750-8606.2011.00191.x.

McClelland MM, Cameron CE, Connor CM, Farris CL, Jewkes AM, Morrison FJ. Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. Dev Psychol. 2007;43(4):947-59. doi:10.1037/0012-1649.43.4.947.

McGowan AL, Gerde HK, Pfeiffer KA, Pontifex MB. Meeting 24-hour movement behavior guidelines in young children: Improved quantity estimation and self-regulation. Early Child Res Q. 2022;59:762-789.

McNeill J, Howard SJ, Vella SA, Cliff DP. Compliance with the 24-Hour movement guidelines for the early years: Cross-sectional and longitudinal associations with executive function and psychosocial health in preschool children. J Sci Med Sport. 2020;23(9):846-853.

Muir K, Liddiard K, Freeman E, Griffiths J, Gadsby S. Interventions and approaches targeting early self-regulation or executive functioning in preschools: A systematic review. Educ Psychol Rev. 2021;33(1):135-163. doi:10.1007/s10648-020-09541-0.

Okely AD, Ghersi D, Hesketh KD, Santos R, Loughran SP, Cliff DP, et al. A collaborative approach to adopting/adapting guidelines - The Australian 24-Hour Movement Guidelines for the early years (Birth to 5 years): an integration of physical activity, sedentary behavior, and sleep. BMC Public Health. 2017;17(Suppl 5):869.

Okely T, Reilly JJ, Tremblay MS, Kariippanon KE, Draper CE, El Hamdouchi A, et al. Cross-sectional examination of 24-hour movement behaviours among 3- and 4-year-old children in urban and rural settings in low-income, middle-income and high-income countries: SUNRISE study protocol. BMJ Open. 2021;11(10). doi:10.1136/bmjopen-2021-049267.

Pawlowsky-Glahn V, Buccianti A, editors. Compositional Data Analysis: Theory and Applications. Chichester: John Wiley & Sons; 2011.

Perry NE. Recognizing early childhood as a critical time for developing and supporting self-regulation. Metacognition Learn. 2019;14(3):327-334. doi:10.1007/s11409-019-09213-8.

Pesce C. Shifting the focus from quantitative to qualitative exercise characteristics in exercise and cognition research. J Sport Exerc Psychol. 2012;34(6):766-786. doi:10.1123/jsep.34.6.766.

Pesce C, Ben-Soussan TD. "Cogito ergo sum" or "ambulo ergo sum"? New perspectives in developmental exercise and cognition research. In: McMorris T, editor. Exercise-Cognition Interaction: Neuroscience Perspectives. London: Academic Press; 2016. p. 251-282.

Rollo S, Prapavessis H, Maddison R. The whole day matters: Understanding 24-hour movement guideline adherence and relationships with health indicators across the lifespan. J Sport Health Sci. 2020;9(6):493-510. doi:10.1016/j.jshs.2020.06.007.

Schmidt H, Daseking M, Gawrilow C, Karbach J, Kerner JK. Self-regulation in preschool: Are executive function and effortful control overlapping constructs? Dev Sci. 2022;25(6) doi:10.1111/desc.13272.

Sezgin E, Ulus L. An Examination of Self-Regulation and Higher-Order Cognitive Skills as Predictors of Preschool Children’s Early Academic Skills. Int Educ Stud. 2020;13(7):65-74. doi:10.5539/ies.v13n7p65.

Taylor RW, Haszard JJ, Meredith-Jones K, Galland BC, Heath ALM, Lawrence J, et al. Adherence to 24-h movement behavior guidelines and psychosocial functioning in young children: a longitudinal analysis. Int J Behav Nutr Phys Act. 2018;15(1):118.

Templ M, Hron K, Filzmoser P. Statistical Analysis of Compositional Data: Methods and Applications. Chichester: John Wiley & Sons; 2011.

Tham EKH, Schneider N, Broekman BFP. Sleep duration trajectories and cognition in early childhood: A systematic review. Sleep Med Rev. 2024;67:101729. doi:10.1016/j.smrv.2024.101729.

Tremblay MS, Carson V, Chaput JP, Connor Gorber S, Dinh T, Duggan M, et al. Canadian 24-Hour Movement Guidelines for Children and Youth: An Integration of Physical Activity, Sedentary Behaviour, and Sleep. Appl Physiol Nutr Metab. 2016;41(Suppl 3).

Vale S, Mota J. Adherence to 24-hour movement guidelines among Portuguese preschool children: the prestyle study. J Sports Sci. 2020;38(18):2149-2154. doi:10.1080/02640414.2020.1775385.

Van den Boogaart KG, Tolosana-Delgado R. Compositional Data Analysis: Theory and Applications. Chichester: John Wiley & Sons; 2013.

Wanless SB, McClelland MM, Tominey SL, Acock AC. How does inhibitory control predict emotion regulation in preschool? The role of individual children’s interactions with teachers and peers. Dev Psychol. 2011;47(5):1283-1296. doi:10.1037/a0023271.

Wiebe SA, Sheffield T, Nelson JM, Clark CA, Chevalier N, Espy KA. Separating the fish from the sharks: A longitudinal study of preschool response inhibition. Child Dev. 2012;83(4):1245-1261. doi:10.1111/j.1467-8624.2012.01765.x.

5.4 ARTIGO 4

Title: The Effects of an Educational Gymnastics Intervention on Self-Regulation, Motor Skills, and Movement Behaviors in Preschool Children: A Cluster-Randomized Controlled Trial

ABSTRACT

Objective: This study aimed to evaluate the effects of an Educational Gymnastics intervention on self-regulation (SR), motor skills, and movement behaviors (physical activity, sedentary behavior, and sleep) in preschool children. **Methods:** A cluster-randomized controlled trial was conducted with 86 children aged 4-5 years from two Early Childhood Education Centers in Petrolina, Brazil. The intervention group participated in a 12-week Educational Gymnastics program, while the control group continued their routine activities. SR was assessed using objective and subjective measures, including the Early Years Toolbox for cognitive SR (inhibitory control, visuospatial working memory, cognitive flexibility), the Head-Toes-Knees-Shoulders-Revised (HTKS-R) test for behavioral SR, and the Child Self-Regulation and Behavior Questionnaire (CSBQ) for parent-reported SR. Motor skills were evaluated using the Test of Gross Motor Development-3rd Edition (TGMD-3). Movement behaviors, including physical activity, sedentary behavior, and sleep, were objectively measured using accelerometers worn for seven consecutive days, supplemented by sleep logs maintained by caregivers. Assessments were conducted at baseline (T1), post-intervention (T2), and 12 weeks post-intervention (T3). **Results:** Significant improvements were observed in inhibitory control, cognitive flexibility, and behavioral SR in the intervention group at T2, with sustained effects on behavioral SR at T3. However, a reduction in light physical activity was noted. **Conclusion:** The coordination-focused Educational Gymnastics intervention effectively improved SR, with sustained effects on behavioral SR at follow-up. The reduction in light physical activity highlights the need for future studies to consider the integrated composition of movement behaviors to better understand the impact of such interventions.

Trial Registration: Brazilian Registry of Clinical Trials (#RBR-8jbhzsz)

Key-words: Self-regulation, Motor Skill, Movement Behaviors, Intervention, Preschooler

1. Introduction

Self-regulation (SR) is a critical developmental skill in early childhood, encompassing the ability to manage behavior, emotions, and thoughts in response to external demands (GARON et al., 2008; BLAIR & RAVER, 2012; BLAIR & KU, 2022). SR consists of three core components: cognitive (CSR), emotional (ESR), and behavioral (BSR) self-regulation (GARON et al., 2008; HOFMANN et al., 2012; BLAIR). Early development of SR is strongly associated with academic achievement, emotional well-being, and the formation of healthy social relationships (MCCLELLAND et al., 2007; BLAIR & DIAMOND, 2008; BLAIR & RAVER, 2012).

Motor development is closely intertwined with SR, with studies suggesting a close relationship between these domains during early childhood (DIAMOND, 2000; VAN DER FELS et al., 2015; SHI; FENG, 2022). The acquisition of fundamental motor skills (FMS) and the development of SR, particularly in the cognitive domain, occur concurrently, sharing common neural pathways (e.g., prefrontal cortex, basal ganglia, cerebellum) and developmental trajectories (DIAMOND, 2000; VAN DER FELS et al., 2015). FMS form the foundation for more advanced movement skills and are categorized into locomotor (e.g., running, jumping), object control (e.g., throwing, kicking), and stability skills (e.g., balance) (STODDEN et al., 2008). Proficiency in both FMS and SR during early childhood is essential for school readiness and successful adaptation to formal learning environments (PESCE, 2012; MCCLELLAND & CAMERON, 2019).

In addition to motor development, SR is influenced by movement behaviors such as physical activity (PA), sedentary behavior (SB), and sleep (ROLLO et al., 2020; KUZIK et al., 2020; 2022). Children with stronger SR are more likely to engage in regular PA, while those with weaker SR tend to display higher levels of SB (MILLER et al., 2017; ROBSON et al., 2020). Early promotion of SR is crucial for overall health, as it influences both PA participation and the reduction of sedentary time (CARSON et al., 2016; LOPRINZI et al., 2016; MCGOWAN et al., 2020). Regular PA improves executive functions like inhibitory control (IC), working memory (WM), and cognitive flexibility (CF), essential components of cognitive self-regulation (CSR) (DIAMOND, 2013; BLAIR & KU, 2022). Conversely, excessive sedentary time, especially screen time, is linked to poorer SR outcomes (PAGANI et al., 2010; CARSON et al., 2017).

Research into SR and movement behaviors has largely been based on cross-sectional analyses; however, emerging longitudinal studies suggest that increasing PA and reducing SB may result in long-term improvements in SR (ÁLVAREZ-BUENO et al., 2017; VASILOPOULOS et al., 2023). Despite these findings, the evidence remains inconclusive, highlighting the need for further investigation to better understand the nature and directionality of these associations (ROLLO et al., 2020; FENG et al., 2021). Studies utilizing compositional analysis and isotemporal substitution models have demonstrated that replacing sedentary time with active time, particularly moderate-to-vigorous PA, can have a positive impact on CSR (BEZERRA et al., 2020; KUZIK et al., 2020; LU et al., 2023). Additionally, targeted PA interventions have been shown to enhance both movement behaviors and SR in children (ÁLVAREZ-BUENO et al., 2017; MUIR et al., 2023; VASILOPOULOS et al., 2023). Reviews by Diamond and Ling (2016) consistently emphasize the positive effects of PA on SR, although further research specifically focused on preschool-aged children is necessary to confirm these findings (GOULART et al., 2023; D'CRUZ et al., 2023; MUIR et al., 2023).

The quality of interventions, rather than PA intensity alone, is key to positively impacting SR (DIAMOND; LING, 2019; MUIR et al., 2023; CALLAGHAN et al., 2024). The quality of movement, including precision, coordination, and adaptation to different contexts, plays a crucial role in the impact of these interventions (PESCE et al., 2016; DIAMOND & LEE, 2016; TOMPOROWSKI & PESCE, 2019). Interventions targeting FMS have shown beneficial effects on SR, driven by the reciprocal development of motor and cognitive domains in early childhood (DIAMOND, 2000; MCCLELLAND & CAMERON, 2012). Tomporowski et al. (2015) demonstrated that programs involving complex motor skills enhance both PA and CSR. However, high-intensity PA does not consistently lead to positive SR outcomes and may induce stress, potentially impairing SR (PESCE et al., 2009; 2012; DIAMOND & LING, 2016; SCHMIDT et al., 2016, 2017).

It is still unclear to what extent interventions focused on both SR and FMS can impact movement behaviors. Questions remain about the extent to which interventions targeting both SR and FMS can also influence movement behaviors, including PA, SB, and sleep, given the reciprocal relationships among these behaviors (CHASTIN et al., 2015; TREMBLAY et al., 2016; PEDISIĆ et al., 2017). This study aims to examine whether a coordination-based intervention can significantly impact SR, motor skills, and movement behaviors in preschoolers. Evidence suggests that PA programs focusing on coordination yield positive effects on SR in young children (DIAMOND & LEE, 2016;

ÁLVAREZ-BUENO et al., 2017; GIORDANO et al., 2021; GUTIÉRREZ-CAPOTE et al., 2024). Consequently, Educational Gymnastics, designed to enhance balance and coordination, was selected as the basis for the intervention to be tested in an ecological context.

2. Methods

2.1 Ethical aspects

The study protocol was registered at the Brazilian Registry of Clinical Trials (#RBR-8jbhzsz), and all procedures were conducted following the ethical principles outlined in the Declaration of Helsinki (World Medical Association, 2013). Approval was obtained from the Research Ethics Committee of the Health Science Center (protocol no. 4.933.29). Informed consent was obtained from all parents or legal guardians prior to the participation of their children. The study ensured participant confidentiality by anonymizing all collected data, which was stored in encrypted files accessible only to the research team. Data were analyzed using anonymized codes to further protect participant identity.

2.2 Study Design

This study was conducted as a cluster-randomized controlled trial (RCT) from 2022 to 2023. The study was conducted at two Early Childhood Education Centers (ECECs) located in low- to middle-income neighborhoods in Petrolina, Brazil. The centers were randomly assigned to either the experimental group or the control group.

A pilot study was conducted prior to the main study to assess the feasibility and acceptability of the intervention. The pilot involved 20 preschoolers who participated in a shortened version of the gymnastics intervention (35 minutes per session, three times a week, for four weeks) in an ECEC that was not participating in the main study. The findings from the pilot study confirmed the feasibility of integrating the gymnastics program into the preschool setting and led to minor modifications, such as adjustments in classroom space and equipment.

The study design included measurements at three time points for both groups. Baseline assessments (T1) were conducted in July-August 2022, followed by reassessments post-intervention (T2) in November-December 2022. Follow-up assessments were conducted three months post-intervention (T3) in March-April 2023, following the summer break and coinciding with the children's progression to their last preschool year.

2.3 Participants

Participants included preschool children, aged 4 to 5 years, enrollment in ECECs. Eligibility criteria included being typically developing and having no neurological or physical disabilities. Parental consent was required for inclusion in the data analysis. Children with neurodevelopmental disorders who had provided parental consent had their data collected but were excluded from the final analysis. Additionally, children whose parents did not provide consent also participated in the intervention activities but did not undergo any data collection or measurement procedures.

2.4 Randomization and Blinding

The randomization process was conducted by an independent researcher who was not involved in the data collection or analysis. A computer-generated randomization sequence was used to assign ECECs to either the experimental or control group. Randomization was stratified by center size and availability of physical space for conducting the intervention. Due to the nature of the intervention, blinding of participants and interventionists was not possible. However, to minimize bias in the analysis phase, the data analysts were blinded to the group allocations. Data were anonymized and provided to the analysts with group labels removed, ensuring that the analysts were unaware of whether the data corresponded to participants in the experimental or control groups.

2.5 Intervention

The intervention was centered on the concept of Educational Gymnastics, an approach particularly suited to preschool-aged children as it promotes active participation and the development of motor skills within an enjoyable and inclusive environment (Nilges-Charles, 2008; Baumgarten & Pagnano-Richardson, 2010). Educational Gymnastics emphasizes exploration and creativity, rather than competition, allowing children to develop physical abilities at their own pace, thereby contributing to overall motor development and enhancing self-confidence. The theoretical framework supporting the intervention was based on two key sources: Stodden et al. (2008), which highlighted the importance of physical activity for motor skill enhancement during early childhood, and Pesce et al. (2016), who emphasized the role of practice variability in early childhood education to support the development of FMS and improve cognitive capacities.

The intervention incorporated elements of Educational Gymnastics, including locomotor movements like traveling, balancing, rotation, and suspension. Additional activities, such as hula hoop and ball games, were integrated into the lessons to stimulate manipulation skills (FIGURE 1). The skills addressed were divided into two categories:

- Progression Movements: Preparatory exercises that help develop the necessary skills for fundamental movements. For example, the "egg roll" (a tucked sideways roll) was used as a progression movement to build skills for more advanced exercises.
- Fundamental Gymnastic Movements: Core movements of gymnastics, such as the forward roll (a roll forward over the neck), which are considered basic skills within gymnastics.

The intervention was conducted over a 12-week period, comprising a total of 30 sessions. These sessions were held three times per week, with each session lasting between 30 and 35 minutes. All sessions were conducted in a designated area within the ECEC.

Each session included three main components:

- Warm-up (15 minutes): This phase involved various locomotor activities (e.g., running, skipping, hopping), animal walks (e.g., pretending to walk like different animals), and balance exercises.
- Gymnastics Stations (15 minutes): Children rotated through a circuit of five stations, each designed to improve specific motor skills (e.g., balancing, jumping, throwing). The tasks were varied in terms of body aspects (e.g., what the body does), space aspects (e.g., where the body moves), and cognitive effort (e.g., remembering specific actions at each station) as outlined by Baumgarten & Pagnano-Richardson (2010). For instance, children were instructed to jump into colored hoops and touch different body parts based on the hoop color (e.g., head for blue, knees for red). Each child was encouraged to complete the circuit three times, with the option to choose their favorite station during the final five minutes (Supplementary I).
- Cool-down (5 minutes): This segment included calming activities and a brief feedback session with the instructor, allowing children to reflect on the activities and relax.

The control group continued with their standard curriculum, which involved one physical education session per week that did not include any structured gymnastics activities.

INSERE FIGURE I

2.6 Fidelity of Intervention

All intervention sessions were recorded, and fidelity assessments were conducted by reviewing the video footage. Two aspects were evaluated: children's participation and adherence to the planned activities. Children's participation was rated on a scale of 1 to 3 (low, moderate, or high), and adherence to the intervention protocol was rated similarly (WILLIAMS & BERTHELSEN; 2019). Additionally, accelerometers were worn by three randomly selected children per session to monitor the intensity of PA during the intervention.

2.7 Outcome Measures

2.7.1 Self-Regulation

Self-Regulation was assessed using both objective and subjective measures:

Cognitive Self-Regulation (CSR): Measured using the Early Years Toolbox (HOWARD; MELHUISH, 2017), which involved three tasks: the Mr. Ant task for Visual-Spatial Working Memory (VSWM) the Go/No-Go task for Inhibitory Control (IC), and Rabbits and Boats for Cognitive Flexibility (CF).

In the Mr. Ant task, children observed Mr. Ant with stickers on different parts of his body for 5 seconds, followed by a 4-second blank screen. Afterward, Mr. Ant reappeared with an auditory prompt to replace the stickers. The task consisted of 8 levels (1-8 stickers), with three trials per level. Each level increased in difficulty as the number of stickers to remember grew. The task ended if all three trials in a level were failed or if all eight levels were completed. Instructions were followed sequentially, with auditory cues and delays before presenting shapes for matching. Performance was assessed using a point system, starting at level 1. Points were awarded when at least 2 out of 3 trials were correct, earning 1 point for that level. If only 1 out of 3 trials was correct, that level and subsequent levels were scored based on the number of correct trials, with 1/3 of a point awarded per correct trial. A maximum score of 8 points was possible for each correct trial. The point score = 8 represents the ceiling value for this task.

In the Go/No-Go task, children tapped the screen for fish (GO - 80% occurrence) but not for sharks (NO GO - 20% occurrence) in three trials. For each trial, 75 stimuli were presented in a semi-random order, lasting 1,500 milliseconds, followed by a 1,000-millisecond of no stimulus. IC was determined by multiplying the proportion of accuracy of Go and accuracy of No-Go, where IC = 1 represents the ceiling value for this task.

In the Rabbits and Boats task, children sorted cards (e.g., red rabbits, blue boats) based on either color or shape into locations identified by a blue rabbit or a red boat. They switch sorting rules after a demonstration and two practice trials, sorting by one dimension for six trials, then switching to the other dimension. Each trial starts with a reminder of the sorting rule, followed by sorting stimuli. Participants advancing to the border phase must sort by color for cards with a black border and by shape for cards without a black border. Cards are arranged to avoid presenting the same stimulus more than twice consecutively. Scores reflect correct sorts after the initial sorting phase (Switch phase). Switch accuracy score = 12 represents the ceiling value for this task.

The Early Years Toolbox has previously shown excellent reliability (Cronbach's $\alpha = 0.92$) and good convergent validity (r: 0.40–0.46) for inhibition, VSWM, and CF with established measures, and has been widely used in several countries to assess CSR in early childhood (CLIFF et al., 2017; KUZIK et al., 2020; BEZERRA et al., 2020; COOK et al., 2023).

Behavior Self-Regulation (BRS): Assessed using Head, Toes, Knee, Shoulder test – Revised (HTKS-R) (GONZALES et al., 2021). The HTKS-R is a validated task that evaluates cognitive abilities such as working memory, inhibitory control, and cognitive flexibility, skills essential for attention, following instructions, and adapting to changes.

