The combination of three movement behaviours is associated with object control skills, but not locomotor skills, in preschoolers

Martins, C., Ribeiro Bandeira, P. F., Filho, A. S., Bezerra, T., Clark, C., Webster, E. K., Mota, J. & Duncan, M.

Original citation & hyperlink:
Martins, C, Ribeiro Bandeira, PF, Filho, AS, Bezerra, T, Clark, C, Webster, EK, Mota, J & Duncan, M 2021, 'The combination of three movement behaviours is associated with object control skills, but not locomotor skills, in preschoolers', *European Journal of Pediatrics*.
https://doi.org/10.1007/s00431-020-03921-z

DOI 10.1007/s00431-020-03921-z
ISSN 0340-6199
ESSN 1432-1076

Publisher: Springer

The final publication is available at Springer via http://dx.doi.org/10.1007/s00431-020-03921-z

The combination of three movement behaviours is associated with object control skills, but not locomotor skills, in preschoolers

Clarice Martins[1,2] & Paulo Felipe Ribeiro Bandeira[3] & Anastácio Souza Filho[1] & Thaynã Bezerra[1] & Cain Clark[4] & Elizabeth Kipling Webster[5] & Jorge Mota[2] & Michael Duncan[4]

Abstract

The objective of this study is to analyze the association between combinations of adherence to movement behaviour recommendations and fundamental movement skills (FMS) in preschoolers. This is a cross-sectional study. Participants of the study were 212 preschool children (M = 3.97 years old; 51.4% male), who provided objectively assessed physical activity (PA) data (Actigraph wGT3X), and completed FMS assessments (TGMD-2). Sleep time and screen time were parent-reported through face-to-face interview. Associations between the combination of two or three movement behaviours and FMS were analyzed using structural equation modeling (Mplus; 8.0; $p < 0.05$). Positive and significant associations were found between adherence to screen + sleep recommendations and locomotor skills ($\beta = 0.23$; $p = 0.027$); and between adherence to PA + screen + sleep recommendations with object control skills ($\beta = 0.28$; $p = 0.014$). Negative and significant associations were found between screen + sleep with object control skills ($\beta = -0.28$; $p = 0.007$). The adherence to the 24-h movement behaviour recommendations explained locomotor and object control skills variability by 5% and 7%, respectively.

Conclusion: The adherence to the combined movement behaviour recommendations may be a more important influence on FMS in preschoolers compared to any single movement behaviour in isolation.

Keywords Physical activity . Screen time . Sleep . Fundamental movement skills . Physical activity . Preschoolers

Abbreviations

SB	Sedentary behaviour
PA	Physical activity
FMS	Fundamental movement skills
ECEC	Early childhood education and care
TGMD-2	Test of Gross Motor Development— Second Edition
BMI	Body mass index
BIC	Bayesian Information Criteria
CFI	Comparative adjustment index
TLI	Tucker-Lewis index
RMSEA	Root mean square error

Introduction

Sleep time, sedentary behaviour and physical activity (PA) comprise the spectrum of movement behaviours that children engage in across a whole day, forming a continuum in which interactions occur between behaviours ranging from sleep (no / little movement), to moderate to vigorous physical activity (MVPA) [1]. Based on previous research findings, the integrative 24-h movement guidelines [2] proposed by the World Health Organization, state that preschoolers aged 3 and 4 years old should spend at least 180 minutes engaged in various physical activities of any intensity, with at least 60 min being of MVPA, no more than 60 min per day of screen time and that good-quality, regular sleep, lasting from 10 to 13 h. For 5-year-old preschoolers besides PA, a healthy 24-h day should include less than 2 h of screen time, and between 9 and 11 hours of good, quality sleep [3].

Prior systematic reviews have highlighted the individual importance of PA, sedentary behaviour, which includes screen time, and sleep, to elicit better health and developmental outcomes [4–6]. However, the degree of evidence provided in these reviews varies from very low to high, depending on the explored behaviour, which may suggest that the adherence to more than one recommended behaviour may potentially have greater health benefits. Nonetheless, global evidence suggests that a significant proportion of children do not adhere to the movement behaviour guidelines [5]. Indeed, these results are particularly important from a lifespan perspective [2], as behaviours established during early childhood tend to track into adolescence and adulthood [7].

Young children's healthy development, which includes motor development, seems to be influenced by the culmination of movement behaviours throughout the day. Early childhood is a critical time to acquire a broad base of fundamental movement skills (FMS) competencies [8], operationally defined as the basis for more complex movements required to participate in sports, games or other context-specific PA throughout the lifespan [9]. FMS are comprised of both locomotor (i.e. transporting the body through space) and object control skills (i.e. projecting or receiving objects in space) dimensions.