HTKS-R is an updated version of the HTKS, including Part 0 (Opposites), where children respond with the opposite action (e.g., "if I say toes, you say head"). The remaining parts involve gross motor tasks: Part 1 focuses on single pair commands (e.g., "if I say touch your toes, touch your head"), Part 2 introduces a second pair (e.g., "if I say touch your knees, touch your shoulders"), and Part 3 switches pairs (e.g., "toes with shoulders, knees with head"). The test comprises 59 items, scored as 0 (incorrect), 1 (self-corrected), and 2 (correct). The total score ranges from 0 to 118, with each section contributing: Part 0 = up to 22 points, Part 1 = up to 34 points, Part 2 = up to 30 points, and Part 3 = up to 32 points. The HTKS-R has strong internal consistency (Cronbach's alpha < .90) and is reliable for children aged 4 to 8. The assessment, conducted by certified research assistants, took place in the centers and was recorded for verification. It lasted no more than 10 minutes.

Parent-Reported SR: Self-regulation was subjective assessed through parent/primary caregivers reports using the Brazilian version of the Child Self-Regulation and Behaviour Questionnaire (CSBQ) (HOWARD; MELHUISH, 2017; LEMOS et al., 2024). Three subscales were used in this study: Cognitive Self-Regulation (CSR-CSBQ) (five items, e.g., “persists with difficult tasks”), Behavioral Self-Regulation (BSR-CSBQ) (five items, e.g., “waits their turn in activities”), and Emotional Self-Regulation (ESR-CSBQ) (three items, e.g., “gets over being upset quickly”). Parents rated their children's behavior on a scale from 1 (not true) to 5 (certainly true). The mean scores of the items in each subscale were used in the analysis, with higher scores indicating greater self-regulation skills.

2.7.2 Fundamental Movement Skill (FMS)

FMS were assessed using the Test of Gross Motor Development-3rd Edition (TGMD-3) (WEBSTER; ULRICH, 2017). The TGMD-3 is a process-oriented, performance-based tool validated for children aged 3 to 10, assessing locomotor skills (LOC) and ball skills (BS). LOC includes running, skipping, galloping, sliding, hopping, and horizontal jumping, while BS includes catching, overhand and underhand throwing, kicking, two-handed and one-handed striking, and stationary dribbling. Each skill is evaluated using three to five performance criteria, with 1 point awarded for each correctly performed criterion (1 = correct, 0 = incorrect). Children completed a practice trial followed by two test trials for each subtest. The maximum scores are 46 for locomotor skills and 54 for ball skills, with a total possible TGMD-3 score of 100 (higher scores reflect better performance). TGMD-3 is widely validated across multiple countries (Estevan et al., 2017; Valentini et al., 2017; Magistro et al., 2020; Rey et al., 2020; Martins et al., 2024; Barnett et al., 2024). Scoring followed the procedures described by Mota et al. (2020), and the intraclass correlation coefficient (ICC) demonstrated strong reliability: 0.91 for locomotor, 0.96 for ball skills, and 0.97 for the total score.

2.7.3 Movement Behaviors

Sedentary Behavior (SB) and Physical Activity (PA) were measured using ActiGraph accelerometers (model WGT3-X), a validated tool for preschoolers

(BORNSTEIN et al., 2011). Teachers and parents/caregivers received verbal and written instructions on proper use, including placement on the right side of the waist, worn under clothing. Children were also introduced to the device playfully, through a story about a "superpower belt," and were instructed not to share it. Participants wore the accelerometer for seven consecutive days (Wednesday morning to Tuesday afternoon), removing it only for water-based activities or sleeping. Parents received reminders via phone messages during the week.

Data collection, reduction, and analysis were conducted using ActiLife software (v6.13.3). Accelerometer data were collected using a 15-second epoch length, reintegrated to 60-second epochs for analysis (CLIFF et al., 2019). Non-wear periods were defined as ≥20 minutes of consecutive zero counts and excluded from the analysis (ESLIGER et al., 2005). The first day's data were omitted to minimize reactivity. A minimum of 6 hours of wear time was required for valid data, with no need for weekend data, between 6 am and 10 pm (BINGHAM et al., 2016).

Sedentary time was defined as ≤819 counts (BUTTE et al., 2014), and physical activity (PA) levels were categorized based on vector magnitude: light PA (LPA) = 820–3,907 counts, moderate PA (MPA) = 3,908–6,111 counts, and vigorous PA (VPA) ≥ 6,112 counts. These cut points were validated against double-labeled water, room calorimetry, and triaxial accelerometer data. For statistical analysis, total PA (TPA), LPA, MPA, and VPA were considered (MARTINS et al., 2021; 2024).

To assess children's sleep behavior, a sleep log was utilized throughout the week of accelerometer use. Caregivers were instructed to record their child's nighttime sleep and nap schedules. Sleep duration each day was calculated as the sum of nighttime sleep (difference between bedtime and wake-up time) and nap duration. The total weekly sleep duration was calculated by summing the daily sleep durations and dividing by 7. To convert the average daily sleep duration from hours to minutes, the average daily sleep duration in hours was multiplied by 60.

2.7.4 Anthropometrics

Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2), with children classified according to WHO cut-offs (DE ONIS et al., 2009; CADENAS-SANCHEZ et al., 2016). Height (cm) was measured using a Holtain stadiometer, and body weight (kg) using a digitized scale (Seca model 708, Hamburg), with participants lightly dressed and barefoot. Two measurements were taken, and the average was used. For height, if the second measurement differed by more than 0.5 cm, a third measurement was taken. The same procedure was applied for weight if the difference exceeded 0.25 kg.

3. Data analysis

Descriptive statistics were calculated for all outcome measures, including means and standard deviations. Normality was assessed using the Shapiro-Wilk test. General linear mixed models were used to assess the effect of the intervention on SR, motor skills, and movement behaviors, with group (intervention vs. control) and time (T1, T2, T3) as fixed effects, and individual differences as random effects. Covariates included sex, age, and BMI. The Akaike Information Criterion (AIC) was used to determine the best-fitting model, and post-hoc analyses were conducted using Bonferroni corrections. The statistical significance of effects was assessed using the Wald χ^2 test, with results reported as betas (β) and 95% confidence intervals. Post-estimation contrast tests and pairwise comparisons were conducted using Bonferroni's post-hoc test to identify the sources of significant main effects and interactions.

4. Results

Participant Flow

Participant recruitment is summarized in Figure II. A total of 86 children were included in the final analysis, with 46 children in the experimental group (Age = 58.3 ± 3.41 months; BMI = 16.2 ± 1.94 kg/m^2), including 24 boys and 22 girls, and 40 children in the control group (Age = 57.0 ± 3.27 months; BMI = 15.7 ± 2.19 kg/m^2), comprising 24 girls and 16 boys. Data from children diagnosed with neurodevelopmental disorders during the study, those who did not complete cognitive and behavioral tests at baseline, and those who did not maintain a minimum attendance rate of 75% in preschool were excluded from the analyses. However, children who completed the cognitive and behavioral tests at baseline but were transferred from the center were retained in the analyses.

INSERE FIGURE II

Intervention Fidelity

Fidelity ratings indicated that 90% of the sessions were implemented according to the intervention plan. Adjustments typically involved minor modifications due to classroom changes, preschool events, or climate conditions (e.g., hot weather or intense rain). Children's participation was rated as high in 88% of sessions and moderate in 12%. The average duration of activities per session was 14.48 minutes in LPA, 6.88 minutes in MPA, and 5.47 minutes in VPA.

During the T3 period, it was observed that the educators at the experimental center had incorporated several gymnastics activities into their psychomotor activity plans. These activities were also incorporated into pre-scheduled activities at the preschools, such as literacy period, and recess period (Supplementary II).

Between-Group Analysis

At T2, the experimental group showed significantly higher SR scores compared to the control group in the cognitive domain (IC: $p = 0.002$; CF: $p < 0.001$), except for visuospatial working memory (VSWM). Significant improvements were also observed in the behavioral domain (BSR: $p = 0.007$; BSR-CSBQ: $p = 0.041$). Additionally, the experimental group exhibited a greater reduction in LPA compared to the control group ($p = 0.034$). By T3, the experimental group continued to show a higher BSR score compared to the control group ($p = 0.019$) (TABLE I).

Within-Group Analysis

In the within-group analysis, the experimental group demonstrated significant improvements at T2 in the cognitive domain (IC: $p < 0.001$; CF: $p = 0.024$), BSR ($p < 0.001$), and FMS (TGMD: $p < 0.001$; LOC: $p < 0.001$; BS: $p < 0.001$). Additionally, there was a significant reduction in LPA ($p = 0.005$). The control group showed increases in TGMD ($p = 0.003$) and LOC ($p < 0.001$) (TABLE I).

INSERT TABLE I

5. Discussion

Main Findings

The aim of this study was to assess the impact of an Educational Gymnastics intervention on SR, motor skills, and movement behaviors in preschoolers. The main findings demonstrated that:

- At T2, the experimental group had higher scores in CSR, with the exception of VSWM, and in both objective and subjective BSR, compared to the control group. Additionally, a significant reduction in LPA was observed in the experimental group.

-

- At T3, sustained improvements in BSR were observed for the experimental group, indicating that the effects of the intervention on objective BSR persisted 12 weeks post-intervention.
- Although both groups showed improvements in the TGMD and LOC at T2, improvements in BS were observed exclusively in the experimental group.

The improvements observed in CSR, specifically in IC and CF, are aligned with previous research demonstrating the positive effects of PA interventions on preschool children (BENTLEY et al., 2022; OLIVE et al., 2024). The dynamic motor activities incorporated in the gymnastics intervention likely contributed to the observed gains in IC by enhancing attention regulation and suppressing automatic responses (BEST, 2010; DIAMOND, 2013). The variety of movement tasks, such as jumping and balancing, likely facilitated improvements in CF by promoting the development of adaptive strategies (YAVAŞLAR et al., 2023; MORALES et al., 2024). However, the absence of long-term cognitive effects suggests that these initial gains may not be sustained without continued intervention (ZHANG et al., 2022; BAI et al., 2022). Furthermore, the lack of improvement in VSWM is consistent with evidence indicating that PA interventions may have limited efficacy in enhancing WM, particularly in younger children (DIAMOND & LEE, 2011; WOOD et al., 2020). These findings underscore the differential response of cognitive domains to movement-based interventions, a topic that warrants further exploration in future studies.

The intervention significantly impacted BSR at T2, with children in the experimental group advancing to the two-pair phase of the HTKS test, indicating improved management of multiple sets of instructions (MCCLELLAND et al., 2021; GONZALES et al., 2021). These results are consistent with other research showing significant improvements in BSR following PA interventions (KENNY et al., 2023; MILLER et al., 2023; VEIGA et al., 2023). For example, Miller et al. (2023) observed notable BSR improvements following a mastery-oriented intervention, particularly in children who scored zero on the pre-test. Our study, using a revised HTKS version to reduce floor effects, found that the scores in our experimental group increased by nearly 20 points, similar to the improvements documented by Veiga et al. (2023) following a body-oriented intervention. Additionally, significant higher scores in SR, as assessed by the BSR-CSBQ, were observed in the experimental group compared to control group at T2. Although no significant differences were observed within the groups, a reduction in scores was noted in the control group, while an increase was observed in the intervention group. This reflects a different pattern of behavior between the groups, despite the lack of statistical significance. These results reflect notable enhancements in family subjective assessments, particularly in the children’s ability to follow rules, remain still when necessary, and demonstrate reduced impulsivity, as also reported by Aadland et al. (2024). No changes were detected in other behavioral domains, reinforcing the specific impact of the intervention on BSR.

No significant differences in FMS were observed between groups at T2, though both the experimental and control groups demonstrated improvements in overall TGMD and LOC scores. These improvements likely reflect the structured physical activities regularly integrated into preschool routines, such as physical education and psychomotor programs (LI et al., 2021; DA SILVA et al., 2022). However, the experimental group showed a significant improvement in BS, despite only 30% of the intervention involving manipulative activities. This suggests that even modest exposure to targeted motor tasks can significantly enhance specific skills such as balance, which is critical for overall motor development. The literature supports the association between motor skills and SR, indicating that children with more advanced motor abilities, particularly in BS, tend to exhibit better SR (GANDOTRA et al., 2022; HAN et al., 2022; VAN DER VEER et al., 2024). Given this relationship, future studies should investigate whether focused motor skills interventions can yield long-term improvements in self-regulation, employing both cross-sectional and longitudinal approaches to explore the causal pathways and broader developmental impacts of motor skill enhancement.

A reduction in LPA and no changes in other movement behaviors were observed in the experimental group at T2. Although unexpected, this may be attributed to the intervention's focus on movement quality rather than intensity (DIAMOND & LING, 2019; PESCE, 2012). The integration of the program into children's routines, without displacing other physical activities, likely led to a compensatory decrease in overall physical activity (BECKE et al., 2022). Variability in movement patterns, particularly sleep, may have also contributed to the lack of statistical significance in the movement data (NEWTON & REID, 2023; LI et al., 2023). These findings suggest that a holistic approach is necessary to understand the intervention’s impact on movement behaviors, as the relationship with health outcomes may vary depending on whether behaviors are assessed individually or as part of a continuum (CARSON et al., 2024; BIANCONI et al., 2024; KUZIK et al., 2020). Future research should assess the overall composition of movement behaviors to better capture their collective impact on health (TREMBLAY et al., 2016; KUZIK et al., 2020). Environmental factors, such as an unusual period of increased rainfall during the post-intervention assessment, may have also influenced results by reducing outdoor activity and recess time. Future studies should integrate meteorological data and maintain detailed activity records to better understand physical activity patterns and behaviors.

One of the most important findings of this study was the sustained improvement in BSR at T3. These results align with those of Çiftçi et al. (2023), who reported long-term BSR improvements following an active learning intervention. The benefits observed in the current study suggest that the gymnastics intervention had a lasting impact, corresponding with the children’s final year of preschool. Given the strong link between BSR and school readiness (HOWARD & VASSELEU, 2020; MCCLELLAND et al., 2019; JYANKI et al., 2022), these results support the integration of gymnastics into the preschool curriculum as a means of enhancing school readiness. The observed fidelity to the intervention likely contributed to the sustained improvements, as teachers continued using activities outlined in the manual, although at a reduced intensity compared to the formal intervention. The incorporation of gymnastics activities into daily educational content may have reinforced the benefits and contributed to the sustained BSR gains.

Strengths and Limitations

The study’s strengths include the use of validated and context-appropriate measures for preschoolers. The cluster-randomized RCT design added methodological rigor, and the direct measurement of both cognitive and behavioral dimensions of SR provided a comprehensive assessment of the intervention's impact. However, several limitations should be noted. Randomization of preschools prior to baseline may have introduced selection bias, as evaluators and the school community were aware of the intervention assignments, potentially affecting initial adherence, especially in the control group. Additionally, the lack of blinding for evaluators and interventionists introduced potential bias, though the instruments used were designed to minimize this. Future studies should consider aligning school calendars with research schedules and financial resources to optimize randomization procedures. Another limitation is the high reliance on maternal reports (98%) for the CSBQ, which may not fully capture the child’s behavior across different contexts. Incorporating assessments from both parents and teachers could provide a more comprehensive view of children’s behavior. Finally, although the activities of the control group were monitored, detailed activity diaries were not maintained, which may have influenced the results. Future research should aim to document these factors in more detail to better understand their impact on study outcomes.

Practical Implications

This study provides evidence that gymnastics interventions focusing on SR can be effectively integrated into preschool settings, yielding significant benefits for both children and the overall preschool environment. Physical activities that enhance SR not only improve behavior but also promote motor skill development, with potential positive impacts on school readiness. The findings suggest that allowing teachers to administer these activities and integrating them with educational content may be a promising strategy for promoting active learning and developmental growth in early childhood education.

6. Conclusion

This study demonstrated the effectiveness of an Educational Gymnastics intervention to promote SR in preschool-aged children, with sustained effects on behavioral domain measured objectively. However, the intervention resulted in an unexpected reduction in LPA in the experimental group, with no significant changes observed in other movement behaviors. Although both groups showed improvements in motor skills over time, only the experimental group exhibited a significant enhancement in BS.

7. References

Álvarez-Bueno, C., Pesce, C., Cavero-Redondo, I., Sánchez-López, M., Martínez-Hortelano, J. A., & Martínez-Vizcaíno, V. (2017). The effect of physical activity interventions on children's cognition and metacognition: A systematic review and meta-analysis. Journal of the American Academy of Child & Adolescent Psychiatry, 56(9), 729-738. doi:10.1016/j.jaac.2017.06.012.

Bai, J., Huang, H., & Ouyang, H. (2022). Effects of group-play moderate to vigorous intensity physical activity intervention on executive function and motor skills in 4- to 5-year-old preschoolers: A pilot cluster randomized controlled trial. Frontiers in

Psychology, 13, 847785. doi:10.3389/fpsyg.2022.847785.

Barnett, L. M., Verswijveren, S. J. J. M., Colvin, B., Lubans, D. R., Telford, R. M., Lander, N. J., ... & Morgan, P. J. (2024). Motor skill competence and moderate- and vigorous-intensity physical activity: A linear and non-linear cross-sectional analysis of eight pooled trials. International Journal of Behavioral Nutrition and Physical Activity, 21(1), 14. doi:10.1186/s12966-023-01546-7.

Becke, F., Engel, F. A., & Reimers, A. K. (2022). Compensation or displacement of physical activity in children and adolescents: A systematic review of empirical studies. Children (Basel), 9(3), 351. doi:10.3390/children9030351.

Bezerra, T. A., Clark, C. C. T., de Souza Filho, A. N., Fortes, L. S., Mota, J. A. P. S., & Duncan, M. J. (2020). 24-hour movement behaviour and executive function in preschoolers: A compositional and isotemporal reallocation analysis. Journal of Sports Sciences, 38(18), 2145-2153. doi:10.1080/02640414.2020.1776925.

Blair, C., & Diamond, A. (2008). Biological processes in prevention and intervention: The promotion of self-regulation as a means of preventing school failure. Development and Psychopathology, 20(3), 899-911. doi:10.1017/S0954579408000436.

Blair, C., & Ku, S. (2022). A Hierarchical Integrated Model of Self-Regulation. Frontiers in Psychology, 13, 725828. doi:10.3389/fpsyg.2022.725828.

Blair, C., & Raver, C. C. (2015). School readiness and self-regulation: A developmental psychobiological approach. Annual Review of Psychology, 66, 711-731. doi:10.1146/annurev-psych-010814-015221.

Cameron, C. E., Brock, L. L., Murrah, W. M., Bell, L. H., Worzalla, S. L., Grissmer, D., & Morrison, F. J. (2012a). Developing together: The role of executive function and motor skills in children’s early academic lives. Developmental Psychology, 48(5), 1220-1230. doi:10.1037/a0026646.

Cameron, C. E., Brock, L. L., Murrah, W. M., Bell, L. H., Worzalla, S. L., Grissmer, D.,

& Morrison, F. J. (2012b). Fine motor skills and executive function both contribute to kindergarten achievement. Child Development, 83(4), 1229-1244. doi:10.1111/j.1467-8624.2012.01768.x.

Carson, V., Draper, C. E., Okely, A. D., & Reilly, J. J. (2024). Future directions for movement behavior research in the early years. Journal of Physical Activity and Health, 21(3), 218-221. doi:10.1123/jpah.2023-0679.

Carson, V., Ezeugwu, V. E., Tamana, S. K., Chikuma, J., Lefebvre, D. L., Azad, M. B., ... & Turvey, S. E. (2019). Associations between meeting the Canadian 24-Hour Movement Guidelines for the Early Years and behavioral and emotional problems among 3-year-olds. Journal of Science and Medicine in Sport, 22(7), 797-802. doi:10.1016/j.jsams.2018.12.004.

Carson, V., Hunter, S., Kuzik, N., Gray, C., Poitras, V. J., Chaput, J. P., ... & Tremblay, M. S. (2016a). Systematic review of physical activity and cognitive development in early childhood. Journal of Science and Medicine in Sport, 19(7), 573-578. doi:10.1016/j.jsams.2015.12.021.

Carson, V., Hunter, S., Kuzik, N., Gray, C. E., Poitras, V. J., Chaput, J. P., ... & Tremblay, M. S. (2016b). Systematic review of sedentary behavior and health indicators in school-aged children and youth: an update. Applied Physiology, Nutrition, and Metabolism, 41(6 Suppl 3). doi:10.1139/apnm-2015-0630.

Çiftçi, H. A., Uyanık, G., & Acar, İ. H. (2023). Supporting preschool children’s executive functions: Evidence from a group-based play intervention. Early Childhood Education Journal. doi:10.1007/s10643-023-01607-3.

Cliff, D. P., McNeill, J., Vella, S. A., Howard, S. J., Santos, R., Batterham, M., ... & Okely, A. D. (2017). Adherence to 24-Hour Movement Guidelines for the Early Years and associations with social-cognitive development among Australian preschool children. BMC Public Health, 17, 857. doi:10.1186/s12889-017-4858-7.

Cook, C. J., Howard, S., Scerif, G., Twine, R., Kahn, K., Norris, S., & Draper, C. (2023).

Executive function and pre-academic skills in preschoolers from South Africa. South African Journal of Childhood Education, 13(1), 1-11. doi:10.4102/sajce.v13i1.1256.

D'Cruz, M., Aw, S., Koh, W., Chua, M. L., Mahmud, A., Wong, C. H., ... & Lim, J. Y. (2023). Association between physical activity and self-regulation in early childhood: A systematic review. Early Childhood Research Quarterly, 64, 50-64. doi:10.1016/j.ecresq.2023.03.002.

Davis, E. E., Pitchford, N. J., & Limback, E. (2011). The interrelation between cognitive and motor development in typically developing children aged 4-11 years is underpinned by visual processing and fine manual control. British Journal of Psychology, 102(3), 569-584. doi:10.1111/j.2044-8295.2011.02024.x.

Diamond, A. (2000). Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. Child Development, 71(1), 44-56. doi:10.1111/1467-8624.00119.

Diamond, A. (2013). Executive functions. Annual Review of Psychology, 64, 135-168. doi:10.1146/annurev-psych-113011-143750.

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. Science, 333(6045), 959-964. doi:10.1126/science.1204529.

Diamond, A., & Ling, D. S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. Developmental Cognitive Neuroscience, 18, 34-48. doi:10.1016/j.dcn.2015.11.005.

Ellis, Y. G., Cliff, D. P., Howard, S. J., & Okely, A. D. (2018). Feasibility, acceptability, and potential efficacy of a childcare-based intervention to reduce sitting time among pre-schoolers: A pilot randomised controlled trial. Journal of Sports Sciences. doi:10.1080/02640414.2018.1486362.

Esliger, D. W., Copeland, J. L., Barnes, J. D., & Tremblay, M. S. (2005). Standardizing and optimizing the use of accelerometer data for free-living physical activity monitoring. Journal of Physical Activity & Health, 3, 366-383. doi:10.1123/jpah.3.s1.s366.

Feng, J., Zheng, C., Sit, C. H. P., Reilly, J. J., & Huang, W. Y. (2021). Associations between meeting 24-hour movement guidelines and health in the early years: A systematic review and meta-analysis. Journal of Sports Sciences, 39(22), 2545-2557. doi:10.1080/02640414.2021.1945183.

Fitton Davies, K., Clarke, S., Martins, R., Rudd, J. R., & Duncan, M. (2024). The effect of a home-based, gamified stability skills intervention on 4-5-year-old children's physical and cognitive outcomes: A pilot study. Psychology of Sport and Exercise, 73, 102636. doi:10.1016/j.psychsport.2024.102636.

Gandotra, A., Csaba, S., Sattar, Y., Cserényi, V., Bizonics, R., & Cserjesi, R. (2021). A meta-analysis of the relationship between motor skills and executive functions in typically-developing children. Developmental Neuropsychology, 46(2), 83-110. doi:10.1080/15248372.2021.197955.

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. Psychological Bulletin, 134(1), 31-60. doi:10.1037/0033-2909.134.1.31.

Giordano, G., Gómez-López, M., & Alesi, M. (2021). Sports, executive functions and academic performance: A comparison between martial arts, team sports, and sedentary children. International Journal of Environmental Research and Public Health, 18(22), 11745. doi:10.3390/ijerph182211745.

Gutiérrez-Capote, A., Jiménez-Martínez, J., Madinabeitia, I., de Orbe-Moreno, M., Pesce, C., & Cardenas, D. (2024). Sport as cognition enhancer from childhood to young adulthood: a systematic review focused on sport modality. International Journal of Sport and Exercise Psychology, 22(2), 395-427. doi:10.1080/1612197X.2023.2289552.

Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. Trends in Cognitive Sciences, 16(3), 174-180. doi:10.1016/j.tics.2012.01.006.

Howard, S. J., & Melhuish, E. (2017). An Early Years Toolbox for assessing early executive function, language, self-regulation, and social development: Validity, reliability, and preliminary norms. Journal of Psychoeducational Assessment, 35(3), 255-275. doi:10.1177/0734282916633009.

Howard, S. J., & Vasseleu, E. (2020). Self-regulation and executive function longitudinally predict advanced learning in preschool. Frontiers in Psychology, 11, 49. doi:10.3389/fpsyg.2020.00049.

Kenny, S. A., Cameron, C. E., Karing, J. T., Ahmadi, A., Braithwaite, P. N., & McClelland, M. M. (2023). A meta-analysis of the validity of the Head-Toes-Knees-Shoulders task in predicting young children's academic performance. Frontiers in Psychology, 14, 1124235. doi:10.3389/fpsyg.2023.1124235.

Kuzik, N., Arkko, K., Blye, C. J., Davie, J., Duddridge, R., ... & Carson, V. (2022). Associations between meeting the Canadian 24-hour movement guidelines and physical, cognitive, social-emotional, and overall development in early childhood. Journal of Activity, Sedentary & Sleep Behaviors, 1(1). doi:10.1186/s44167-022-00002-4.

Kuzik, N., Carson, V., Andersen, L. B., ... & Spence, J. C. (2017). Movement behaviours and physical, cognitive, and social-emotional development in preschool-aged children: Cross-sectional associations using compositional analyses. PLoS One, 12(8). doi:10.1371/journal.pone.0182454.

LeGear, M., Grey, C., Dunlap, K., Badovinac, S., & Dodd, B. (2012). A window of opportunity? Motor skills and perceptions of competence of children in kindergarten. Journal of Science and Medicine in Sport, 15(5), 350-355. doi:10.1016/j.jsams.2011.11.097.

Li, N., Wang, H., Song, Q., Su, W., Guo, X., Liang, Q., Ding, X., Liu, H., Liang, M., Zhang, J., Sun, L., Qin, Q., Chen, M., Qu, G., Sun, Y. (2023). Association between sleep change patterns and mental health among preschoolers: The mediating role of resilience.

Journal of Psychiatric Research, 165, 336-343. doi:10.1016/j.jpsychires.2023.06.010.

Loprinzi, P. D., & Nooe, A. (2016). Executive function influences sedentary behavior: A longitudinal study. Health Promotion Perspectives, 6(4), 180-184. doi:10.15171/hpp.2016.29.

Magistro, D., Piumatti, G., Carlevaro, F., Sherar, L. B., Esliger, D. W., & Bardaglio, G. (2020). Psychometric properties of the Test of Gross Motor Development-Third Edition in a large sample of Italian children. Journal of Science and Medicine in Sport, 23(9), 860-865. doi:10.1016/j.jsams.2020.02.014.

Mavilidi, M. F., Pesce, C., Mazzoli, E., Bennett, S., Paas, F., Okely, A. D., & Howard, S. J. (2023). Effects of cognitively engaging physical activity on preschool children's cognitive outcomes. Research Quarterly for Exercise and Sport, 94(3), 839-852. doi:10.1080/02701367.2022.2059435.

McClelland, M. M., & Cameron, C. E. (2019). Developing together: The role of executive function and motor skills in children's early academic lives. Current Directions in Psychological Science, 28(4), 388-393. doi:10.1177/0963721419849784.

McClelland, M. M., Cameron, C. E., Connor, C. M., Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. Developmental Psychology, 43(4), 947-959. doi:10.1037/0012-1649.43.4.947.

McClelland, M. M., Tominey, S. L., & Schmitt, S. A. (2019). Red Light, Purple Light! Results of an intervention to promote school readiness for children from low-income backgrounds. Frontiers in Psychology, 10, 2365. doi:10.3389/fpsyg.2019.02365.

McGowan, A. L., Gerde, H. K., Pfeiffer, K. A., & Pontifex, M. B. (2022). Meeting 24-hour movement behavior guidelines in young children: Improved quantity estimation and self-regulation. Early Childhood Research Quarterly, 59, 762-789. doi:10.1016/j.ecresq.2021.10.003.

Miller, A. L., Gearhardt, A. N., Fredericks, E. M., Katz, B., Shapiro, L. F., Holden, K., ... & Lumeng, J. C. (2018). Targeting self-regulation to promote health behaviors in children. Behaviour Research and Therapy, 101, 71-81. doi:10.1016/j.brat.2017.09.008.

Mota, J. G., Clark, C. C. T., Bezerra, T. A., Lemos, L., Reuter, C. P., Mota, J. A. P. S., ... & Duncan, M. J. (2020). Twenty-four-hour movement behaviours and fundamental movement skills in preschool children: A compositional and isotemporal substitution analysis. Journal of Sports Sciences, 38(18), 2071-2079. doi:10.1080/02640414.2020.1770415.

Muir, R. A., Howard, S. J., & Kervin, L. (2023). Interventions and approaches targeting early self-regulation or executive functioning in preschools: A systematic review. Educational Psychology Review, 35, 27. doi:10.1007/s10648-023-09756-7.

Newton, A. T., & Reid, G. J. (2023). Regular, intermittent, and spontaneous: Patterns of preschool children's nap behavior and their correlates. Sleep Medicine, 102, 105-116. doi:10.1016/j.sleep.2023.01.005.

Nilges-Charles, L. M. (2008). Assessing skill in educational gymnastics. Journal of Physical Education, Recreation & Dance, 79(3), 41-51. doi:10.1080/07303084.2008.10598153.

Olive, L. S., Telford, R. M., Westrupp, E., & Telford, R. D. (2023). Physical activity intervention improves executive function and language development during early childhood: The active early learning cluster randomized controlled trial. Child Development. doi:10.1111/cdev.13999.

Palmer, K. K., Chinn, K. M., & Robinson, L. E. (2013). The effect of the mastery climate motor program on object control skills in preschoolers. Journal of Motor Learning and Development, 1(1), 59-69. doi:10.1123/jmld.1.1.59.

Pesce, C., Croce, R., Ben-Soussan, T. D., Vazou, S., & McCullick, B. (2016). Variability of practice as an interface between motor and cognitive development. International Journal of Sport and Exercise Psychology, 17(1), 133-159.

doi:10.1080/1612197X.2016.1170822.

Rollo, S., Antsygina, O., & Tremblay, M. S. (2020). The whole day matters: Understanding 24-hour movement guideline adherence and relationships with health indicators across the lifespan. Journal of Sport and Health Science, 9(6), 493-510. doi:10.1016/j.jshs.2020.07.004.

Robson, D. A., Allen, M. S., & Howard, S. J. (2020). Self-regulation in childhood as a predictor of future outcomes: A meta-analytic review. Psychological Bulletin, 146(4), 324-354. doi:10.1037/bul0000227.

Schmidt, M., Benzing, V., & Kamer, M. (2016). Classroom-based physical activity breaks and children's attention: Cognitive engagement works! Frontiers in Psychology, 7, 1474. doi:10.3389/fpsyg.2016.01474.

Schmidt, M., Egger, F., Benzing, V., Jäger, K., Conzelmann, A., Roebers, C. M., & Pesce, C. (2017). Disentangling the relationship between children's motor ability, executive function and academic achievement. PLoS One, 12(8). doi:10.1371/journal.pone.0182845.

Spencer, J. P. (2020). The development of working memory. Current Directions in Psychological Science, 29(6), 545-553. doi:10.1177/0963721420959835.

Stodden, D. F., Goodway, J. D., Langendorfer, S. J., Roberton, M. A., Rudisill, M. E., Garcia, C., ... & Garcia, L. E. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. Quest, 60(2), 290-306. doi:10.1080/00336297.2008.10483582.

Tomporowski, P. D., McCullick, B., Pendleton, D. M., & Pesce, C. (2015). Exercise and children's cognition: The role of exercise characteristics and a place for metacognition. Journal of Sport and Health Science, 4(1), 47-55. doi:10.1016/j.jshs.2014.09.003.

Tomporowski, P. D., & Pesce, C. (2019). Exercise, sports, and performance arts benefit cognition via a common process. Psychological Bulletin, 145(9), 929-951.

doi:10.1037/bul0000200.

Tremblay, M. S., Carson, V., Chaput, J. P., & Zehr, L. (2016). Canadian 24-Hour Movement Guidelines for Children and Youth: An Integration of Physical Activity, Sedentary Behaviour, and Sleep. Applied Physiology, Nutrition, and Metabolism, 41(6 Suppl 3). doi:10.1139/apnm-2016-0151.

van der Fels, I. M., te Wierike, S. C., Hartman, E., Elferink-Gemser, M. T., Smith, J., & Visscher, C. (2015). The relationship between motor skills and cognitive skills in 4-16 year old typically developing children: a systematic review. Journal of Science and Medicine in Sport, 18(6), 697-703. doi:10.1016/j.jsams.2014.09.007.

van der Veer, G., Cantell, M. H., Minnaert, A. E. M. G., & Houwen, S. (2023). The relationship between motor performance and executive functioning in early childhood: A systematic review on motor demands embedded within executive function tasks. Developmental Neuropsychology, 48(1), 62-83. doi:10.1080/21622965.2022.2128675.

Vasilopoulos, F., Jeffrey, H., Wu, Y., & Dumontheil, I. (2023). Multi-level meta-analysis of physical activity interventions during childhood: Effects of physical activity on cognition and academic achievement. Educational Psychology Review, 35, 59. doi:10.1007/s10648-023-09758-5.

Webster, E. K., & Ulrich, D. (2017). Evaluation of the psychometric properties of the test of gross motor development—third edition. Journal of Motor Learning and Development, 5(1), 45-58. doi:10.1123/jmld.2016-0003.

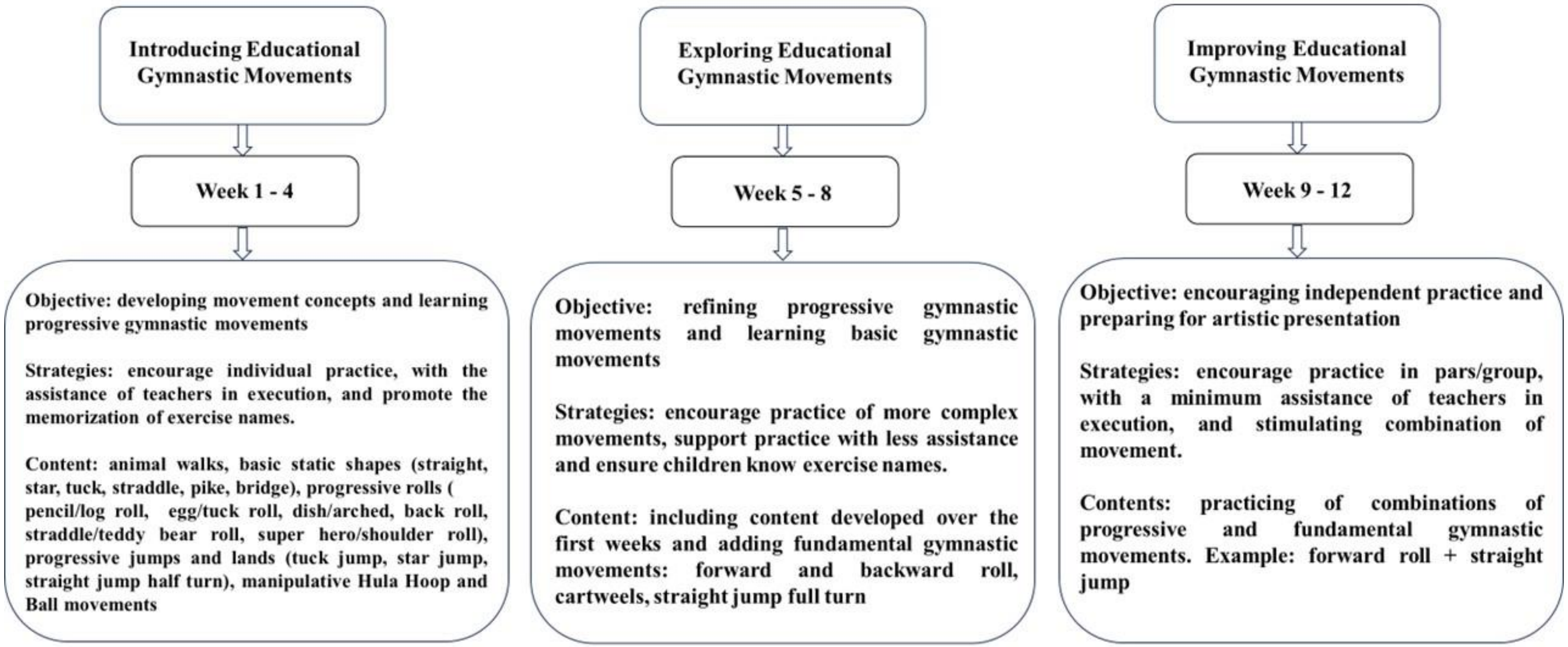
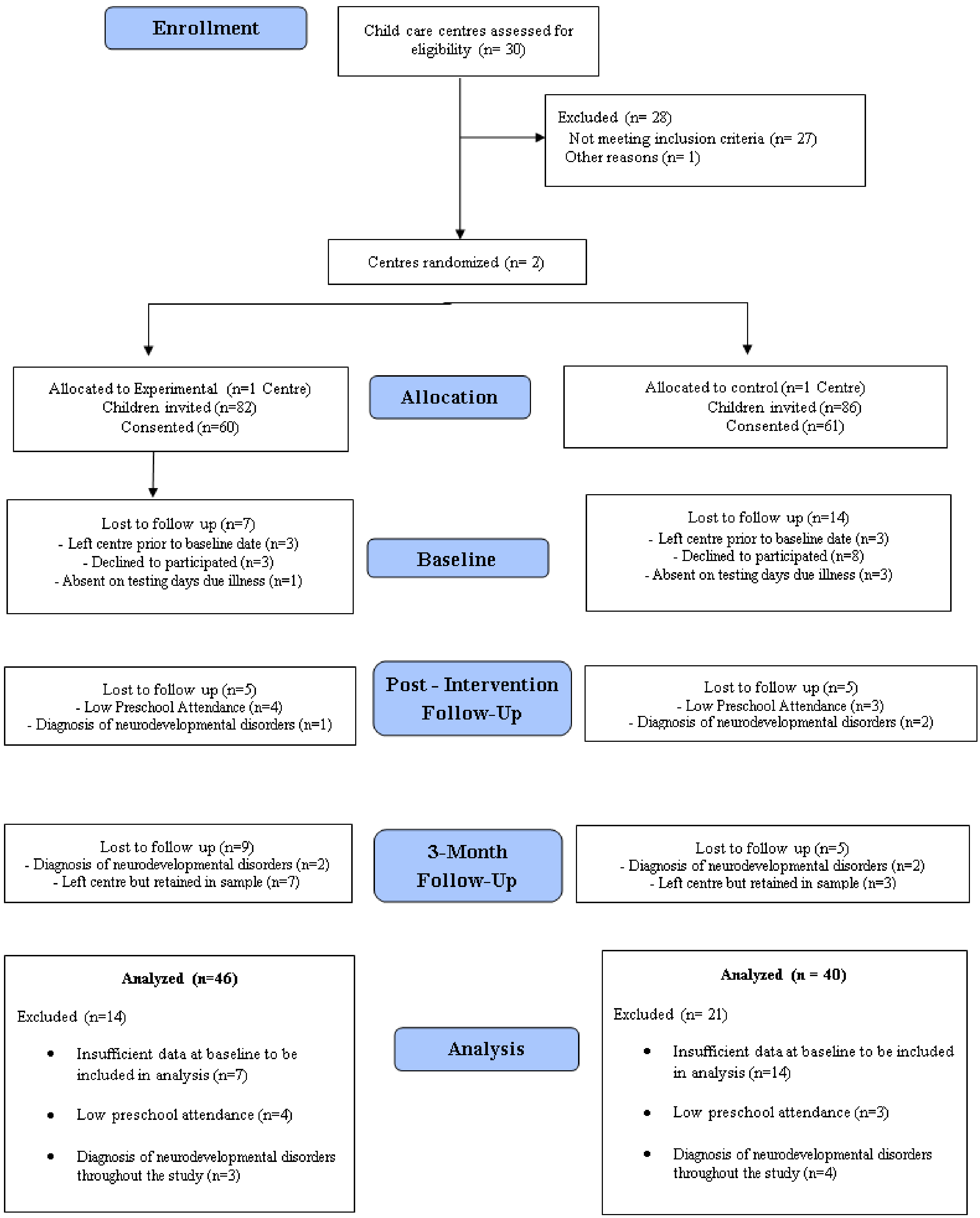