Indeed, this acquisition of various FMS might provide the potential for skill transfer [10], which could be related to the execution of individual movement behaviours. Despite a weak-to-moderate degree of evidence, currently available studies show that low levels of PA in childhood [11] may be related to low levels of FMS, and preschoolers who spend an excessive amount of time engaged in screen-based activities are more likely to have lower FMS. Furthermore, the isolated role of sleep on FMS is not well established; however, adequate sleep time is related to the acquisition and retention of information [12], which may impact the FMS learning process.

We have previously reported the association between the adherence to isolated movement behaviour recommendations and FMS in early childhood [13], and the role of the 24-h movement behaviour composition on FMS [14].

Nonetheless, whether the association between the combined adherence of two or three movement behaviours might be more strongly related to FMS than the adherence to a single recommendation is still unknown. Children explore the environment through movement behaviours; thus, when considering the dynamic relationship between PA and FMS [15], and the co-dependency between movement behaviours, it is key to explore how the combined adherence to PA and screen time, PA and sleep, sleep and screen time, and the adherence to the three-combined recommendations impact locomotor and/or object control skills. Given the low prevalence of children who are compliant with all three recommendations worldwide [5], gaining a better understanding of the combinations of movement behaviours that contribute to FMS competencies would be useful for physical education teachers, health professionals and researchers, to develop interventions specifically targeting FMS development. Thus, this study analyzed the association between combinations of adherence to movement behaviour recommendations and FMS in preschoolers.

Methods

Preschool children aged 3 to 5 years, registered in early childhood education and care services (ECEC) of João Pessoa, Brazil, were eligible to participate. We randomly selected one ECEC from six different school districts, which corresponds to 573 preschoolers of varying ages. A total of 276 eligible children were invited to participate, of which, 64 (23%) did not provide consent, or did not have valid measures in any variable. Therefore, the final sample included 212 preschool children with complete movement behaviours and FMS data.

All school staff and parents of the six selected preschools were informed about the goals, protocols and procedures of the research in meetings with the project coordinator, prior to agreeing to participate in the present study.

Each preschool administration provided all the sociodemographic data. Screen and sleep time information were collected during a face-to-face interview with parents/ guardians, and they were also informed about accelerometer use.

Assessments were conducted during a 4-month period. Anthropometric data and FMS were assessed at preschools, and accelerometers were placed on the participating children for a period of seven consecutive days.

PA was measured using accelerometry (Actigraph, model wGT3-X, Pensacola, FL, USA), a valid technique for measuring PA in preschoolers [16]. The preschool teachers of the ECEC received training (verbal and written instructions) for the correct usage of the accelerometer, including placement. Participants were instructed to wear the accelerometer on the right hip for seven consecutive days. Children were allowed to remove the device during water-based activities and while sleeping (at night).

The device initialization, data reduction and analysis were performed using the ActiLife software (Version 6.13.3) (Pensacola, FL, USA). Accelerometers were set to measure ActiGraph counts, considering vector magnitude, and using a 15-s epoch length. Data were reintegrated in 60-s epochs for analysis. Periods of $\geq$ 20 min of consecutive zero counts were defined as non-wear time and removed from the analysis, and the first day of accelerometer data was omitted from the analysis to avoid subject reactivity. Valid data were considered with a minimum of 8 h of wear time, across 3 days (one weekend and two weekdays). The average total wear time was 10.9 h/day (SD $\pm$ 1.4 h).

Time spent in the commonly defined intensity domains (light, moderate and vigorous) was estimated using the cutpoints proposed by Butte et al. [17], for vector magnitude, with light-intensity defined as 820 to 3.907 counts, moderate-intensity defined as 3.908 to 6.111 counts and vigorous-intensity as $\geq$ 6.112 counts.

Parents reported children's usual daily sleep hours and screen time behaviours. This approach has been validated against estimates from sleep logs of objective actigraphy in young children [18]. Parents were asked to recall the total number of hours their child slept, on average, as follows: "On weekdays, how many hours of sleep does your child usually have during the night?" and "On weekend days, how many hours of sleep does your child usually have during the night?" Overall sleep hours were calculated as follows: ((Sleep on weekdays $\times$ 5) + (Sleep on weekend days $\times$ 2))/7. Finally, the results were multiplied by 60 to represent minutes per day.