Figure 1: Intervention Progression

Flow diagram



Outcome	Variable	Groups	T1 (mean,SE) [a]	T2 (mean,SE) [a]	Estimate (β) [b] CI (95%) T1-T2	z	Estimate (β) [b] CI (95%) T2-T3	z
SR	**IC**	Exp Con	0.65 (0.17) 0.59 (0.21)	0.78 (0.11) *# 0.59 (0.20)	0.12 (0.06 – 0.19)	3.75	0.055 (-0,124 – 0,014)	-1,55
	VSWM	Exp Con	1.60 (0.44) 1.35 (0.72)	1.85 (0.42) 1.41 (0.70)	0.15 (-0.10 – 0.42)	1.15	0.266 (-0,545 – 1,078)	0,64
	FC	Exp Con	4.82 (4.35) 2.22 (3.46)	7.51 (3.32) *# 3.47 (4.20)	1.78 (0.18 – 3.39)	2.18	-0.699 (-2,47 – 1,076)	-0,77
	BSR	Exp Con	48.10 (27.3) 33.10 (27.2)	72.76 (27.7) *# 44.61 (33.9)	21.23 (13,98 – 28,48)	5,74	12.08 (1,985 – 22,18)	2.34
	BSR-CSBQ	Exp Con	3.81 (0.79) 3.38 (0.88)	3.89 (0.70) * 3.03 (0.80)	0,34 (0,045 – 0,641)	2,26	-0.26 (-0,58 – 0,05)	-1,60
	CSR-CSBQ	Exp Con	3.40 (0.95) 3.61 (0.73)	3.65 (0.75) 3.60 (0.86)	0,29 (-0,058 – 0,655)	1,64	-0,05 (-0,45 – 0,33)	-0,28
	ESR-CSBQ	Exp Con	3.67 (0.70) 3.39 (0.80)	3.67 (0.76) 3.28 (0.80)	-0.082 (-0,378 – 0,212)	-0,55	0.08 (-0,24 – 0,40)	0,49
FMS	**TGMD**	Exp Con	46.73 (9.06) 49.81 (11.8)	63.95 (7.25) # 58.13 (10.0) #	9.38 (5.40 – 13.35)	4,62	0,855 (-5,432 – 3,722)	-0,36
	LOC	Exp Con	24.02 (6.84) 26.73 (8.68)	35.89 (3.57) # 33.18 (5.95) #	6.14 (3,56 – 8,71)	4,68	-0.164 (-3,155 – 2,826)	-0,10
	BS	Exp Con	22.87 (4.86) 23.72 (5.70)	28.21 (6.38) # 25.81 (5.14)	2.91 (0.25 – 5.57)	2,15	0,292 (-2,519 – 3,104)	0,20
MB	**CS**	Exp Con	464.9 (79.1) 460.1 (91.9)	466.3 (94.7) 441.8 (75.1)	12.14 (-25.02 – 49.31)	0,64	50.40 (8,16 – 92,64)	2,33
	LPA	Exp Con	338.0 (61.1) 367.6 (63.4)	307.9 (81.8) *# 347.0 (51.4)	-30.03 (-62.39 – 2.32)	-1.81	41.55 (8,26 – 74,85)	2,44
	MPA	Exp Con	39.96 (18.7) 46.80 (20.8)	34.03 (16.3) 41.59 (17.5)	-0.608 (-7.79 – 6.57)	-0,16	3.43 (-4,18 – 11,05)	0,88
	VPA	Exp Con	9.72 (6.36) 9.99 (7.60)	8.76 (6.20) 8.31 (6.31)	-0,078 (-2.62 – 2.47)	-0,06	-1.20 (-3,87 – 1,45)	-0,88
	SL	Exp Con	543.6 (34.50) 560.9 (46.76)	559.7 (46.18) 567.4 (39.39)	8.59 (-12.06 – 29.25)	-0,81	12.83 (-9,82 – 35,48)	1,11

Note. SE = *standard error; CI = confidence interval; SR = Self-regulation; FMS = Fundamental Movement Skill; MB = Movement Behaviors; EXP = Experimental Group; CON = Control Group; IC = Inhibitory Control; VSWM = Visual-Spatial Working Memory; FC = Cognitive Flexibility; BSR = Behavior Self-Regulation; LOC = Locomotor; BS = Ball Skill; TGMD = Test of Gross Motor Development; CS = Sedentary Behavior; LPA = Light Physical Activity; MPA = Moderate Physical Activity; VPA = Vigorous Physical Activity; MVPA = Moderate to Vigorous Physical Activity, SL = Sleep time; BSR-CSBQ = Behavior Self-regulation subscale from the Child Self-Regulation and Behavior Questionnaire; CSR = Cognitive Self-Regulation subscale from the Child Self-Regulation and Behavior Questionnaire; ESR = Emotional Self-Regulation subscale from the Child Self-Regulation and Behavior Questionnaire*

[a] Mean and Standard errors before adjustment for covariates

[b] Adjusted for sex, age (month) and Body Mass Index

* Significant differences between experimental and control group (*P* < 0.05)

Significant differences within intervention and control groups (*P* < 0.05)

SUPPLEMENTARY I

Figure 2: Materials used in gymnastic intervention

Figure 3: Gymnastics Activities. 1: Balance; 2: Suspended; 3: Jump Full Turn; 4: Preparatory movement for the forward roll; 5: Cartwheel over the step

SUPPLEMENATRY II

Figure 4: Gymnastics activities incorporated into the center's routine. The image illustrates hula hoop games and the center coordinator performing forward rolls with the children during recess, as well as a literacy activity involving rhythmic gymnastics content.

6. CONSIDERAÇÕES FINAIS

A presente tese teve como objetivo investigar as possíveis relações transversais e longitudinais entre comportamentos de movimento – 24 horas e AR em pré-escolares.

O desenvolvimento deste trabalho começou com uma análise bibliométrica, motivada por leituras prévias de revisões sistemáticas que indicavam um aumento significativo de estudos experimentais voltados a compreender os possíveis efeitos das intervenções de atividade física (AF) na AR em pré-escolares. Esses estudos, no entanto, frequentemente utilizavam termos como "funções executivas" e "autorregulação" de forma intercambiável, sem esclarecer claramente os tópicos de interesse. Além disso, observou-se uma predominância de estudos oriundos de laboratórios internacionais, especialmente de países de alta renda. Assim, optou-se por, primeiramente, realizar uma análise bibliométrica para sintetizar e compreender a dinâmica do estado da arte nesse tópico, focando na formação de redes de colaboração e nos tópicos de interesse emergentes. Os resultados dessa análise revelaram uma carência de estudos focados em pré-escolares, com ênfase central na cognição voltada para funções executivas, predominantemente conduzidos em colaborações entre países de alta renda. Esses achados motivaram a realização dos estudos subsequentes que compuseram a presente tese.

Contudo, antes de prosseguir para a investigação das relações entre AR e AF de forma experimental, foi necessário compreender essas relações de maneira transversal. Notou-se que não apenas a AF, mas os comportamentos de movimento como um todo estavam sendo investigados em suas relações com a AR. Isso levou ao desenvolvimento do segundo e terceiro estudos da tese, que abordaram os comportamentos de movimento tanto em termos de aderência às recomendações quanto em sua composição. Os resultados mostraram que a aderência às recomendações estava positivamente associada à flexibilidade cognitiva, mas negativamente relacionada à AR comportamental. Em contraste, considerar os comportamentos de movimento como uma composição integrada demonstrou relações positivas com a AR comportamental. Além disso, observou-se que substituições teóricas de AF moderada a vigorosa por AF leve e comportamento sedentário poderiam trazer benefícios para a AR comportamental.

Esses achados impulsionaram o desenvolvimento do quarto estudo, de caráter experimental, que focou em uma intervenção de base coordenativa, a partir de uma modalidade de ginástica voltada ao ambiente educacional. Esta intervenção não buscou diretamente aumentar os níveis de AF, mas sim incorporar a AF na rotina das crianças de maneira que pudesse promover efeitos na AR, nas HMF e nos comportamentos de movimento. O estudo experimental mostrou efeitos positivos em algumas habilidades da AR cognitiva, com impacto significativo na AR comportamental. No entanto, houve uma redução na AF leve, sem mudanças nos outros comportamentos. Como já havia sido evidenciado nos resultados do terceiro estudo, considerar os comportamentos de movimento como uma composição integrada parece ser uma abordagem mais robusta. Sendo assim, avaliar os efeitos das intervenções na composição dos comportamentos pode ser mais eficaz do que analisar cada comportamento de forma isolada. Essa abordagem pode proporcionar uma compreensão mais abrangente e precisa dos impactos das intervenções nas relações da AR e dos comportamentos de movimento em pré-escolares.

A análise bibliométrica mapeou o estado da arte das intervenções de AF e seus efeitos na cognição infantil. Esse estudo destacou a necessidade de formação de redes de colaboração entre países de diferentes níveis de renda para fortalecer a produção científica global na área. A presente tese avança ao realizar um estudo em um país de renda média, envolvendo crianças de baixa e média renda, contribuindo para a diversificação e potencial integração dessa pesquisa na rede internacional de produção científica. Esta tese também avança no sentido de entender melhor as relações estabelecidas entre os domínios cognitivos e comportamentais da AR e os comportamentos de movimento. Foi evidenciado que diferentes relações são estabelecidas conforme a forma como o comportamento de movimento é analisado, bem como no domínio da AR considerado. Este avanço é crucial, pois a literatura atual carece de estudos que explorem essas interações de forma abrangente, contribuindo para a construção de modelos teóricos futuros que possam estabelecer essas relações na primeira infância. Por fim, a intervenção de ginástica educacional demonstrou-se eficaz na melhoria da AR, especialmente no domínio comportamental, com efeitos sustentados no follow-up. Observou-se também uma mudança no ambiente da creche experimental, onde as atividades da intervenção foram incorporadas nas atividades acadêmicas das crianças e durante o recreio. Isso demonstra que uma intervenção inserida nesses ambientes não afeta apenas os participantes diretos, mas também impacta todo o ambiente de maneira indireta. Este é um argumento forte para a realização de estudos futuros em maior escala, aplicados pelos próprios professores, a fim de maximizar o alcance e a sustentabilidade dos benefícios. Além disso, é essencial desenvolver pesquisas longitudinais que avaliem as crianças na transição da pré-escola para o ensino fundamental, para entender melhor como os benefícios adquiridos por uma intervenção na pré-escola podem predizer desempenhos futuros e gerar efeitos de longo prazo.

Apesar do acima exposto, recomenda-se que novas pesquisas incorporem técnicas que minimizem o viés do avaliador, bem como o viés associado às avaliações realizadas pelas famílias. Nesse sentido, a utilização de avaliações computadorizadas e a análise do sono por meio de algoritmos de acelerometria podem ser caminhos promissores para reduzir esses possíveis vieses.

Do ponto de vista social, a relevância desta tese centra-se na disseminação do conhecimento sobre AR, comportamentos de movimento e a importância da realização de AF de forma estruturada e orientada já na primeira infância, como os cruciais do desenvolvimento infantil,. Este conhecimento foi compartilhado com a comunidade escolar e com as famílias em todas as etapas do projeto, desde a apresentação dos objetivos do projeto, passando pelas avaliações realizadas com as crianças, até a comunicação dos resultados finais para as famílias. Portanto, estratégias de disseminação desse conhecimento nos espaços educacionais são fundamentais e devem ser priorizadas em ações futuras, ampliando o impacto positivo da pesquisa no ambiente escolar e na comunidade.

A relevância pessoal/profissional, como professora de ginástica no ensino superior, o conhecimento adquirido no desenvolvimento desta tese enriquece a atuação profissional da autora, permitindo que a demonstração aos discentes como a ginástica pode contribuir não apenas para o desenvolvimento motor, mas também para o aprimoramento da AR em crianças. Além disso, a experiência capacita a autora a pensar em projetos futuros que possam ser implementados em um número maior de locais e aplicados pelos próprios professores, ampliando o impacto positivo nas práticas educacionais e no desenvolvimento infantil.

7. REFERÊNCIAS

AADLAND, Katrine Nyvoll et al. Effects of a Staff Physical Activity Professional Development Intervention on Preschoolers' Mental Health and Self-regulation: The Active Learning Norwegian Preschool (er) s (ACTNOW) Cluster Randomised Controlled Trial. **Psychology of Sport and Exercise**, p. 102705, 2024.

ANDERSON, Neil; BUTTON, Chris; LAMB, Peter. The effect of educational gymnastics on postural control of young children. **Frontiers in psychology**, v. 13, p. 936680, 2022.

ARNSTEN, Amy FT. Toward a new understanding of attention-deficit hyperactivity disorder pathophysiology: an important role for prefrontal cortex dysfunction. **CNS drugs**, v. 23, n. Suppl 1, p. 33-41, 2009.

ARNSTEN, Amy FT et al. The effects of stress exposure on prefrontal cortex: Translating basic research into successful treatments for post-traumatic stress disorder. **Neurobiology of stress**, v. 1, p. 89-99, 2015.

BARNETT, Lisa M. et al. Fundamental movement skills: An important focus. **Journal of teaching in physical education**, v. 35, n. 3, p. 219-225, 2016.

BAUMGARTEN, Sam; PAGNANO-RICHARDSON, Karen. Educational gymnastics: Enhancing children's physical literacy. **Journal of Physical Education, Recreation & Dance**, v. 81, n. 4, p. 18-25, 2010.

BECK, Franziska; ENGEL, Florian A.; REIMERS, Anne Kerstin. Compensation or displacement of physical activity in children and adolescents: a systematic review of empirical studies. **Children**, v. 9, n. 3, p. 351, 2022.

BECKER, Derek R. et al. Physical activity, self-regulation, and early academic achievement in preschool children. **Early Education & Development**, v. 25, n. 1, p. 56-70, 2014.

BERBOTH, Stella; MORAWETZ, Carmen. Amygdala-prefrontal connectivity during emotion regulation: A meta-analysis of psychophysiological interactions. **Neuropsychologia**, v. 153, p. 107767, 2021.

BEZERRA, Thaynã Alves et al. 24-hour movement behaviour and executive function in preschoolers: a compositional and isotemporal reallocation analysis. **European journal of sport science**, v. 21, n. 7, p. 1064-1072, 2021.

BIANCONI, Alessandro et al. How strong is the evidence supporting the WHO guidelines on physical activity, sedentary behaviour and sleep in early childhood? **European Journal of Clinical Investigation**, p. e14294, 2024.

BINGHAM, Daniel D. et al. Accelerometer data requirements for reliable estimation of habitual physical activity and sedentary time of children during the early years-a worked example following a stepped approach. J**ournal of Sports Sciences**, v. 34, n. 20, p. 2005-2010, 2016.

BLAIR, Clancy; RAZZA, Rachel Peters. Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. **Child**

development, v. 78, n. 2, p. 647-663, 2007.

BLAIR, Clancy; URSACHE, Alexandra. A bidirectional model of executive functions and self-regulation. **Handbook of self-regulation: Research, theory, and applications**, v. 2, p. 300-320, 2011.

BLAIR, Clancy; CALKINS, Susan; KOPP, Lisa. Self-regulation as the interface of emotional and cognitive development: Implications for education and academic achievement. **Handbook of personality and self-regulation**, p. 64-90, 2010.

BLAIR, Clancy; RAVER, C. Cybele. Individual development and evolution: experiential canalization of self-regulation. **Developmental psychology**, v. 48, n. 3, p. 647, 2012a.

BLAIR, Clancy; RAVER, C. Cybele. School readiness and self-regulation: A developmental psychobiological approach. **Annual review of psychology**, v. 66, n. 1, p. 711-731, 2015.

BLAIR, Clancy; KU, Seulki. A hierarchical integrated model of self-regulation. **Frontiers in Psychology**, v. 13, p. 725828, 2022.

BOURKE, Matthew et al. Association between childcare movement behaviour compositions with health and development among preschoolers: Finding the optimal combinations of physical activities and sedentary time. **Journal of Sports Sciences**, v. 40, n. 18, p. 2085-2094, 2022.

BRONFENBRENNER, Urie et al. Ecological models of human development. **International encyclopedia of education**, v. 3, n. 2, p. 37-43, 1994.

BULL, Rebecca; SCERIF, Gaia. Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. **Developmental neuropsychology**, v. 19, n. 3, p. 273-293, 2001.

BURKE, Kenda N.; ZATTO, Brenna RL; HOGLUND, Wendy LG. Developmental patterns of behavioural self-regulation and peer relations in early childhood. **Early Childhood Research Quarterly**, v. 65, p. 179-194, 2023.

BUSTAMANTE, Juan Carlos; FERNÁNDEZ-CASTILLA, Belén; ALCARAZ-IBORRA, Manuel. Relation between executive functions and screen time exposure in under 6-year-olds: A meta-analysis. **Computers in Human Behavior**, v. 145, p. 107739, 2023.

CAINE, Dennis J.; RUSSELL, Keith; LIM, Liesbeth (Ed.). **Handbook of sports medicine and science: gymnastics**. John Wiley & Sons, 2013.

CARSON, Valerie et al. Systematic review of physical activity and cognitive development in early childhood. **Journal of science and medicine in sport**, v. 19, n. 7, p. 573-578, 2016.

CARSON, Valerie; RAHMAN, Aishah Abdul; WIEBE, Sandra A. Associations of subjectively and objectively measured sedentary behavior and physical activity with cognitive development in the early years. **Mental Health and Physical Activity**, v. 13, p. 1-8, 2017.

CARSON, Valerie et al. Associations between meeting the Canadian 24-hour movement guidelines for the early years and behavioral and emotional problems among 3-year-olds. **Journal of Science and Medicine in Sport**, v. 22, n. 7, p. 797-802, 2019a.

CARSON, Valerie et al. Physical activity and sedentary behavior across three time-points and associations with social skills in early childhood. **BMC public health**, v. 19, p. 1-8, 2019b.

CARSON, Valerie et al. Future Directions for Movement Behavior Research in the Early Years. **Journal of Physical Activity and Health**, v. 21, n. 3, p. 218-221, 2023.

CHAPUT, Jean-Philippe et al. Systematic review of the relationships between sleep duration and health indicators in the early years (0–4 years). **BMC public health**, v. 17, p. 91-107, 2017.

CHASTIN, Sebastien FM et al. Combined effects of time spent in physical activity, sedentary behaviors and sleep on obesity and cardio-metabolic health markers: a novel compositional data analysis approach. **PloS one**, v. 10, n. 10, p. e0139984, 2015.

CHEN, Bozhi et al. Socio-demographic and maternal predictors of adherence to 24-hour movement guidelines in Singaporean children. **International Journal of Behavioral Nutrition and Physical Activity**, v. 16, p. 1-11, 2019.

CLIFF, Dylan P. et al. Adherence to 24-hour movement guidelines for the early years and associations with social-cognitive development among Australian preschool children. **BMC public health**, v. 17, p. 207-215, 2017.

D'CRUZ, Abhigale FL et al. Are physical activity and sleep associated with emotional self-regulation in toddlers? a cross-sectional study. **BMC Public Health**, v. 24, n. 1, p. 61, 2024.

D'CRUZ, Abhigale FL et al. Association between physical activity and self-regulation in early childhood: A systematic review. **Obesity Reviews**, v. 25, n. 2, p. e13657, 2024.

DE LUCENA MARTINS, Clarice Maria et al. Adherence to 24-hour movement guidelines in low-income Brazilian preschoolers and associations with demographic correlates. **American Journal of Human Biology**, v. 33, n. 4, p. e23519, 2021.

DE SOUZA, Alesandra Araújo et al. Paths towards a healthier BMI among short and adequate sleepers: A pathway network analysis considering movement behaviors in low-income preschoolers. **American Journal of Human Biology**, v. 35, n. 9, p. e23915, 2023.

DIAMOND, Adele. Biological and social influences on cognitive control processes dependent on prefrontal cortex. **Progress in brain research**, v. 189, p. 319-339, 2011.

DIAMOND, Adele. Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. **Child development**, v. 71, n. 1, p. 44-56, 2000.

DIAMOND, Adele. Executive functions. **Annual review of psychology**, v. 64, n. 1, p. 135-168, 2013.

DIAMOND, Adele; LEE, Kathleen. Interventions shown to aid executive function development in children 4 to 12 years old. **Science**, v. 333, n. 6045, p. 959-964, 2011.

DIAMOND, Adele; LING, Daphne S. Aerobic-Exercise and resistance-training interventions have been among the least effective ways to improve executive functions of any method tried thus far. **Developmental cognitive neuroscience**, v. 37, 2019.

DIAMOND, Adele; LING, Daphne S. Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. **Developmental cognitive neuroscience**, v. 18, p. 34-48, 2016.

DONHAM-FOUTCH, Shae. Teaching skills and health-related fitness through a preservice gymnastics program. **Journal of Physical Education, Recreation & Dance**, v. 78, n. 5, p. 35-44, 2007.

DUCKWORTH, Angela L.; SELIGMAN, Martin EP. Self-discipline outdoes IQ in predicting academic performance of adolescents. **Psychological science**, v. 16, n. 12, p. 939-944, 2005.

DUCKWORTH, Angela Lee; CARLSON, Stephanie M. Self-regulation and school success. **Self-regulation and autonomy: Social and developmental dimensions of human conduct**, v. 40, n. 1, p. 208-230, 2013.

DUMUID, Dorothea et al. Compositional data analysis for physical activity, sedentary time and sleep research. **Statistical methods in medical research**, v. 27, n. 12, p. 3726-3738, 2018.

DUMUID, Dorothea et al. Compositional data analysis in time-use epidemiology: what, why, how. **International journal of environmental research and public health**, v. 17, n. 7, p. 2220, 2020.

EISENBERG, Nancy; VALIENTE, Carlos; EGGUM, Natalie D. Self-regulation and school readiness. **Early education and development**, v. 21, n. 5, p. 681-698, 2010.

EISENBERG, Nancy; SULIK, Michael J. Emotion-related self-regulation in children. **Teaching of Psychology**, v. 39, n. 1, p. 77-83, 2012.

ESSEX, Marilyn J. et al. Influence of early life stress on later hypothalamic–pituitary–adrenal axis functioning and its covariation with mental health symptoms: A study of the allostatic process from childhood into adolescence. **Development and psychopathology**, v. 23, n. 4, p. 1039-1058, 2011.

FENG, Jie et al. Associations between meeting 24-hour movement guidelines and health in the early years: a systematic review and meta-analysis. **Journal of sports sciences**, v. 39, n. 22, p. 2545-2557, 2021.