Parents were also asked to recall the total amount of time, on average, their child watched TV, used the computer and played videogames. The questions addressed weekdays and weekend days separately and were combined in the analysis (Cronbach's α = 0.87). For screen time, 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?" Subsequently, the same procedure used to calculate overall sleep was applied.

FMS were measured using the Test of Gross Motor Development—Second Edition (TGMD-2) [24]. The TGMD-2 is valid and reliable for use in Brazilian children [19]. This test evaluates gross motor performance in children aged 3 to 10 years and consists of two factors: six locomotor skills (run, gallop, hop, leap, jump and slide) and six ball skills (strike, dribble, catch, kick, throw and underhand roll). The TGMD-2 was administered at each preschool, according to the manual guidelines [20]. Before testing each skill, participants were given a visual demonstration of the skill by the researcher using the correct technique, but were not told what components of the skill were being assessed. Participants were then allowed one practice trial. After that, participants performed each skill twice. General encouragement, but no verbal feedback on performance, was given during or after the tests. All skills were video-recorded and later assessed by one trained assessor who did not administer the tests.

Using media player classic software, a total of 4896 videos were analyzed to evaluate the skills' criteria. Two professors in the motor behaviour field, with experience in assessing the TGMD-2, carried out a training program on the protocol's criteria with a master's student who did not participate in the data collection. The training process was carried out over 2 weeks and 10% of the videos were randomly analyzed twice by the evaluator, with an interval of 10 days between each evaluation, to determine the inter-rater intraclass correlation coefficient (ICC). A high agreement for the locomotor score: ICC = 0.93 (95% CI: 0.69–0.98), for the object control score: ICC = 0.98 (95% CI: 0.93–0.99) and for total motor score (MS): ICC: 0.96; (95% CI: 0.82–0.99) were observed. Per the TGMD-2 manual, locomotor and object control scores were based on the presence (one) or absence (zero) of each of the performance criteria. For each subtest, the sum of the raw scores ranged from 0 to 48 points.

All procedures were approved by the university committee and the board of education. The Helsinki Declarations' ethical aspects were followed. The Research Ethics Committee of the Health Science Center and the local board of education approved the study (protocol no. 2.727.698).

Children were classified as adhering or not to the daily movement behaviour recommendations [2, 3] as follow: at least 180 min in various PA of any intensity, with at least 60 min of MVPA, no more than 60 min of sedentary screen time and regular sleep lasting from 10 to 13 h, for 3- and 4year-old preschoolers. For 5-year-old preschoolers, besides PA, less than 2 h of screen time, and between 9 and 11 hours of sleep. The means and standard deviations were calculated for continuous variables and the frequency distributions were calculated for categorical variables. The Kolmogorov Smirnov test was used to test the normality of continuous variables. Cohen's d test was used to calculate the size of the effect of locomotor skills, object control skills and BMI according to sex. The level of significance was set at alpha level of 0.05. Data were analyzed using Jasp v 13.1.

To evaluate the TGMD-2 measurement model, a confirmatory factor analysis was performed with oblique rotation and maximum likelihood estimation method. The Bayesian Information Criteria (BIC) was calculated, and the comparative adjustment index (CFI), the Tucker-Lewis index (TLI) and the root mean square error (RMSEA) were used to assess the model adjustments [21]. An approximate value of 0.90 for CFI and TLI indicates a good fit of the model and the RMSEA values from zero to 0.08 were considered acceptable [22]. After the measurement model was carried out, a structural model was conducted to evaluate the relationship between the combinations of adherence to 24-h movement behaviour (PA, screen time and sleep) recommendations with the FMS. The same adjustment indexes of the measurement model were used in the structural model. Mplus program (version 8.0) was used, and statistical significance was set a priori at $p < 0.05$.

Results

The final sample included 212 children (109 boys). Performance in FMS was similar between boys and girls, differing only in kicking, with a moderate effect size (Table 1). Most of the children did not comply with the 24-h movement behaviour combinations. A higher percentage of adherence to recommendations was seen for boys and girls when combining screen time and sleep (11.92% and 5.82%, respectively).

The original model of the TGMD-2 with 12 FMS, six locomotor and six object control, did not present adequate adjustment indexes in RMSEA (0.112 [0.110–0.112]), CFI (0.84) and TLI (0.79). The factorial loads of the run and leap skills were low (< 0.20). Therefore, a second model was tested without the run and leap skills. The adjustment indices showed adequate values RMSEA (0.07 [0.05–0.09]), CFI (0.92) and TLI (0.90). The table of adjustment indices and the final measurement model can be found in the supplementary material.