FENG, Jie et al. Movement behaviors and mental health of caregivers of preschoolers in China during the COVID-19 pandemic. **Preventive medicine**, v. 155, p. 106913, 2022.

FRIEDMAN, Naomi P.; ROBBINS, Trevor W. The role of prefrontal cortex in cognitive control and executive function. **Neuropsychopharmacology**, v. 47, n. 1, p. 72-89, 2022.

FUNAHASHI, Shintaro; ANDREAU, Jorge Mario. Prefrontal cortex and neural mechanisms of executive function. **Journal of Physiology-Paris**, v. 107, n. 6, p. 471-482, 2013.

GAFFREY, Michael S. et al. Amygdala functional connectivity is associated with emotion regulation and amygdala reactivity in 4-to 6-year-olds. **Journal of the American Academy of Child & Adolescent Psychiatry**, v. 60, n. 1, p. 176-185, 2021.

GARON, Nancy. A review of hot executive functions in preschoolers. **Journal of Self-Regulation and Regulation**, v. 2, p. 57-80, 2016.

GARON, Nancy; BRYSON, Susan E.; SMITH, Isabel M. Executive function in preschoolers: a review using an integrative framework. **Psychological bulletin**, v. 134, n. 1, p. 31, 2008.

GRAYBIEL, Ann M. Habits, rituals, and the evaluative brain. **Annu. Rev. Neurosci.**, v. 31, n. 1, p. 359-387, 2008.

GRUBER, Reut et al. Impact of sleep extension and restriction on children's emotional lability and impulsivity. **Pediatrics**, v. 130, n. 5, p. e1155-e1161, 2012.

GUTIÉRREZ-CAPOTE, Alejandro et al. Sport as cognition enhancer from childhood to young adulthood: a systematic review focused on sport modality. **International Journal of Sport and Exercise Psychology**, v. 22, n. 2, p. 395-427, 2024.

HILLMAN, C. H.; BIGGAN, J. R. A Review of Childhood Physical Activity, Brain, and Cognition: Perspectives on the Future. Pediatric Exercise Science, v. 29, n. 2, p. 170–176, 2017.

HOFMANN, Wilhelm; SCHMEICHEL, Brandon J.; BADDELEY, Alan D. Executive functions and self-regulation. **Trends in cognitive sciences**, v. 16, n. 3, p. 174-180, 2012.

HULTEEN, Ryan M.; TRUE, Larissa; PFEIFFER, Karin A. Differences in associations of product-and process-oriented motor competence assessments with physical activity in children. **Journal of sports sciences**, v. 38, n. 4, p. 375-382, 2020.

KAHN, Michal et al. Effects of one night of induced night-wakings versus sleep restriction on sustained attention and mood: a pilot study. **Sleep medicine**, v. 15, n. 7, p. 825-832, 2014.

KANAYAMA, Atsushi et al. PROTOCOL: Key characteristics of effective preschool-based interventions to promote self-regulation: A systematic review and meta-analysis. **Campbell Systematic Reviews**, v. 20, n. 2, p. e1383, 2024.

KIM, M. Justin; WHALEN, Paul J. The structural integrity of an amygdala–prefrontal pathway predicts trait anxiety. **Journal of Neuroscience**, v. 29, n. 37, p. 11614-11618, 2009.

KORUCU, Irem et al. Self-regulation in preschool: Examining its factor structure and associations with pre-academic skills and social-emotional competence. **Frontiers in psychology**, v. 12, p. 717317, 2022.

KUZIK, Nicholas et al. Systematic review of the relationships between combinations of movement behaviours and health indicators in the early years (0-4 years). **BMC public health**, v. 17, p. 109-122, 2017.

KUZIK, Nicholas et al. Movement behaviours and physical, cognitive, and social-emotional development in preschool-aged children: Cross-sectional associations using compositional analyses. **PLoS One**, v. 15, n. 8, p. e0237945, 2020.

KUZIK, Nicholas et al. Associations between meeting the Canadian 24-hour movement guidelines and physical, cognitive, social-emotional, and overall development in early childhood. **Journal of Activity, Sedentary and Sleep Behaviors**, v. 1, n. 1, p. 2, 2022.

LAU, Patrick WC et al. 24-hour movement behaviors and executive functions in preschoolers: a compositional and isotemporal reallocation analysis. **Child Development**, v. 95, n. 2, p. e110-e121, 2024.

LEDOUX, Joseph. The amygdala and emotion: a view through fear. **The amygdala**, p. 289-310, 2000.

LEMOS, Luís et al. 24-hour movement behaviors and fitness in preschoolers: A compositional and isotemporal reallocation analysis. **Scandinavian Journal of Medicine & Science in Sports**, v. 31, n. 6, p. 1371-1379, 2021.

LEMOS, Natália Batista Albuquerque Goulart et al. Evidence of the validity of the child self-regulation & behaviour questionnaire for the Brazilian context. **Infant and Child Development**, p. e2526, 2024.

LI, Lin; PENG, Wei. Does health information technology promote healthy behaviors? The mediating role of self-regulation. **Health Communication**, v. 35, n. 14, p. 1772-1781, 2020.

LU, Zhaoxu et al. Reallocation of time between preschoolers' 24-h movement behaviours and executive functions: A compositional data analysis. **Journal of Sports Sciences**, v. 41, n. 12, p. 1187-1195, 2023.

MARTINEZ-MERINO, Nagore; RICO-GONZÁLEZ, Markel. Effects of Physical Education on Preschool Children's Physical Activity Levels and Motor, Cognitive, and Social Competences: A Systematic Review. **Journal of Teaching in Physical Education**, v. 1, n. aop, p. 1-11, 2024.

MAVILIDI, Myrto F. et al. Effects of cognitively engaging physical activity on preschool children's cognitive outcomes. **Research quarterly for exercise and sport**, v. 94, n. 3, p. 839-852, 2023.

MCCLELLAND, Megan M. et al. Executive function, behavioral self-regulation, and social-emotional competence. **Contemporary perspectives on social learning in early childhood education**, v. 1, p. 113-137, 2007.

MCCLELLAND, Megan M.; ACOCK, Alan C.; MORRISON, Frederick J. The impact of kindergarten learning-related skills on academic trajectories at the end of elementary school. **Early childhood research quarterly**, v. 21, n. 4, p. 471-490, 2006.

MCCLELLAND, Megan M.; CAMERON, Claire E. Developing together: The role of executive function and motor skills in children's early academic lives. **Early childhood research quarterly**, v. 46, p. 142-151, 2019.

MCCLELLAND, Megan M.; CAMERON, Claire E. Self-regulation in early childhood:

Improving conceptual clarity and developing ecologically valid measures. **Child development perspectives**, v. 6, n. 2, p. 136-142, 2012.

MCCLELLAND, Megan M.; WANLESS, Shannon B. Growing up with assets and risks: The importance of self-regulation for academic achievement. **Research in Human Development**, v. 9, n. 4, p. 278-297, 2012.

MCCLELLAND, Megan M. et al. The Head-Toes-Knees-Shoulders revised: Links to academic outcomes and measures of EF in young children. **Frontiers in Psychology**, v. 12, p. 721846, 2021.

MCGOWAN, Amanda L. et al. Meeting 24-hour movement behavior guidelines in young children: Improved quantity estimation and self-regulation. **Early Education and Development**, v. 34, n. 3, p. 762-789, 2023.

MCNEILL, Jade et al. Compliance with the 24-Hour movement guidelines for the early years: Cross-sectional and longitudinal associations with executive function and psychosocial health in preschool children. **Journal of Science and Medicine in Sport**, v. 23, n. 9, p. 846-853, 2020.

MILLER, Earl K.; COHEN, Jonathan D. An integrative theory of prefrontal cortex function. **Annual review of neuroscience**, v. 24, n. 1, p. 167-202, 2001.

MOFFITT, Terrie E. et al. A gradient of childhood self-control predicts health, wealth, and public safety. **Proceedings of the national Academy of Sciences**, v. 108, n. 7, p. 2693-2698, 2011.

MOFFITT, Terrie E.; POULTON, Richie; CASPI, Avshalom. Lifelong impact of early self-control. **American Scientist**, v. 101, n. 5, p. 352-359, 2013.

MORRISON, Frederick J.; PONITZ, Claire Cameron; MCCLELLAND, Megan M. Self-regulation and academic achievement in the transition to school. 2010.

MOTA, Jessica Gomes et al. Twenty-four-hour movement behaviours and fundamental movement skills in preschool children: A compositional and isotemporal substitution analysis. **Journal of sports sciences**, v. 38, n. 18, p. 2071-2079, 2020.

MUIR, Rosalyn A.; HOWARD, Steven J.; KERVIN, Lisa. Interventions and approaches targeting early self-regulation or executive functioning in preschools: a systematic review. **Educational Psychology Review**, v. 35, n. 1, p. 27, 2023.

NILGES, Lynda M. Educational gymnastics—stages of content development. **Journal of Physical Education, Recreation & Dance**, v. 68, n. 3, p. 50-55, 1997.

NILGES-CHARLES, Lynda M. Assessing skill in educational gymnastics. **Journal of Physical Education, Recreation & Dance**, v. 79, n. 3, p. 41-51, 2008.

O'CALLAGHAN, Laura et al. Associations of physical activity dose and movement quality with executive functions in socioeconomically disadvantaged children aged 5–6 years. **Psychology of sport and exercise**, v. 70, p. 102546, 2024.

OLIVE, Lisa S. et al. Physical activity intervention improves executive function and language development during early childhood: The active early learning cluster randomized controlled trial. **Child Development**, v. 95, n. 2, p. 544-558, 2024.

PAGANI, Linda S. et al. Prospective associations between early childhood television exposure and academic, psychosocial, and physical well-being by middle childhood. **Archives of pediatrics & adolescent medicine**, v. 164, n. 5, p. 425-431, 2010.

PEDIŠIĆ, Željko; DUMUID, Dorothea; S OLDS, Timothy. Integrating sleep, sedentary behaviour, and physical activity research in the emerging field of time-use epidemiology: definitions, concepts, statistical methods, theoretical framework, and future directions. **Kinesiology**, v. 49, n. 2., p. 252-269, 2017.

PERRY, Nancy E. Recognizing early childhood as a critical time for developing and supporting self-regulation. **Metacognition and learning**, v. 14, n. 3, p. 327-334, 2019.

PESCE, Caterina et al. Variability of practice as an interface between motor and cognitive development. **International Journal of Sport and Exercise Psychology**, v. 17, n. 2, p. 133-152, 2019.

PESCE, Caterina. Shifting the focus from quantitative to qualitative exercise characteristics in exercise and cognition research. **Journal of Sport and Exercise Psychology**, v. 34, n. 6, p. 766-786, 2012.

PESCE, Caterina et al. Fostering self-control development with a designed intervention in physical education: A two-year class-randomized trial. **Child Development**, v. 92, n. 3, p. 937-958, 2021.

POITRAS, Veronica J. et al. Systematic review of the relationships between sedentary behaviour and health indicators in the early years (0–4 years). **BMC public health**, v. 17, p. 65-89, 2017.

RAVER, C. Cybele et al. Poverty, household chaos, and interparental aggression predict children's ability to recognize and modulate negative emotions. **Development and psychopathology**, v. 27, n. 3, p. 695-708, 2015.

REZAEIZADEH, Golnaz et al. Maternal education and its influence on child growth and nutritional status during the first two years of life: a systematic review and meta-analysis. **Eclinicalmedicine**, v. 71, 2024.

ROLLO, Scott; ANTSYGINA, Olga; TREMBLAY, Mark S. The whole day matters: understanding 24-hour movement guideline adherence and relationships with health indicators across the lifespan. **Journal of sport and health science**, v. 9, n. 6, p. 493-510, 2020.

RUDD, James R. et al. Effectiveness of a 16 week gymnastics curriculum at developing movement competence in children. **Journal of science and medicine in sport**, v. 20, n. 2, p. 164-169, 2017a.

RUDD, J. R. et al. The impact of gymnastics on children’s physical self-concept and movement skill development in primary schools. **Measurement in physical education and exercise**

science, v. 21, n. 2, p. 92-100, 2017b.

RUDD, James R. et al. Skill acquisition methods fostering physical literacy in early-physical education (SAMPLE-PE): Rationale and study protocol for a cluster randomized controlled trial in 5–6-year-old children from deprived areas of North West England. **Frontiers in Psychology**, v. 11, p. 1228, 2020.

RUSSELL, Keith. The evolution of gymnastics. **Gymnastics**, p. 1-14, 2013.

RUSU, Silviu I.; PENNARTZ, Cyriel MA. Learning, memory and consolidation mechanisms for behavioral control in hierarchically organized cortico-basal ganglia systems. **Hippocampus**, v. 30, n. 1, p. 73-98, 2020.

SONG, Wenjing et al. Play smart, be smart? Effect of cognitively engaging physical activity interventions on executive function among children 4~ 12 years old: a systematic review and meta-analysis. **Brain sciences**, v. 12, n. 6, p. 762, 2022.

SPENCER, Nicholas James et al. Household income and maternal education in early childhood and activity-limiting chronic health conditions in late childhood: findings from birth cohort studies from six countries. **J Epidemiol Community Health**, v. 76, n. 11, p. 939-948, 2022.

STODDEN, David F. et al. A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. **Quest,** v. 60, n. 2, p. 290-306, 2008.

TAYLOR, Rachael W. et al. 24-h movement behaviors from infancy to preschool: cross-sectional and longitudinal relationships with body composition and bone health. **International Journal of Behavioral Nutrition and Physical Activity**, v. 15, p. 1-14, 2018.

TAYLOR, Rachael W. et al. Adherence to 24-h movement behavior guidelines and psychosocial functioning in young children: a longitudinal analysis. **International Journal of Behavioral Nutrition and Physical Activity**, v. 18, p. 1-13, 2021.

THAM, Elaine KH et al. Variations in longitudinal sleep duration trajectories from infancy to early childhood. **Sleep Health**, v. 7, n. 1, p. 56-64, 2021.

THAM, Elaine KH; SCHNEIDER, Nora; BROEKMAN, Birit FP. Infant sleep and its relation with cognition and growth: a narrative review. **Nature and science of sleep**, p. 135-149, 2017.

THOMPSON, Ross A.; NELSON, Charles A. Developmental science and the media: Early brain development. **American Psychologist**, v. 56, n. 1, p. 5, 2001.

THOMPSON, Simon. **The political theory of recognition: A critical introduction**. Polity, 2006.

TOMPOROWSKI, Phillip D.; PESCE, Caterina. Exercise, sports, and performance arts benefit cognition via a common process. **Psychological bulletin**, v. 145, n. 9, p. 929, 2019.

TOMPOROWSKI, Phillip D.; LAMBOURNE, Kate; OKUMURA, Michelle S. Physical activity interventions and children's mental function: an introduction and overview. **Preventive medicine**, v. 52, p. S3-S9, 2011.

TREMBLAY, Mark S. et al. Canadian 24-hour movement guidelines for children and youth: an integration of physical activity, sedentary behaviour, and sleep. **Applied physiology, nutrition, and metabolism**, v. 41, n. 6, p. S311-S327, 2016.

TREMBLAY, Mark S. et al. Towards precision 24-hour movement behavior recommendations—The next new paradigm? **Journal of Sport and Health Science**, v. 13, n. 6, p. 743-748, 2024.

URSACHE, Alexandra; BLAIR, Clancy; RAVER, C. Cybele. The promotion of self-regulation as a means of enhancing school readiness and early achievement in children at risk for school failure. **Child development perspectives**, v. 6, n. 2, p. 122-128, 2012.

VAN DER FELS, Irene MJ et al. The relationship between motor skills and cognitive skills in 4–16 year old typically developing children: A systematic review. **Journal of science and medicine in sport**, v. 18, n. 6, p. 697-703, 2015.

VASILOPOULOS, Fotini et al. Multi-level meta-analysis of physical activity interventions during childhood: Effects of physical activity on cognition and academic achievement. **Educational Psychology Review**, v. 35, n. 2, p. 59, 2023.

WALSH, E. I.; SMITH, L.; NORTHEY, J.; RATTRAY, B.; CHERBUIN, N. Towards an understanding of the physical activity-BDNF-cognition triumvirate: A review of associations and dosage. Ageing Research Reviews, v. 60, n.1, p. 101044, 2020. Elsevier.

WANG, Yu et al. A cortico-basal ganglia-thalamo-cortical channel underlying short-term memory. **Neuron**, v. 109, n. 21, p. 3486-3499. e7, 2021.

WEI, Yonggang et al. Enhancing young children's executive function through physical activities: A three-level meta-analysis. **Mental Health and Physical Activity**, v. 26, p. 100592, 2024.

WHITE, Pär Andersson et al. Household income and maternal education in early childhood and risk of overweight and obesity in late childhood: Findings from seven birth cohort studies in six high-income countries. **International Journal of Obesity**, v. 46, n. 9, p. 1703-1711, 2022.

WILLOUGHBY, Michael et al. Improvements in motor competence skills are associated with improvements in executive function and math problem-solving skills in early childhood. **Developmental Psychology**, v. 57, n. 9, p. 1463, 2021.

WOOD, Aaron P. et al. Physical activity and cognitive aspects of self-regulation in preschool-aged children: A systematic review. **International Journal of Environmental Research and Public Health**, v. 17, n. 18, p. 6576, 2020.

WORLD HEALTH ORGANIZATION et al. Guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age. World Health Organization, 2019.

ZELAZO, Philip David. Executive function: Reflection, iterative reprocessing, complexity, and the developing brain. **Developmental Review**, v. 38, p. 55-68, 2015.

ZELAZO, Philip David; CARLSON, Stephanie M.; KESEK, Amanda. The Development of Executive Function in Childhood. **Handbook of developmental cognitive neuroscience**, p. 553, 2008.

ZELAZO, Philip David; CARLSON, Stephanie M. Hot and cool executive function in childhood and adolescence: Development and plasticity. **Child development perspectives**, v. 6, n. 4, p. 354-360, 2012.

ZHAO, G.; QUAN, M.; SU, L.; et al. Effect of Physical Activity on Cognitive Development: Protocol for a 15-Year Longitudinal Follow-Up Study. BioMed Research International, v. 2017, p.1-7, 2017.

ZHU, Na et al. The association between 24 h movement guidelines and internalising and externalising behaviour problems among Chinese preschool children. **Children**, v. 10, n. 7, p. 1146, 2023.

APÊNDICE I - Termo de Consentimento Livre e Esclarecido

Nome do Projeto: COMPORTAMENTOS DE MOVIMENTO EM 24 HORAS E DESFECHOS EM SAÚDE DE PRÉ-ESCOLARES DA CIDADE DE PETROLINA-PE - PROJETO MOVEMENT´S COOL
CAEE Nº 47542921.7.0000.8267
Pesquisador Responsável: Natália Batista Albuquerque Goulart Lemos

Seu(a) filho(a) está sendo convidado(a) a participar desta pesquisa, coordenada pela prof. Natália Lemos – UNIVASF. Por favor, leia atentamente as informações abaixo e faça, se desejar, qualquer pergunta para esclarecimento.
Seu(a) filho(a), está sendo convidado(a) por ter idade entre 3 a 5 anos e estar matriculado(a) na classe pré-1 no ensino municipal de Petrolina (PE).

Objetivos: Investigar como a atividade física, tempo de sono e uso de eletrônicos, como celulares e televisão influenciam na atenção e emoção (ex: aprendizagem, relação com outras pessoas), na capacidade motora (ex: correr, saltar, equilibrar), na capacidade física (ex: ter força, resistência) e em aspectos fisiológicos de seu(a) filho(a).

Avaliações: Estas informações serão coletadas por meio das seguintes avaliações: 1) nível de atividade física e sono: As crianças usarão por oito (8) dias um aparelho na cintura (acelerômetro) durante o dia, tirando para atividades aquáticas e banho, sendo colocado de maneira confortável no mesmo lado da cintura e na mesma posição, e a noite usarão este mesmo aparelho para dormir; 2) capacidade motora e física: as crianças farão testes em que precisarão fazer atividades como correr, saltar e chutar uma bola; 3) desempenho cognitivo: as crianças irão realizar alguns jogos em que precisarão prestar atenção e tomar uma decisão sempre que uma imagem aparecer; 4) avaliação fisiológica: um avaliador coletará um pouco de saliva das crianças.

O senhor(a) também será convidado a responder alguns questionários de informações socioeconômicas, sobre uso de telas e eletrônicos e sobre o comportamento seu filho(a) no dia-dia. Todas as informações ficarão sobre sigilo. A identidade de seu filho(a), bem como a sua identidade não serão reveladas em nenhuma forma de apresentação.

Riscos: A participação de seu filho(a) nesta pesquisa envolve riscos mínimos: ele(a) pode ficar cansado(a) no teste motor e cognitivo e sentir incomodo na cintura decorrente do uso do acelerômetro. Para minimizar, todas as avaliações serão ministradas por pesquisadores treinados, as avaliações não irão durar mais que 30 minutos. O acelerômetro será utilizado por meio de uma cinta confortável.

Todas as avaliações serão realizadas no CMEI no horário que seu filho(a) estuda, em acordo com a professora de sala para não comprometer as atividades curriculares. O senhor(a) poderá responder os questionários em casa (por meio do link) ou diretamente com os pesquisadores.

Enfatiza-se que seu(a) filho(a) poderá se negar a realizar qualquer teste e o senhor(a) também pode se negar a responder qualquer pergunta se assim desejar. Também o senhor(a) poderá retirar o seu consentimento para seu(a) filho(a) deixar de participar da pesquisa a qualquer momento, sem penalização alguma.

Benefícios: Este estudo oferecerá um relatório dos resultados ao final do projeto e busca incentivar a prática de atividade física para melhoria da saúde. Não será pago nenhum valor financeiro ou prêmio ao seu(a) filho(a) ou ao senhor(a) para participação nesta pesquisa.

Eu,____, responsável por

(nome e sobrenome da criança) ____

DECLARO, outrossim, que após convenientemente esclarecido pelo pesquisador e ter entendido o que me foi explicado, consinto voluntariamente na participação de meu(a) filho(a) nesta pesquisa, declarando ainda que o termo foi assinado em duas vias, uma ficando comigo e outra com o responsável pela pesquisa.

__________________ , _____ de _____________________ de 20____

____

Assinatura do(a) Responsável

____

Polegar Direito

(Assinatura do Pesquisador Responsável)

Pesquisador responsável: Natália Batista Albuquerque Goulart Lemos
Endereço Profissional: Universidade Federal do Vale do São Francisco, Colegiado de Educação Física. Av. José de Sá Maniçoba, s/n, Centro, Petrolina.
E-mail: natalia.goulart@univasf.edu.br; telefone: (87) 21016856

Em caso de dúvidas com respeito aos aspectos éticos deste estudo, você poderá consultar:

COMITÊ DE ÉTICA EM PESQUISA – FACULDADE DE INTEGRAÇÃO DO SERTÃO (FIS)
R. João Luiz de Melo, 2110 - Tancredo Neves, Serra Talhada - PE, 56909-205.
CONTATO: (87) 3831-1472 - cepfis@fis.edu.br

APÊNDICE II - Termo de Consentimento Livre e Esclarecido-Experimental

Nome do Projeto: RELAÇÕES TRANSVERSAIS E LONGITUDINAIS ENTRE COMPORTAMENTOS DE MOVIMENTO EM 24 HORAS E DESFECHOS EM SAÚDE DE PRÉ-ESCOLARES DA CIDADE DE PETROLINA-PE - PROJETO MOVEMENT´S COOL

CAEE Nº 47542921.7.0000.8267

Pesquisador Responsável: Natália Batista Albuquerque Goulart Lemos

Equipe de Pesquisa: Jéssica Mota, Tamires Mendes, Clarice Martins, Rafael Tassitano, Ferdinando Carvalho, Fernando Lemos, Larissa da Silva, Paulo Filipe Bandeira.

Seu(a) filho(a) está sendo convidado(a) a participar da pesquisa acima intitulada**,** coordenada pela pesquisadora responsável Natália Batista Albuquerque Goulart Lemos. Por favor, leia atentamente as informações abaixo e faça, se desejar, qualquer pergunta para esclarecimento. **Critérios de inclusão:** Seu(a) filho(a), está sendo convidado(a) a participar desta pesquisa por ter idade entre 4 e 5 anos e estar matriculado(a) na classe pré-1 no ensino municipal de Petrolina (PE). **Justificativa e Objetivos:** Este projeto objetiva investigar como os comportamentos diários da atividade física, tempo de sono e uso de eletrônicos, como celulares e televisão influenciam na cognição (ex: aprendizagem, atenção, relação com outras pessoas), na capacidade motora (ex: correr, saltar, equilibrar), na capacidade física (ex: ter força, resistência) e em aspectos fisiológicos (genótipos do gene FTO) antes e após participação em aulas de ginástica. Para tanto, a creche que seu(a) filho(a) estuda foi sorteada para um dos seguintes grupos: Creche Intervenção de ginástica (INT) ou Creche Controle sem Intervenção de ginástica (CON). Se seu(a) filho(a) estudar na creche INT ele participará de aulas de ginástica por 12 semanas durante o horário de aula dele. Se seu(a) filho(a) estudar na creche CON as atividades que ele(a) realiza na creche serão acompanhados por um pesquisador durante as 12 semanas, sem participar das aulas de ginástica. **Avaliações:** Estas informações serão coletadas por meio das seguintes avaliações: 1) nível de atividade física e sono: As crianças usarão por sete (7) dias um aparelho na cintura (acelerômetro), tirando apenas para atividades aquáticas e banho; 2) capacidade motora e física: as crianças farão testes em que precisarão fazer atividades como correr, saltar e chutar uma bola; 3) desempenho cognitivo: as crianças irão realizar alguns jogos em que precisarão prestar atenção e tomar uma decisão sempre que uma imagem aparecer (ex: tocar na tela sempre que aparecer um peixinho), lembrar uma sequência de comandos (ex: tocar no ombro, tocar na cabeça) ou classificar figuras de acordo com a cor ou forma; 4) avaliação genética: um avaliador coletará um pouco de saliva das crianças; 5) avaliação das ondas do cérebro: a criança irá jogar um jogo enquanto as ondas do cérebro dele(a) é monitorado por meio de um aparelho de eletroencefalograma. Além disso, o senhor(a) também será convidado a responder alguns questionários que conterão algumas perguntas sobre: 1) questões da família, como renda financeira e escolaridade dos pais; 2) atividades físicas praticadas pelo senhor(a); 3) atividades físicas praticadas pelo seu filho; 4) comportamento do sono do seu filho(a). As avaliações irão ocorrer nos seguintes tempos: 1) antes das aulas de ginástica começar; 2) logo após terminar as 12 semanas (4 meses) de aula de ginástica; e 3) 12 semanas (4 meses) após o final das aulas de ginástica. Após este período, se seu(a) filho(a) tiver participado da creche CON, ele(a) também receberá aulas de ginástica. **Sigilo:** É garantido o sigilo e confidencialidade sobre os registros dos resultados e o desempenho das crianças nos testes. As informações a respeito deste projeto ficarão sob a guarda pessoal da equipe de pesquisadores que se comprometem em destruir os dados cinco anos após a coleta. A identidade de seu filho(a), bem como a sua identidade não serão reveladas em nenhuma forma de apresentação. **Riscos:** A participação de seu filho(a) nesta pesquisa envolve riscos mínimos tais como quedas durante os testes motores e físicos, bem como cansaço nos testes cognitivos. Para minimizar a chance destes riscos acontecerem, todas as avaliações serão ministradas por pesquisadores treinados, os testes não irão durar mais que 30 minutos e as crianças farão algumas tentativas de teste. Além disso, sua participação no preenchimento dos questionários pode envolver riscos psicológicos como cansaço ou constrangimento diante de alguma pergunta. Para tanto, o senhor(a) irá preencher os questionários em um local reservado e poderá parar de responder sempre que achar necessário.

Enfatiza-se que seu(a) filho(a) poderá se negar a realizar qualquer teste e o senhor(a) também pode se negar a responder qualquer pergunta se assim desejar. Também o senhor(a) poderá retirar o seu consentimento para seu(a) filho(a) deixar de participar da pesquisa a qualquer momento, sem penalização alguma. **Benefícios:** Este estudo oferecerá um relatório dos resultados ao final do projeto e busca incentivar a prática de atividade física para melhoria da saúde. Indiretamente, espera-se que a pesquisa possa contribuir com informações sobre o estado de saúde das crianças em idade pré-escolar no município de Petrolina (PE). **Local de realização:** todos os testes e as aulas de ginástica serão realizados na creche em que seu(a) filho(a) estudam, no horário de aula dele(a). Já o teste de eletroencefalograma (ondas do cérebro) será realizado no Colegiado de Educação Física da UNIVASF. **Indenização e Ressarcimento:** Não será pago nenhum valor financeiro ou prêmio ao seu(a) filho(a) ou ao senhor(a) para participação nesta pesquisa. Caso seu(a) filho(a) ou o senhor(a) tenham algum dano físico ou material decorrentes da participação nesta pesquisa, vocês terão direito a solicitar indenização. Caso o senhor(a) necessite, as despesas com deslocamento até a Univasf poderão ser ressarcidas.

Eu,____

DECLARO, outrossim, que após convenientemente esclarecido pelo pesquisador e ter entendido o que me foi explicado, consinto voluntariamente a participação de meu(a) filho(a) nesta pesquisa, declarando ainda que o termo foi assinado em duas vias, uma ficando comigo e outra com o responsável pela pesquisa.

________________ , _____ de ____________________ de 20____

____

Assinatura do(a) Responsável

Polegar Direito

____

(Assinatura do Pesquisador Responsável)

Pesquisador responsável: Natália Batista Albuquerque Goulart Lemos
Endereço Profissional: Universidade Federal do Vale do São Francisco, Colegiado de Educação Física. Av. José de Sá Maniçoba, s/n, Centro, Petrolina. E-mail: natalia.goulart@univasf.edu.br; telefone: (87) 21016856

Received: 17 May 2023 | Revised: 16 April 2024 | Accepted: 26 May 2024

Apêndice III

DOI: 10.1002/icd.2526

METHODOLOGICAL ARTICLE

Evidence of the validity of the child self-regulation & behaviour questionnaire for the Brazilian context

Natália Batista Albuquerque Goulart Lemos[1,2] | Valerie Carson[3] | Steven Howard[4] | Carlos Cristi-Montero[5] | Glacithane Lins da Cunha[6] | Jéssica Gomes Mota[7] | Antony Okely[8] | Paulo Felipe Ribeiro Bandeira[6,9] | Clarice Maria de Lucena Martins[10,11]

[1]Physical Education Department, Federal University of Vale do São Francisco, Petrolina, Pernambuco, Brazil

[2]Associate Graduate Program in Physical Education, Federal University of Paraiba, João Pessoa, Brazil

[3]Faculty of Kinesiology, Sport, and Recreation, University of Alberta, Edmonton, Alberta, Canada

[4]School of Education, University of Wollongong, Wollongong, New South Wales, Australia

[5]IRyS Group, Physical Education School, Pontificia Universidad Católica de Valparaíso, Valparaíso, Chile

[6]Graduate Program in Physical Education, Federal University of Vale do São Francisco, Petrolina, Pernambuco, Brazil

[7]Associate Graduate Program in Physical Education, University of Pernambuco, Recife, Pernambuco, Brazil

[8]Early Start, Faculty of Social Sciences, University of Wollongong, Wollongong, New South Wales, Australia

[9]Department of Physical Education, Regional University of Cariri, Crato, Ceará, Brazil

[10]Research Centre of Physical Activity, Health and Leisure, Faculty of Sports; Laboratory for Integrative and Translational Research in Population Health (ITR), University of Porto, Porto, Portugal

[11]Department of Physical Education, Federal University of Paraíba, João Pessoa, Brazil

Correspondence
Natália Batista Albuquerque Goulart Lemos, Federal University of Vale do São Francisco, Petrolina, Pernambuco, Brazil.
Email: natalia.goulart@univasf.edu.br

Abstract

Poor early childhood self-regulation is related to many mental health problems and antisocial behaviours, so it is important to use psychometrically sound instruments to assess children's self-regulation and behavioural development. The aim of this study is to report the translation, adaptation, as well as explore the construct validity of the child self-regulation & behaviour questionnaire (CSBQ) for the Brazilian context. The process consisted of different steps, such as transcultural translation, item intelligibility analysis, and psychometric analysis based on classical and

Received: 17 May 2023 | Revised: 16 April 2024 | Accepted: 26 May 2024

Inf Child Dev. 2024;e2526. wileyonlinelibrary.com/journal/icd
https://doi.org/10.1002/icd.2526

contemporary theories. The validation process was carried out on a sample of 277 parents/caregivers (35.00 ± 6.72 years old) of 281 children (4.92 ± 1.45 years old; 156 females). The final Brazilian version showed adequate values of semantic, idiomatic, and conceptual equivalence. The validation process resulted in a seven-dimensional model with 33 items. The validation of Brazilian CSBQ is promising for investigating early self-regulation and behaviour problems in low-middle income contexts.

KEYWORDS
child, questionnaire, self-regulation, validation

1 | INTRODUCTION

Self-regulation is generally defined as the ability to control thoughts, behaviours, and feelings to achieve goal-directed behaviours, which involves three domains: cognitive processes (i.e., executive function—EF), behavioural, and emotional regulation (Hofmann et al., 2012; McClelland et al., 2017). Children's self-regulation has been associated with short- and long-term health and educational outcomes (Robson et al., 2020) and with favourable later-life outcomes for those children at average or high levels of self-regulation (Howard & Williams, 2018; Moffitt et al., 2011). Children's self-regulation is also related to aspects of socioemotional function and development, including dimensions of social competence, such as sociability (social situations and interactions), prosocial behaviour (sharing, helping, and cooperation) (Chen et al., 2000; Gross et al., 2015), disruptive/negative behaviours described as externalizing (defiance, impulsivity, disruptiveness, aggression antisocial), and internalizing (withdrawal, anxiety or depressed) (Gilliom & Shaw, 2004). According to Blair, self-regulation's broad application to emotion, behaviour, and cognition provides the foundation for social competence and school readiness (Blair, 2002). Additionally, longitudinal studies support the association between early childhood self-regulation and the co-occurrence of internalizing and externalizing problems with (mal)adaptive functioning outcomes in emerging adulthood (Arslan et al., 2021; Moffitt et al., 2011).

Considering the above-mentioned predictive value of self-regulation on health outcomes, it is crucial to underlie the relationship between self-regulation and socio-competence during early childhood. This information can be used by parents, childcare professionals, and stakeholders to implement preventive and promotion intervention strategies (Korucu et al., 2022; McClelland et al., 2007; Robson et al., 2020). Studies have adopted several approaches to assess self-regulation in early childhood, based on adult reports, task-based, and observation, showing adequate psychometric properties, though no 'gold standard' measure has yet been established (Howard et al., 2022; McCoy, 2019).

The child self-regulation & behaviour questionnaire (CSBQ; Howard & Melhuish, 2017) is a 34-item educator or parent report that includes subscales of cognitive self-regulation, behavioural self-regulation, emotional self-regulation, positive (sociability and prosocial) and negative (externalizing and internalizing) social behaviours. Factor analysis of the CSBQ yielded seven separable, yet related subscales, providing evidence for diversity in the constructs being captured, and correlations between CSBQ and analogous subscales from other instruments showed similarity between constructs (Howard & Melhuish, 2017). The CSBQ provides percentile scores (80th, 90th, and 95th for negative behaviours and 5th, 10th, and 20th for positive behaviours) and categorization norms (slightly high/low, high/low, and very high/low) for framed subscales. However, since these percentile scores and norms were created from an Australian sample, it limits the use of these normative values in other contexts.

Given the good psychometric properties (Howard & Melhuish, 2017), the CSBQ has been used in different countries, including low-middle-income and low-income contexts, though only in countries in which English in the first or second language. (Cj et al., 2021; Howard et al., 2022; Huang et al., 2022; Kuzik et al., 2022; Melhuish et al., 2016). However, the CSBQ has not been validated for use in these other contexts. As a result, the cross-cultural adaptation of measurement scales involving systematic and empirical procedures, such as translation into the target language and content validity for use in broader contexts is urgently needed (Caetano et al., 2020; Campbell et al., 2016; Cj et al., 2021; Haslam et al., 2019).

This study aims to translate, adapt, and construct validate the CSBQ for the Brazilian context. Brazil is a middle-income country, with a population distribution among different macro-regions, where social and cultural characteristics are quite specific (IBGE, 2015). According to cross-sectional studies, Brazilian children's behavioural problems are associated with family risk factors (e.g., low maternal education, absence of a maternal partner, and a great number of siblings) and economic inequalities, such as limited access to health and education, especially in children living in poor urban areas (Caetano et al., 2020; dos Santos et al., 2016; Rocha et al., 2013). Though these studies provide important information about the risk factors for the socio-emotional development of Brazilian children, they focused on externaling and internalizing problems. The Brazilian version of the CSBQ can provide a broader assessment of children's mental health, since it includes subscales of self-regulation and social competence.

2 | MATERIALS AND METHODS

2.1 | Study design

This study is a cross-cultural translation, adaptation, and validation of the CSBQ questionnaire in the Brazilian context. The translation and adaptation procedures included five steps, as follows: (1) instrument analysis and conceptual foundation; (2) translation; (3) experts´ analysis and item adjustment, (4) item intelligibility analysis and readjustments, (5) back-translation to the original language. Finally, psychometric analysis was performed, based on classical and contemporary theories (Golino & Epskamp, 2017; Mertens, 2019).

2.2 | Participants

This study includes mothers/fathers/primary caregivers of 3-to-5-year-old children from all five Brazilian regions (South, Southeast, Midwest, Northeast, North) who agreed to participate. The following participants were excluded: (a) those who did not complete the CSBQ, and (b) those who reported a psychiatric, neurological, and/or neuropsychological diagnosis in their child within the last 2 months from the date of response to the questionnaire. A link to an online version of the Brazilian questionnaire was disseminated through email and social media using snowball sampling, wherein initial participants were encouraged to identify and share the research with other potential participants (Leighton et al., 2021).The data collection was conducted during the COVID-19 pandemic, in which mandatory social distancing was in effect. The average time to fulfil the questionnaire was 5 min.

2.3 | Procedures for translation

First, instrument analysis and conceptual foundation were performed. The research's team identified the CSBQ as an instrument widely used to assess self-regulation and social behaviour in preschoolers. Then, the original author was contacted with a request for authorization to adapt the questionnaire to the Brazilian context.

Second, the English version was independently translated into Portuguese by the principal author and a native Portuguese speaker who was not involved in the study. The summary of translations was performed by three other researchers (CM, PB, JM), and through consensus, they defined the Portuguese version of the items.

Third, experts´ analysis and item adjustment were proceeded. A committee of experts formed by five researchers with expertise in the area was formed to analyse the preliminary translated version of CSBQ, consideringthe following criteria: (1) semantic equivalence (evaluate grammatical aspects and meaning of the item); (2) idiomatic equivalence (adjust the item without detriment to the original meaning), and (3) conceptual equivalence (assess whether the adapted item evaluates the same quality in different cultures). Each of these criteria was applied to all CSBQ items using a Likert scale from '1' (inadequate) to '5' (very adequate), and the items were adjusted after the expert committee analysis.

In the fourth step, the intelligibility analysis was conducted in a subgroup of respondents ($N = 6$), aged between 33 and 41 years (M = 36,83; SD = 3,31). Items were assessed for age-appropriateness (the item can be understood by people of the same age from different backgrounds), clarity (the item is grammatically correct and can be understood by people of the same culture), and language comprehension (the meaning of the item has been understood), considering: '1' agree; '2' for I have questions about it; or '3' for not agree. For each question, respondents were asked to consider the item and express whether or not the specific items should be reviewed.

Lastly, the back-translation into English was carried out by a native English speaker researcher who did not have previous access to CSBQ. Then, the research team analysed the back-translated items and, through consensus, defined the English version of the items. Finally, the translation process was forwarded to the author of the questionnaire, as summarized in Figure 1.

2.4 | Psychometric analysis

2.4.1 | Content validity

The content validity and the homogeneity of the evaluation of an item between expert researchers for the intelligibility of the scale were performed using Aiken's V and H, respectively (Aiken & Groth-Marnat, 2005). The results

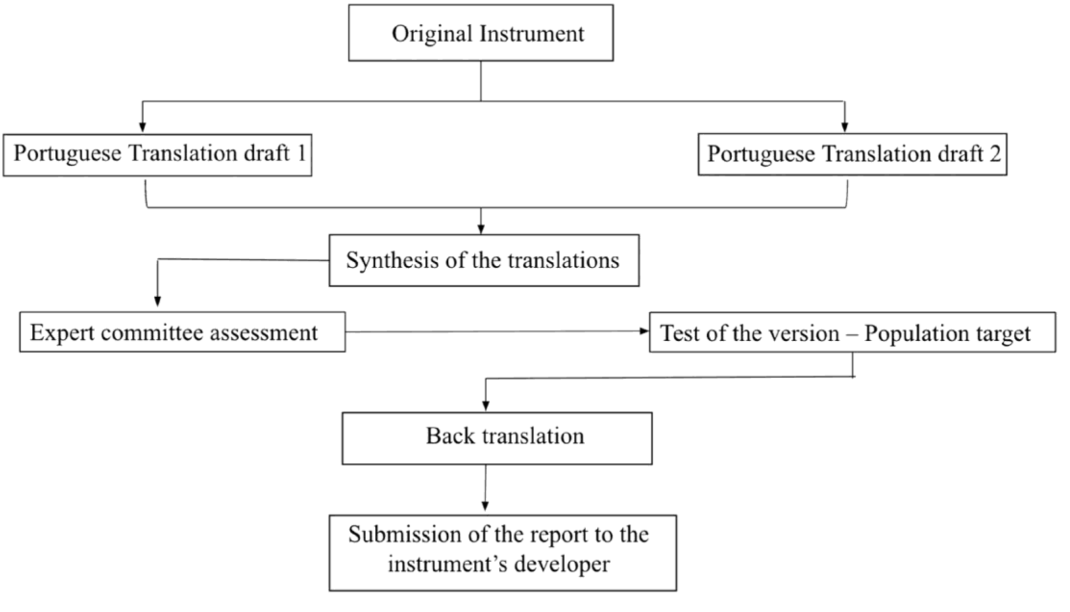


FIGURE 1 Study's procedures for translation.

allowed us to verify the raters' agreement on the items' content validity for five or more expert researchers (Lai & Chang, 2007; Popping, 2019).