Table 2 details the associations between the combination of 24-h movement behaviours with locomotor and object control skills. Positive and significant associations were found between screen + sleep recommendations with locomotor skills ($\beta = 0.23$; $p = 0.027$), and between PA + screen + sleep recommendations with object control skills ($\beta = 0.28$; $p =$
0.014). Negative and significant associations were found between screen + sleep and object control skills ($\beta = -0.28$; $p = 0.007$). The 24-h movement behaviour variables explained locomotor and object control skill variability by 5% and 7%, respectively. The structural model adjustment indexes showed adequate values (Fig. 1).

Table 1 Sample's characteristics and differences by gender

Variables	Boys M (SD)	Girls M (SD)	Cohen's d	
Hop	3.04 (2.52)	3.16 (2.60)	− 0.046	
Leap	3.31 (1.89)	2.68 (1.90)	0.333	
Jump	3.56 (2.90)	3.26 (2.82)	0.107	
Slide	2.42 (2.84)	2.19 (2.70)	0.082	
Strike	4.42 (2.41)	3.65 (2.25)	0.330	
Dribble	0.83 (1.74)	0.82 (1.63)	0.006	
Catch	3.01 (1.64)	2.68 (1.78)	0.192	
Kick	6.54 (1.58)	5.78 (1.54)	0.482	
Throw	1.76 (2.23)	1.28 (2.05)	0.223	
Roll	2.27 (1.88)	1.75 (1.85)	0.277	
BMI	15.93 (1.68)	15.96 (1.67)	− 0.020	
Movement behaviours	Boys N (%)		Girls N (%)	
	Compliant (%)	Non-compliant (%)	Compliant (%)	Non-compliant (%)
PA_SC_SL	3 (2.75)	106 (97.24)	2 (1.94)	101 (98.05)
PA_SC	5 (4.58)	104 (95.41)	5 (4.85)	98 (95.14)
PA_SL	13 (11.92)	96 (88.07)	6 (5.82)	97 (94.17)
SC_SL	4 (3.67)	105 (96.33)	4 (3.88)	99 (96.11)

Legend: PA, physical activity; SC, screen; SL, sleep

Discussion

This study analyzed the association between combined adherence to movement recommendations and FMS in preschoolers. The results of the current study demonstrate that adherence to the three movement behaviour recommendations is positively associated to object control skills in preschoolers. Although prior studies have shown the very low to high evidence on the relationship between single movement behaviours and FMS [4–6], and that the daily composition of movement behaviours positively predicts FMS in preschoolers[14], to the authors' knowledge, this is the first study to explore how adherence to different combinations of movement behaviours is associated with locomotor and object control skills. Results concerning the isolated movement behaviour associations are ambiguous in evidencing its potential predictive role on FMS in early childhood [23–25]. As a consequence, the results of the current study make a novel contribution to the literature on this topic.

FMS mastery develops in a slow and gradual process [8], and is influenced by biological [23], social and environmental aspects [26]. The skills analyzed require a high demand for neuromotor control in the interaction between the neural and musculoskeletal systems [27] and for the interaction with the environment, which are improved through lived motor experiences [10]. Evidence suggests that PA, and especially MVPA [14], is associated with greater scores in object control skills. Moreover, object control skills require a greater cognitive demand, which is dependent on the type of sedentary behaviour developed [28], and also take longer to develop, when compared to locomotor skills [29]. Our findings may suggest that object control skills are more difficult to improve than locomotor skills. This may be due to the greater skill component complexity and perceptual demand of object control skills, which may require more intensive skill instruction and practice [29]. Also, there is a predisposing assumption that to undertake many of the object control skills in a proficient manner, the child needs at least adequate locomotor skills; for example in the TGMD-2 assessment, the throw, strike, kick, for example, have a locomotor element in the behavioural components that are used to score them. Although excessive screen time should be discouraged [28], screen time that is considered carefully managed, and where possible, replaced by a "quality" sedentary behaviour in terms of content and co-viewing with parent could be included throughout the day (e.g. reading with a parent). Additionally, during sleep, the neuroplasticity process occurs, which is essential for memory consolidation [30] and may suggest an important component for skills acquisition and development. The positive association observed between compliance with the combined three movement behaviours and object control skills in the current study reinforces the potentially greater impact of combined movement behaviours on health outcomes, rather than focusing on single behaviours, as has been the case in prior studies.

Throughout the day, children's movement hours are predominantly comprised of sedentary time. In this sense, a recent study has reported that adding even just 10 min of [1] a certain behaviour can markedly influence preschoolers' FMS [14], and that is important for future movement experiences. If children change behaviours by 10 mins a day, the cumulative weekly amount of PA or MVPA is increased by 70 mins, which would constitute a meaningful change. Thus, the significant results reported in our study could potentially be meaningful in showing the best combination of movements behaviours for the children's daily functioning, particularly with reference to the fact that FMS are the basic building blocks for all future movements, and crucial for participation and engagement in sports, games and other forms of PA during childhood and adolescence [15].

It is, however, important to note that the relationship between the combination of the three movement behaviours and locomotor skills was not significant. Possibly, in this age group, interactions between movement behaviour combinations are more sensitive to fluctuations in object control skills, as previously reported [13]. It is plausible to suggest that locomotor skills are developed earlier, and play a primary role in the acquisition of more complex motor skills [29], such as those involved in sports. Moreover, there are also skills, such as walking skills, that develop first, and therefore are less sensitive to significant interactions with 24-h movement behaviours.

Table 2 Associations between combination of movement behaviours and motor skills

Variables	Locomotor				Object control			
	B	SE	p	R^2	B	SE	p	R^2
PA + SC + SL	0.20	0.11	.081		0.28	0.11	0.014	
PA + SC	− 0.07	0.09	.432	0.05	− 0.07	0.09	0.457	0.07
PA + SL	− 0.12	0.08	0.156		− 0.15	0.08	0.074	
SC + SL	0.23	0.10	0.027		− 0.28	0.11	0.007	

PA, physical activity; SC, screen; SL, sleep

The results of the present study also highlight that adherence to both the sleep and screen time recommendations was positively associated with locomotor skills, and negatively associated with object control skills. The positive association observed with locomotor skills is, to some extent, expected. Lower screen time exposure predisposes children to more free time to explore the environment and engage in PA opportunities, as in MVPA, which are strongly related to proficient movement skills [29]. It is plausible to argue that this predisposition increases when preschoolers are compliant with sleep time recommendations. Indeed, those with good night time sleep tend to have less time spent in daytime naps [31] and decrease the chance of getting drowsy or irritated throughout the day. Conversely, a negative association was observed between the combined compliance with these two behaviours (i.e. sleep and screen time) and object control skills, which may suggest that MVPA has a determining role in improving object control skills, once when children comply with all three 24-h movement behaviours, the relationship becomes positive. This hypothesis is supported by previous theoretical models [10, 15].

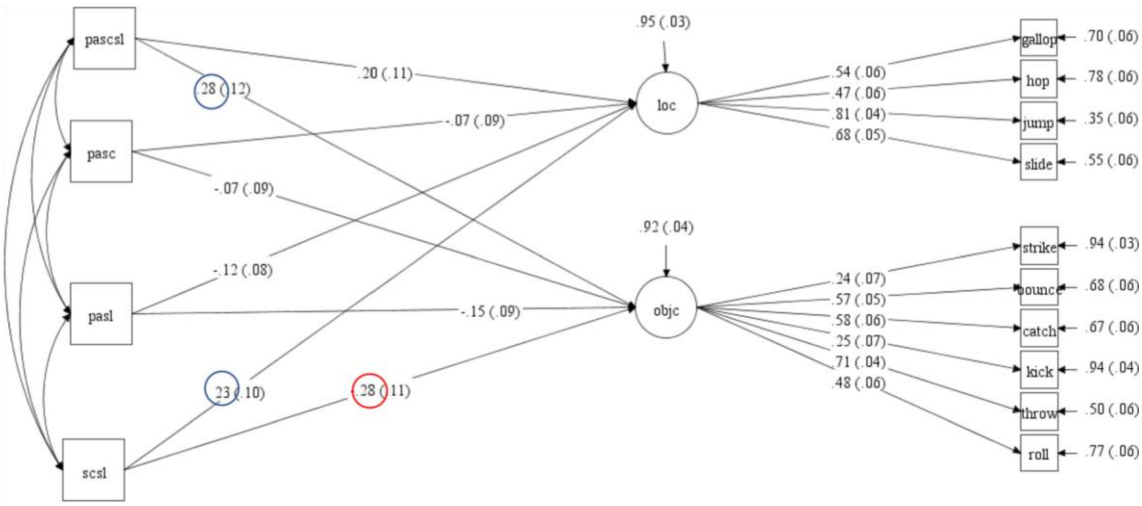

Fig. 1 Structural model of the association of FMS with 24-h movement behaviour. (pascsl = physical activity + screen time + sleep; pasc = physical activity + screen time; pasl = physical activity + sleep time; scsl = screen time + sleep time)