Aiken's V was calculated from each item (j), considering the evaluation of 5 judges and six respondents (Vj), as follows:

$$Vj = \frac{Sj}{[n(c-1)]} \qquad (1)$$

$$Sj = \sum_{i=1}^{n} rij - 1 \quad (j = 1 \ldots m,\ i = 1 \ldots n) \qquad (2)$$

where c = the highest valid value (5), r = score given by an expert (between 1 and 5), and m = total number of items (n = 34). The V index varies between 0 and 1. A value close to 1 indicates a high content validity, and a significant pattern ($p < 0.05$) assumes that the experts agreed that the item has content validity.

The level of evaluation homogeneity was calculated by the Aiken H index for each item j (Hj), from the following formula:

$$Hj = 1 - \frac{4Sj}{(c-1)(n^2-k)} \qquad (3)$$

where Hj = value of agreement between raters regarding how a particular item (j) should be measured, n = number of raters (N = 5 and 21, respectively), c = highest valid value (4), k = is a dummy variable, where k = 0 if n is even, k = 1 if n is odd and Sj = sum of absolute values between the differences in the classification assigned by two evaluators. The H index varies between 0 and 1. A value close to 1 indicates high reliability and a significant value ($p < 0.05$) of good internal consistency between observations.

Findings for both Aiken's V and H that are not significant should be followed up with a qualitative analysis of the items or an exclusion of the items. However, for each of these decisions, the theoretical framework must be considered (Lai & Chang, 2007).

2.4.2 | Confirmatory factorial analysis (CFA)

Results indicated the data did not meet the normality assumption. As a result, the weighted least square mean and variance-adjusted estimator was used in all the analysis procedures (Asparouhov & Muthén, 2009).

To evaluate the quality of the adjustments of the models, we used the Comparative Fit Index—CFI (Bentler, 1990), the Tucker-Lewis Index—TLI (Tucker & Lewis, 1973), the mean square error of approximation— RMSEA (Sörbom & Jöreskog, 1981; Steiger, 1990), and the residual standardized mean square root—SRMR(Hu &Bentler, 1999; Sörbom & Jöreskog, 1981). An adequate adjustment was considered when CFI and TLI values were >0.90, while values of >0.95 indicated a good (Bentler, 1990; Hu & Bentler, 1999). RMSEA and SRMR values between 0.05 and 0.08 indicated an acceptable fit, while values <0.05 indicated a good fit (Hu & Bentler, 1999). Internal consistency was evaluated by considering the composite reliability (CR) (Raykov, 2004).

Mplus 8.0 and the Rstudio (free version) were used for the analysis. The reliability analysis was calculated through CR. The CR is an indicator of the structural quality of a psychometric instrument (Hair et al., 2009). To calculate the CR, the parameters estimated by the structural equations modelling of the CFA are used. The CR values can be altered by the number of items in the dimension and by the homogeneity of the factorial loadings, so the cut-off point for this indicator may be questionable in dimensions with few items (Valentini & Damásio, 2016). An acceptable value for CR is 0.60 (Bagozzi & Yi, 1988).

2.4.3 | Network analysis

Network Analysis estimates the way that items are grouped through their correlation strength. For the Network estimation method, the graphical Least Absolute Shrinkage and Selection Operator (Friedman et al., 2008) (GLASSO), which estimates a Gaussian graphical model (Lauritzen, 1996) (GGM) was used. Nodes (circles) represent variables and edges (lines) represent the conditional dependence (or partial correlations) between nodes. LASSO uses a parameter called lambda (λλ), which controls the sparsity of the network. Lower values of λλ remove fewer edges, increasing the possibility of including spurious correlations, whereas larger values remove more edges, increasing the possibility of removing relevant edges. When λλ = 0, the estimates are equal to the ordinary least-squares solution for the partial correlation matrix. In this study, the ratio of the minimum and maximum λλ was set to 0.1 (0.5 is the highest value).

The popular approach in the network psychometrics literature is to compute models across several values of λλ (usually 100) and to select the model that minimizes the extended Bayesian information criterion (Chen &Chen, 2008; Epskamp et al., 2018) (EBIC). The EBIC model selection uses a hyperparameter gamma (γγ) to controlhow much it prefers simpler models (Foygel & Drton, 2010) (i.e., models with fewer edges). Larger γγ values lead to simpler models, whereas smaller γγ values lead to denser models. When γγ = 0, the EBIC is equal to the Bayesian information criterion. In this study, γγ was set to 0. In the network psychometrics literature, this approach has been termed EBICglasso and is applied using the qgraph package.

Recent studies have employed network psychometrics as an additional approach for instrument validation. The calculations of centrality measures, such as the expected influence, enables researchers to explore patterns of associations among variables within a complex system (Bandeira et al., 2020; Duncan et al., 2022; Salami et al., 2023). Considering self-regulation as a latent concept, for the current study, the Network Analysis was used to estimate the variable with the highest expected influence value for each dimension of the original and translated CBSQ versions. The *expected influence* indicates the importance of a node for the structure and functioning of the network. This centrality measure consists of the sum of all possible edge weights that connect one node to another and was used to assess the nature and strength of a skill's cumulative influence within the network and, thus, the role it may be expected to play in the activation, persistence, and remission of the network (Robinaugh et al., 2016). A positive expected influence means that the influence of that specific node in the network tends to increase to acquire an adequate network pattern (Polishchuk et al., 2014).

3 | RESULTS

The validation process was based on data from 281 reports that were completed for 277 mothers/fathers/caregivers (35.00 ± 6.72 years old) from different Brazilian states, collected over three months (Table 1). Four mothers reported data for two children. The children mean age were 4.92 (SD = 1.45) and the sample included 156 females (55.51%).

The content validity analyses for semantic, idiomatic, and conceptual equivalences for intelligibility between the five judges are shown in Table 2. All the items showed high content (V) and reliability (H) values, showing the experts agreed with the content of the items, and internal consistency between the experts was seen.

The original model of the CSBQ with 7 dimensions and 34 items was tested, showing inadequate general fit indexes (CFI and TLI <0.85 and RMSEA >0.08). After removing item 11(Easily upset over small events), which showed the lowest factor loading (0.11), an alternative model was tested. With the exclusion of item 11, most items showed adequate standardized estimates on the CFA. Exceptions were items 14 (Gets over excited), 18 (Likes to work things out for self), and 22 (Is shy when meeting new children). These items were maintained in the model due to their lack of influence in the general adjustment indexes.

TABLE 1 Participants' sociodemographic description.

	n	%
Reports	281	100
Respondents	277	100
Mothers	234	84.47
Fathers	35	12.63
Uncle/Aunt	6	2.16
Others	2	0.72
Schooling		
Elementary school or less	12	4.33
High school	55	19.85
Bachelor's degree	75	27.07
Postgraduate degree/MBA	135	48.73
Income		
Bellow to R$510.00	17	6.13
From R$ 510.00 up to R$ 1.020	11	3.97
From R$ 1.020 up to R$ 2.040	38	13.71
From R$ 2.040 up to R$ 5.100	60	21.66
Above R$ 5.100	134	48.37
Uninformed	17	6.13
Region		
North	15	5.41
Northeast	159	57.40
Midwest	21	7.58
Southeast	32	11.55
South	50	18.05

Overall, the seven-dimensional model with 33 items demonstrated excellent fit indexes (x^2(df) = 1177.788 (474); CFI = 0.95 and TLI = 0.94; RMSEA (0.074 [IC95: 0.069-0.079]); and SRMR (0.096)). Information from the CFA analysis is shown in Table 3.

In the graphical representation (Figure 2), the correlations between CBSQ items (nodes) for the original (Panel a) and the translated (Panel b) versions are visualized by edges that can vary in colour and intensity. For both versions,the emergent pattern highlighted that while items that comprise the externalizing behaviours and emotional self-regulation domains grouped between items from other domains, the remaining items were grouped within their domains. The items with the highest expected influence for each of the seven dimensions of the CSBQ are highlighted in bold circles and remained unchangeable for both versions.

4 | DISCUSSION

This study aimed to translate, adapt, and explore construct validate of the CSBQ for the Brazilian context. The translation process presented a version adapted to the Brazilian context from a summary of the translations carried out by a committee of experts. The final version showed adequate values of semantic, idiomatic, and conceptual equivalence.

TABLE 2 Content validity for CSBQ Portuguese Brazilian translation.

Item	IE		SE		CE	
	V	H	V	H	V	H
1	0.95*	0.83*	1.00*	1.00*	1.00*	1.00*
2	0.85*	0.75*	1.00*	1.00*	1.00*	1.00*
3	0.95*	0.83*	1.00*	1.00*	1.00*	1.00*
4	0.95*	0.83*	1.00*	1.00*	1.00*	1.00*
5	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
6	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
7	0.95*	0.83*	1.00*	1.00*	1.00*	1.00*
8	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
9	0.95*	0.83*	1.00*	1.00*	1.00*	1.00*
10	0.95*	0.83*	1.00*	1.00*	1.00*	1.00*
11	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
12	0.95*	0.83*	1.00*	1.00*	1.00*	1.00*
13	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
14	0.95*	0.83*	1.00*	1.00*	0.95*	0.83*
15	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
16	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
17	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
18	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
19	0.95*	0.83*	1.00*	1.00*	1.00*	1.00*
20	0.90*	0.75*	1.00*	1.00*	1.00*	1.00*
21	0.95*	0.83*	0.95*	0.83*	1.00*	1.00*
22	0.95*	0.83*	1.00*	1.00*	1.00*	1.00*
23	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
24	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
25	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
26	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
27	0.90*	0.75*	1.00*	1.00*	1.00*	1.00*
28	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
29	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
30	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
31	0.95*	0.83*	0.95*	0.83*	1.00*	1.00*
32	0.90*	0.75*	1.00*	1.00*	1.00*	1.00*
33	0.90*	0.75*	1.00*	1.00*	1.00*	1.00*
34	0.95*	0.83*	0.95*	0.83*	0.95*	0.83*

Note: Values represent the content validity of CSBQ considering the evaluation of experts ($N = 5$) regarding CE, conceptual equivalence; IE, idiomatic equivalence; SE, semantic equivalence.
*$p < 0.05$.

For the original CSBQ validation study, Cronbach's alpha was used to calculate the internal consistency, and the alpha coefficient was predetermined to be equal (Zijlmans et al., 2018). In the current study, internal consistency was calculated using CR, allowing the items' factor loadings to change. This method presents more robust reliability

TABLE 3 Confirmatory factor analysis.

Items	CFA model (7 dimensions)	Composite reliability
Internalizing behaviours		
CSBQ17	0.598	
CSBQ21	0.688	
CSBQ25	0.641	0.85
CSBQ33	0.824	
CSBQ34	0.895	
Externalizing behaviours		
CSBQ3	0.396	
CSBQ20	0.571	
CSBQ23	0.776	0.77
CSBQ28	0.668	
CSBQ26	—0.770	
Sociability		
CSBQ1	0.715	
CSBQ4	0.678	
CSBQ9	0.741	
CSBQ16	0.366	0.84
CSBQ22	0.280	
CSBQ27	0.942	
CSBQ32	0.780	
Prosocial behaviour		
CSBQ19	0.673	
CSBQ24	0.804	0.78
CSBQ30	0.765	
Behavioural self-regulation		
CSBQ7	0.482	
CSBQ13	0.656	
CSBQ15	0.722	0.76
CSBQ29	0.594	
CSBQ31	0.709	
Cognitive self-regulation		
CSBQ5	0.824	
CSBQ6	0.416	
CSBQ8	0.606	0.73
CSBQ12	0.818	
CSBQ18	0.283	
Emotional self-regulation		
CSBQ2	0.709	
CSBQ10	0.493	0.48
CSBQ14	0.261	
Total		0.96

indicators when compared to Cronbach's alpha (Bertoldi et al., 2022; Valentini & Damásio, 2016). In the final Brazilian CSBQ version proposed, the CR of the CSBQ dimensions showed adequate values, except for the emotional SR dimension (0.48). In fact, the CR value may vary according to the number of items per dimension (i.e., the smaller the number of items, the lower the reliability). Thus, parsimony in its interpretation is important, besides the number of items presented, variability also depends on the factor loadings (Bertoldi et al., 2022; Valentini & Damásio, 2016).

In the translated version proposed in the current study, the item 11 was excluded from the emotional SR domain, proposing a version with three items in this dimension. It is important to highlight that for the original CSBQ version, Cronbach's alphas subscales ranged from acceptable to very good (i.e., Sociability = 0.74, Internalizing = 0.78, Emotional Self-Regulation = 0.83, Cognitive Self-Regulation = 0.87, Externalizing = .88, Prosocial = 0.89, and Behavioural Self-Regulation = 0.89) (Howard & Melhuish, 2017), though the authors stated that some items contributed to more than one subscale, reflecting the correlated nature of the subscales.

Indeed, through the network analysis (Figure 2, Panels a and b), it is possible to see how the emotional SR domain is graphically dispersed, and strongly related to items that belong to other domains. For instance, in the Portuguese version, the reverse items 23 (Most days will lose temper) and 26 (Shows wide mood swings) were maintained in the externalization domain. In fact, emotional regulation problems have been associated with externalizing behaviour in early childhood (Supplee et al., 2009). Moreover, studies have considered emotion and behaviour regulation as the ground for basic regulatory mechanisms and have consistently related it to social and externalizing behaviour (Batum & Yagmurlu, 2007). This fact may partially justify the low CR value observed, particularly for the emotional SR domain in the CFA analysis performed.

The network approach gives a complementary theoretical and mathematical approach by shifting the perspective from an attribute's validity to its components' validity. The CSBQ validation proposed in the current study describes the network composed of connected components of SR and social competence (Marsman et al., 2018). This network approach measures the internal structure that can be used to assess the extent to which a dimension is composed of a set of items that are homogeneously interrelated in a multidimensional context (Christensen et al., 2020). SR development is unfavourably impacted by early stressors and impacts stress response physiology (Wesarg et al., 2020). Living in socioeconomic disadvantage contexts can increase children's stress hormones that impair neural regions associated with SR (Arnsten et al., 2015), gradually and negatively modifying their responses to emotional, behavioural, and cognitive demands (Blair & Raver, 2012, 2016). Identifying poorer SR skills may be a key mechanism through which early poverty yields school readiness and ongoing achievement gaps (Perry et al., 2018; Williams & Bentley, 2021), buffering the effects of early risk (Crespo et al., 2019).

Recently, both cross-sectional and longitudinal methodologies have utilized CSBQ scores to predict early academic skills and school readiness (Howard et al., 2021; Howard et al., 2022), as well as to investigate associations of living in socioeconomic disadvantage with emotional and behavioural problems in children (Flouri et al., 2014; Kuziq et al., 2022). Additionally, the cognitive, behavioural, and emotional CSBQ scores have shown positive correlations with objective measures (Ponitz et al., 2009) and observational assessments (Howard et al., 2019), resulting in a latent variable of self-regulation (Howard et al., 2021). Since SR has been highlighted as a moderator to the relationship between socioeconomic disadvantages and behavioural problems, the validation of this Brazilian is crucial to fur- ther exploration of SR in low-middle income contexts.

This study has some limitations that should be highlighted. The original CSBQ was validated using educator or parent-reported responses via an iPad app or paper. However, collecting data in person was not possible in the present study due to the COVID-19 pandemic. Despite of employing snowball sampling as a low-cost and accessible methodology to include hard-to-reach participants, we are aware of the potential limited generalizability bias, stemming from the participants' personal networks. Furthermore, the adoption of an online procedure, which requires an internet connection and being familiarized with completing online documents may have also favoured a greatest number of respondents with higher income and education levels. Despite these limitations, this on-line procedure made it possible to obtain data from the Northeast region, where more than the half (63%) of the population lives in

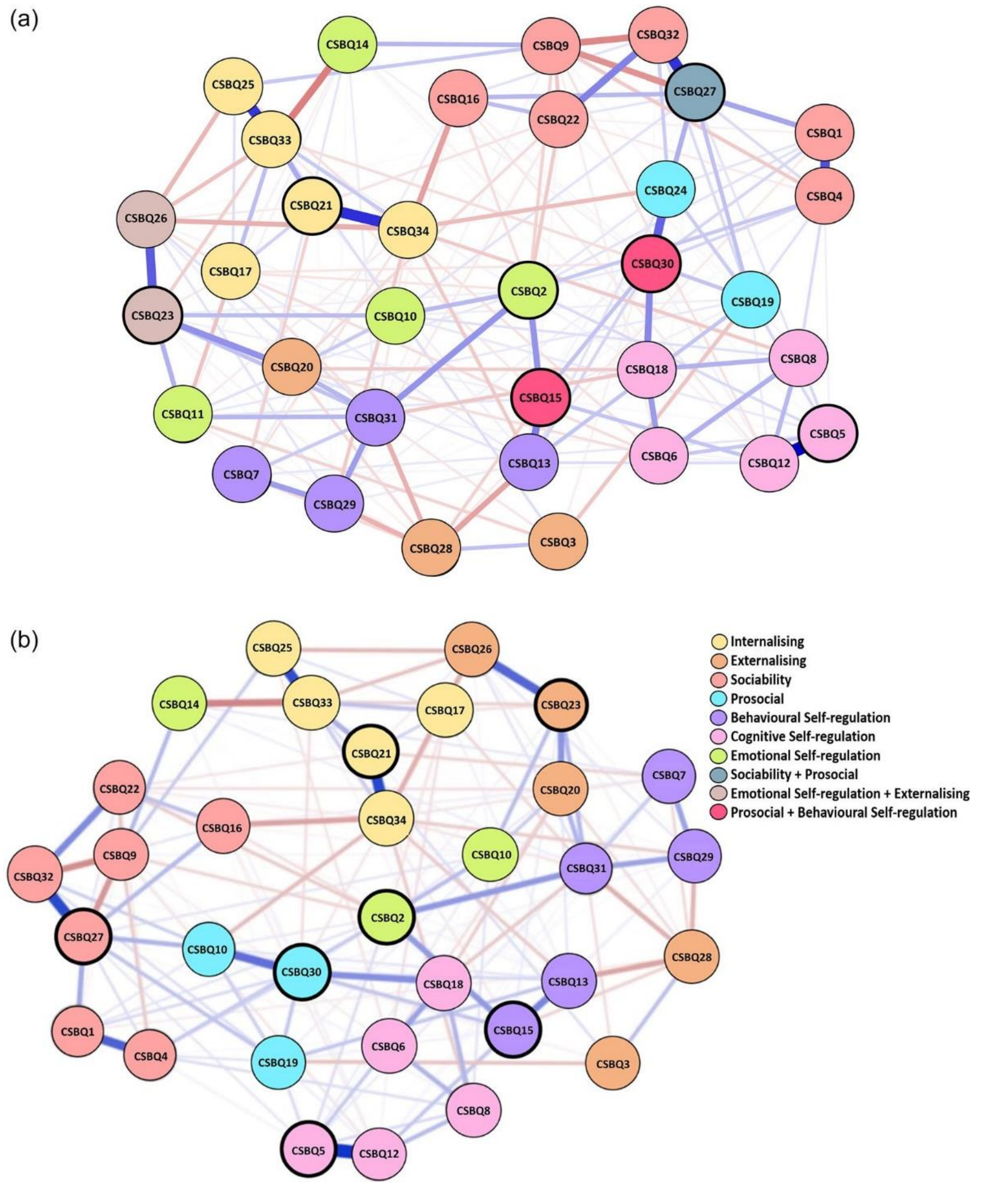


FIGURE 2 Gaussian graphical model of the CSBQ (Panel a: original version; Panel b: translated and adapted version); correlations between items (nodes) are visualized by edges. Blue edges indicate a positive correlation between the nodes, and red edges indicate a negative correlation. Thicker edges indicate stronger correlations, and thinner edges indicate weaker correlations. Bold circles indicate the constructs with the highest expected influence values in the network.

extreme poverty (Benevenuto et al., 2019). Additionally, 25% of the sample lacks higher education and lives with less than two minimum salaries. Future studies might consider data collection in specific areas of socioeconomic disadvantage.

The CSBQ is an assessment tool for self-regulation (i.e., cognitive, behavioural, emotional) and social competence (i.e., sociability, externalizing, internalizing, and prosocial behaviour), which are multifaceted constructs composed of distinct dimensions dynamically interacting (Blair, 2002; Howard & Melhuish, 2017). Given the multidimensional nature of these constructs, the present study employed network analysis as an additional statistical approach to examine these dynamic and complex phenomena. This approach allowed for the understanding of interactions among items that form the emerging specific dimensions of self-regulation and social competence. However, other methodologies, such as split-half reliability or external validity assessments, may warrant further exploration in future research.

The original CSBQ presents percentiles based on an Australian sample, which were calculated using cross-loading items. Future studies using the Brazilian version of the CSBQ should focus on the homogeneous composition of items to calculate scales scores for Brazilian samples. It is expected that with the validated Brazilian version of the CSBQ, the association between the different dimensions of SR and healthy developmental outcomes during childhood, and the measurement of SR in the context of interventions aiming at increasing children's socioemotional development could be explored in the Brazilian population.

5 | CONCLUSION

The Brazilian CSBQ version is a valid adult-reported instrument to assess this young children SR and related behaviours. It is expected that the Brazilian CSBQ version will be helpful for primary educators and Brazilian researchers to access children's SR.

AUTHOR CONTRIBUTIONS

Natália Batista Albuquerque Goulart Lemos: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; validation; visualization; writing - original draft; writing - review and editing. Valerie Carson: Conceptualization; formal analysis; investigation; methodology; visualization; writing - original draft; writing - review and editing. Steven Howard: Conceptualization; investigation; methodology; supervision; visualiza-tion; writing - original draft; writing - review and editing. Carlos Cristi-Montero: Conceptualization; methodology; validation; visualization; writing - original draft; writing - review and editing. Glacithane Lins da Cunha: Formal analysis; investigation; methodology; validation; visualization; writing - original draft. Jéssica Gomes Mota: Formal analysis; investigation; validation; visualization; writing - original draft. Antony Okely: Conceptualization; methodology; visualization; writing - review and editing. Paulo Felipe Ribeiro Bandeira: Conceptualization; formal analysis; investigation; methodology; supervision; validation; writing - original draft; writing - review and editing. Clarice Maria de Lucena Martins: Conceptualization; formal analysis; methodology; project administration; supervision; visualization; writing - original draft; writing - review and editing.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1002/icd.2526.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ORCID

Natália Batista Albuquerque Goulart Lemos https://orcid.org/0000-0003-2361-9837
Valerie Carson https://orcid.org/0000-0002-3009-3282 *Steven Howard* https://orcid.org/0000-0002-1258-3210 *Carlos Cristi-Montero* https://orcid.org/0000-0002-9940-507X *Jéssica Gomes Mota* https://orcid.org/0000-0002-7358-0814 *Antony Okely* https://orcid.org/0000-0002-1626-8170
Paulo Felipe Ribeiro Bandeira https://orcid.org/0000-0001-8260-0189
Clarice Maria de Lucena Martins https://orcid.org/0000-0002-4947-9329

REFERENCES

Aiken, L. R., & Groth-Marnat, G. (2005). *Psychological testing and assessment* (12th ed.). Pearson.

Arnsten, A. F. T., Raskind, M. A., Taylor, F. B., & Connor, D. F. (2015). The effects of stress exposure on prefrontal cortex: Translating basic research into successful treatments for post-traumatic stress disorder. *Neurobiology of Stress*, *1*(1), 89-99. https://doi.org/10.1016/j.ynstr.2014.10.002

Arslan, I–. B., Lucassen, N., van Lier, P. A. C., de Haan, A. D., & Prinzie, P. (2021). Early childhood internalizing problems, externalizing problems and their co-occurrence and (mal)adaptive functioning in emerging adulthood: A 16-year follow-up study. *Social Psychiatry and Psychiatric Epidemiology*, *56*(2), 193-206. https://doi.org/10.1007/s00127-020-01959-w

Asparouhov, T., & Muthén, B. (2009). Exploratory structural equation modeling. *Structural Equation Modeling*, *16*(3), 397-438. https://doi.org/10.1080/10705510903008204

Bagozzi, R. P., & Yi, Y. (1988). On the evaluation of structural equation models. *Journal of the Academy of Marketing Science*, *16*, 74-94.

Bandeira, P., Duncan, M., Pessoa, M. L., Soares, I., Da Silva, L., Mota, J., & Martins, C. (2020). TGMD-2 short version: Evidence of validity and associations with sex, age and BMI in preschool children. *Journal of Motor Learning and Develop- ment*, *8*(3), 528-543. https://doi.org/10.1123/jmld.2019-0040

Batum, P., & Yagmurlu, B. (2007). What counts in externalizing behaviors? The contributions of emotion and behavior regulation. *Current Psychology: Developmental Learning Personality Social*, *25*, 272-294.

Benevenuto, R. G., Azevedo, I. C. C., & Caulfield, B. (2019). Assessing the spatial burden in health care accessibility of low-income families in rural Northeast Brazil. *Journal of Transport & Health*, *14*, 100595.

Bentler, P. (1990). Quantitative methods in psychology. *Psychological Bulletin*, *107*, 238-246.

Bertoldi, R., Bandeira, P. F. R., da Silva, M. A., de Lara Machado, W., Mazo, J. Z., & Bandeira, D. R. (2022). Psychometric evidence of the coping inventory for Brazilian paralympic athletes in competition situations. *Paideia*, *32*, e3221. https://doi.org/10.1590/1982-4327E3221

Blair, C. (2002). School readiness: Integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *American Psychologist*, *57*(2), 111-127. https://doi.org/10.1037/0003-066X.57.2.111

Blair, C., & Raver, C. C. (2012). Child development in the context of adversity; experiential canalization of brain and behavior. *American Psychologist*, *67*(4), 309-318. https://doi.org/10.1037/a0027493

Blair, C., & Raver, C. C. (2016). Poverty, stress, and brain development: New directions for prevention and intervention. *Academic Pediatrics*, *16*(3), S30-S36. https://doi.org/10.1016/j.acap.2016.01.010

Caetano, S. C., Ribeiro, M. V., Askari, M. S., Sanchez, Z. M., do Rosário, M. C., Perissinoto, J., Resegue, R., Felix, E., Mariano, M., Fidalgo, T. M., Caetano, M., Mari, J. J., Surkan, P. J., & Martins, S. S. (2020). An epidemiological study of childhood development in an urban setting in Brazil. *Braz J Psychiatry*, *43*, 43-54. https://doi.org/10.1590/1516-4446-2020-0934

Campbell, S. B., Denham, S. A., Howarth, G. Z., Jones, S. M., Whittaker, J. V., Williford, A. P., Willoughby, M. T., Yudron, M., & Darling-Churchill, K. (2016). Commentary on the review of measures of early childhood social and emotional development: Conceptualization, critique, and recommendations. *Journal of Applied Developmental Psychology*, *45*, 19-41. https://doi.org/10.1016/j.appdev.2016.01.008

Chen, J., & Chen, Z. (2008). Extended Bayesian information criteria for model selection with large model spaces. *Biometrika*, *95*(3), 759-771.

Chen, X., Li, D., Li, Z.-Y., Li, B.-S., & Liu, M. (2000). Sociable and prosocial dimensions of social competence in Chinese children: Common and unique contributions to social, academic, and psychological adjustment. *Developmental Psychology*, *36*(3), 302-314. https://doi.org/10.1037/0012-1649.36.3.302

Christensen, A. P., Golino, H., & Silvia, P. J. (2020). A psychometric network perspective on the validity and validation of personality trait questionnaires. *European Journal of Personality*, *34*(6), 1095-1108. https://doi.org/10.1002/per.2265

Cj, C., Sj, H., Scerif, G., Twine, R., Kahn, K., Sa, N., & Ce, D. (2021). Associations between South African preschoolers' routine physical activity, self-regulation and psychosocial well-being. *Mental Health and Physical Activity*, *20*, 100383. https://doi.org/10.1016/j.mhpa.2021.100383

Crespo, L. M., Trentacosta, C. J., Udo-Inyang, I., Northerner, L., Chaudhry, K., & Williams, A. (2019). Self-regulation mitigates the association between household chaos and children's behavior problems. *Journal of Applied Developmental Psychology*,*60*, 56-64. https://doi.org/10.1016/j.appdev.2018.10.005

dos Santos, L. M., Queirós, F. C., Barreto, M. L., & dos Santos, D. N. (2016). Prevalence of behavior problems and associated factors in preschool children from the city of Salvador, state of Bahia, Brazil. *Revista Brasileira de Psiquiatria*, *38*(1), 46-52. https://doi.org/10.1590/1516-4446-2014-1596

Duncan, M. J., Martins, C., Ribeiro Bandeira, P. F., Issartel, J., Peers, C., Belton, S., O'Connor, N. E., & Behan, S. (2022). TGMD-3 short version: Evidence of validity and associations with sex in Irish children. *Journal of Sports Sciences*, *40*, 138-145. https://doi.org/10.1080/02640414.2021.1978161

Epskamp, S., Borsboom, D., & Fried, E. I. (2018). Estimating psychological networks and their accuracy: A tutorial paper. *Behavior Research Methods*, *50*(1), 195-212. https://doi.org/10.3758/s13428-017-0862-1

Flouri, E., Midouhas, E., & Joshi, H. (2014). Family poverty and trajectories of children's emotional and behavioural problems: The moderating roles of self-regulation and verbal cognitive ability. *Journal of Abnormal Child Psychology*, *42*, 1043- 1056.

Foygel, R., & Drton, M. (2010). Extended Bayesian Information Criteria for Gaussian Graphical Models. http://arxiv.org/abs/1011.6640

Friedman, J., Hastie, T., & Tibshirani, R. (2008). Sparse inverse covariance estimation with the graphical lasso. *Biostatistics*, *9*(3), 432-441. https://doi.org/10.1093/biostatistics/kxm045

Gilliom, M., & Shaw, D. S. (2004). Codevelopment of externalizing and internalizing problems in early childhood. *Development and Psychopathology*, *16*(2), 313-333. https://doi.org/10.1017/s0954579404044530

Golino, H. F., & Epskamp, S. (2017). Exploratory graph analysis: A new approach for estimating the number of dimensions in psychological research. *PLoS One*, *12*(6), e0174035. https://doi.org/10.1371/journal.pone.0174035

Gross, R. L., Drummond, J., Satlof-Bedrick, E., Waugh, W. E., Svetlova, M., & Brownell, C. A. (2015). Individual differences in toddlers' social understanding and prosocial behavior: Disposition or socialization? *Frontiers in Psychology*, *6*, 132044. https://doi.org/10.3389/fpsyg.2015.00600

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2009). *Análise multivariada de dados*. Bookman editora.

Haslam, D., Mejia, A., Thomson, D., & Betancourt, T. (2019). Self-regulation in low- and middle-income countries: Challenges and future directions. *Clinical Child and Family Psychology Review*, *22*(1), 104-117. https://doi.org/10.1007/s10567- 019-00278-0

Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. *Trends in Cognitive Sciences*, *16*(3), 174-180. https://doi.org/10.1016/j.tics.2012.01.006

Howard, S. J., & Melhuish, E. (2017). An early years toolbox for assessing early executive function, language, self-regulation, and social development: Validity, reliability, and preliminary norms. *Journal of Psychoeducational Assessment*, *35*(3), 255- 275. https://doi.org/10.1177/0734282916633009

Howard, S. J., Neilsen-Hewett, C., de Rosnay, M., Vasseleu, E., & Melhuish, E. C. (2019). Evaluating the viability of a structured observational approach to assessing early self-regulation. *Early Childhood Research Quarterly*, *48*(3), 186-197. https://doi.org/10.1016/jecresq.2019.03.003

Howard, S. J., Vasseleu, E., Neilsen-Hewett, C., de Rosnay, M., Chan, A. Y., Johnstone, S., Mavilidi, M., Paas, F., & Melhuish, E. C. (2021). Executive function and self-regulation: Bi-directional longitudinal associations and prediction of early academic skills. *Frontiers in Psychology*, *12*, 733328. https://doi.org/10.3389/fpsyg.2021.733328

Howard, S. J., Vasseleu, E., Neilsen-Hewett, C., de Rosnay, M., & Williams, K. E. (2022). Predicting academic school readiness and risk status from different assessment approaches and constructs of early self-regulation. *Child and Youth Care Forum*, *51*(2), 369-393. https://doi.org/10.1007/s10566-021-09636-y

Howard, S. J., & Williams, K. E. (2018). Early self-regulation, early self-regulatory change, and their longitudinal relations to adolescents' academic, health, and mental well-being outcomes. *Journal of Developmental & Behavioral Pediatrics*, *39*(6), 489-496. https://doi.org/10.1097/DBP.0000000000000578

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*(1), 1-55. https://doi.org/10.1080/10705519909540118

Huang, R., Geng, Z., & Siraj, I. (2022). Exploring the Associations among Chinese Kindergartners between Academic Achievement and Behavioral, Cognitive and Emotional Self-Regulation. Early Education and Development. https://doi.org/10.1080/10409289.2022.2056695

Instituto Brasileiro de Geografia e Estatística. (2015). Síntese de Indicadores Sociais: uma análise das condições de vida da população brasileira. Estudos & Pesquisas: informação demográfica e socioeconômica n. 35—Rio de Janeiro: IBGE.137p. Available from https://www.ibge.gov.br/biblioteca/visualizacao/livros/liv95011.pdf

Korucu, I., Ayturk, E., Finders, J. K., Schnur, G., Bailey, C. S., Tominey, S. L., & Schmitt, S. A. (2022). Self-regulation in preschool: Examining its factor structure and associations with pre-academic skills and social-emotional competence. *Fron- tiers in Psychology*, *12*, 717317. https://doi.org/10.3389/fpsyg.2021.717317

Kuzik, N., Spence, J. C., Arkko, K., Blye, C.-J., Davie, J., Duddridge, R., Ekeli, T., English, A., Etruw, E., Hunter, S., Lamboglia, C. G., Nesdoly, A., Predy, M., Rubuliak, R., Wohlers, B., Wright, K., & Carson, V. (2022). Associations between meeting the Canadian 24-hour movement guidelines and physical, cognitive, social-emotional, and overall development in early childhood. *Journal of Activity, Sedentary and Sleep Behaviors*, *1*(1), 2. https://doi.org/10.1186/s44167-022-00002-4

Lai, S. K., & Chang, C. M. (2007). The application of aiken content validity coefficient and homogeneity reliability coefficient in enterprise business risks scale for hot-spring hotel industries. *Journal of Management Practices and Principles*, *1*(2), 64-75.

Lauritzen, S. L. (1996). *Graphical models*. Oxford UK. Clarendon Press.

Leighton, K., Kardong-Edgren, S., Schneidereith, T., & Foisy-Doll, C. (2021). Using social media and snowball sampling as an alternative recruitment strategy for research. *Clinical Simulation in Nursing*, *55*, 37-42. https://doi.org/10.1016/j.ecns.2021.03.006

Marsman, M., Borsboom, D., Kruis, J., Epskamp, S., van Bork, R., Waldorp, L. J., van der Maas, H. L. J., & Maris, G. (2018). An introduction to network psychometrics: Relating ising network models to item response theory models. *Multivariate Behavioral Research*, *53*(1), 15-35. https://doi.org/10.1080/00273171.2017.1379379

McClelland, M., Geldhof, J., Morrison, F., Gestsdóttir, S., Cameron, C., Bowers, E., Duckworth, A., Little, T., & Grammer, J. (2017). Self-regulation. *Handbook of Life Course Health Development*, 275-298. https://doi.org/10.1007/978-3-319-47143-3_12

McClelland, M. M., Cameron, C. E., Connor, C. M. D., Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007). Links between behavioral regulation and Preschoolers' literacy, vocabulary, and math skills. *Developmental Psychology*, *43*(4), 947-959. https://doi.org/10.1037/0012-1649.43.4.947

McCoy, D. C. (2019). Measuring young Children's executive function and self-regulation in classrooms and other real-world settings. *Clinical child and family psychology review*, *22*(1), 63-74. https://doi.org/10.1007/s10567-019-00285-1

Melhuish, E., Howard, S. J., Siraj, I., Neilsen-Hewett, C., Kingston, D., de Rosnay, M., Duursma, E., & Luu, B. (2016). Fostering effective early learning (FEEL) through a professional development programme for early childhood educators to improve professional practice and child outcomes in the year before formal schooling: Study protocol for a cluster randomised controlled trial. *Trials*, *17*(1), 1-10. https://doi.org/10.1186/s13063-016-1742-1

Mertens, D. M. (2019). *Research and evaluation in education and psychology: Integrating diversity with quantitative, qualitative, and mixed methods*. Sage publications.

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H. L., Houts, R., Poulton, R., Roberts, B. W., Ross, S., Sears, M. R., Thomson, W. M., & Caspi, A. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(7), 2693-2698. https://doi.org/10.1073/pnas.1010076108

Perry, R. E., Braren, S. H., Blair, C., Vernon-Feagans, L., Cox, M., Burchinal, M., Garrett-Peters, P., Greenberg, M., Mills-Koonce, R., & Willoughby, M. (2018). Socioeconomic risk and school readiness: Longitudinal mediation through children's social competence and executive function. *Frontiers in Psychology*, *9*, 403614. https://doi.org/10.3389/fpsyg.2018.01544

Polishchuk, O., Polishchuk, D., & Yadzhak, M. (2014). Complex evaluation of hierarchically-network systems. *Automatic Control and Information Sciences*, *2*(2), 32-44. https://doi.org/10.12691/acis-2-2-1

Ponitz, C. C., McClelland, M. M., Matthews, J. S., & Morrison, F. J. (2009). A structured observation of behavioral self-regulation and its contribution to kindergarten outcomes. *Developmental Psychology, 45*(3), 605. https://doi.org/10.1037/a0015365

Popping, R. (2019). *Introduction to interrater agreement for nominal data*. Springer.

Raykov, T. (2004). Point and interval estimation of reliability for multiple-component measuring instruments via linear constraint covariance structure modeling. *Structural Equation Modeling*. Vol. *11*, Issue 3, pp. 342-356. Routledge. https://doi.org/10.1207/s15328007sem1103_3

Robinaugh, D. J., Millner, A. J., & McNally, R. J. (2016). Identifying highly influential nodes in the complicated grief network. *Journal of Abnormal Psychology*, *125*(6), 747-757. https://doi.org/10.1037/abn0000181

Robson, D. A., Allen, M. S., & Howard, S. J. (2020). Self-regulation in childhood as a predictor of future outcomes: A meta-analytic review. *Psychological Bulletin*, *146*(4), 324-354. https://doi.org/10.1037/bul0000227.supp

Rocha, M. M., Rescorla, L. A., Emerich, D. R., Silvares, E. F. M., Borsa, J. C., Araújo, L. G. S., Bertolla, M. H. S. M., Oliveira, M. S., Perez, N. C. S., Freitas, P. M., & Assis, S. G. (2013). Behavioural/emotional problems in Brazilian children: Findings from parents' reports on the child behavior checklist. *Epidemiology and Psychiatric Sciences*, *22*(4), 329-338. https://doi.org/10.1017/S2045796012000637

Salami, S., Bandeira, P. F. R., Dehkordi, P. S., Sohrabi, F., Martins, C., Duncan, M. J., Hardy, L. L., & Shams, A. (2023). Investigating the construct validity and reliability of the test of motor competence across Iranians' lifespan. *Perceptual and Motor Skills*, *130*(2), 658-679. https://doi.org/10.1177/00315125231152669

Sörbom, D., & Jöreskog, K. G. (1981). *The use of structural equation models in evaluation research*. Univ., Department of Statistics.

Steiger, J. H. (1990). Structural model evaluation and modification: An interval estimation approach. *Multivariate Behavioral Research*, *25*(2), 173-180. https://doi.org/10.1207/s15327906mbr2502_4

Supplee, L. H., Skuban, E. M., Shaw, D. S., & Prout, J. (2009). Emotion regulation strategies and later externalizing behavior among European American and African American children. *Development and Psychopathology*, *21*(2), 393-415. https://doi.org/10.1017/S0954579409000224

Tucker, R. L., & Lewis, C. (1973). A reability coefficient for maximum likelihood factor analysis. *Psychometrika*, *38*(1), 1-10.

Valentini, F., & Damásio, B. F. (2016). Average variance extracted and composite reliability: Reliability coefficients. *Psicologia: Teoria e Pesquisa*, *32*(2), 1-7. https://doi.org/10.1590/0102-3772e322225

Wesarg, C., van den Akker, A. L., Oei, N. Y. L., Hoeve, M., & Wiers, R. W. (2020). Identifying pathways from early adversity to psychopathology: A review on dysregulated HPA axis functioning and impaired self-regulation in early childhood. *European Journal of Developmental Psychology*, *17*(6), 808-827. https://doi.org/10.1080/17405629.2020.1748594

Williams, K. E., & Bentley, L. A. (2021). Latent profiles of teacher-reported self-regulation and assessed executive function in low-income community preschools: Relations with motor, social, and school readiness outcomes. *Frontiers in Psychology*, *12*, 708514. https://doi.org/10.3389/fpsyg.2021.708514

Zijlmans, E. A. O., van der Ark, L. A., Tijmstra, J., & Sijtsma, K. (2018). Methods for estimating item-score reliability. *Applied Psychological Measurement*, *42*(7), 553-570. https://doi.org/10.1177/0146621618758290

How to cite this article: Lemos, N. B. A. G., Carson, V., Howard, S., Cristi-Montero, C., da Cunha, G. L., Mota, J. G., Okely, A., Bandeira, P. F. R., & de Lucena Martins, C. M. (2024). Evidence of the validity of the child self-regulation & behaviour questionnaire for the Brazilian context. *Infant and Child Development*, e2526. https://doi.org/10.1002/icd.2526