The current study is not without limitations which should be considered when interpreting the results. The study is specific to a Brazilian preschooler cohort, with specific context and cultural characteristics. As there are no prior published studies that the authors are aware of, which have addressed the combination of 24-h movement behaviours on motor competence, direct comparisons with other studies are difficult to make. This highlights the need for further examination of this topic in different countries and in different environmental contexts. Indeed, compliance with movement behaviours is also driven by environment correlates, such as socioeconomic factors, family environment, access to PA opportunities, that are contributing factors that warrant further investigation. Moreover, the parent-reported assessment of sleep time is a limitation in the current study and objective measures of sleep, although difficult to undertake with preschoolers, should be considered for future research.

Based on the limited number of children adhering to the combined movement guideline recommendations, the reduced sample size may have influenced the strength of the present study's results. However, appropriate adjustments were made in the analysis for individual and general indices of the model, to account for a smaller sample size [32]. Despite this, the practical evidence that achieving all three recommended movement behaviours may allow children to get involved in activities that are specific to the manipulation of objects, which are generally found in sport-specific contexts activities, is an important strength of the current study, especially when considering the adherence of three movement behaviour recommendations simultaneously, which to date has not been forthcoming in the literature.

Conclusion

Our results suggest that combined compliance with the three movement behaviour recommendations, consisting of sleep, screen time and PA, is positively associated with object control skills, but not with locomotor skills in preschool children. Public health practitioners should be aware that the combination of sedentary time(i.e. screen time) and sleep is positively associated with locomotor skills, and negatively associated with object control skills. Given the importance of developing FMS, and especially object control skills for future health benefits, the current results suggest that combination of movement behaviours may be a more important influence on FMS in preschoolers, more than any single movement behaviour in isolation.

Practical implications

Combined compliance with sleep time, screen exposure and physical activity recommendations is positively associated with object control skills in preschoolers;

The combination of screen time and sleep adherence is positively associated with locomotor skills, and negatively associated with object control skills.

Public health practitioners should be aware that the compliance with movement behaviour recommendations may be a more important influence on motor skills in preschoolers, than any isolated movement behaviour.

References

1. Pedisic Z, Dumuid D, Olds T (2017) 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 49:252–269
2. World Health O (2019) Guidelines on physical activity. In: sedentary behaviour and sleep for children under 5 years of age. World Health Organization, Geneva
3. Tremblay MS, Carson V, Chaput JP (2016) Introduction to the Canadian 24-hour movement guidelines for children and youth: an integration of physical activity, sedentary behaviour, and sleep. Appl Physiol Nutr Metab 41:iii–iv
4. Carson V, Lee E-Y, Hewitt L, Jennings C, Hunter S, Kuzik N, Stearns JA, Unrau SP, Poitras VJ, Gray C, Adamo KB, Janssen I, Okely AD, Spence JC, Timmons BW, Sampson M, Tremblay MS (2017) Systematic review of the relationships between physical activity and health indicators in the early years (0-4 years). BMC Public Health 17:854
5. Chaput JP, Colley RC, Aubert S, Carson V, Janssen I, Roberts KC, Tremblay MS (2017) Proportion of preschool-aged children meeting the Canadian 24-hour movement guidelines and associations with adiposity: results from the Canadian Health Measures Survey. BMC Public Health 17:829
6. Poitras VJ, Gray CE, Janssen X, Aubert S, Carson V, Faulkner G, Goldfield GS, Reilly JJ, Sampson M, Tremblay MS (2017) Systematic review ofthe relationships between sedentary behaviour and health indicators in the early years (0–4 years). BMC Public Health 17:868
7. Telama R, Yang X, Leskinen E, Kankaanpää A, Hirvensalo M, Tammelin T, Viikari J, Raitakari O (2013) Tracking of physical activity from early childhood through youth into adulthood. Med Sci Sports Exerc 46:955–962
8. Metcalfe J, Clark J (2002) The mountain of motor development: a metaphor. Motor Dev Res Rev 2:183–202
9. Clark JE, Metcalfe JS (2002) The mountain of motor development: a metaphor. J Motor Dev Res Rev 2:183–202
10. Hulteen R, Morgan P, Barnett L, Stodden D, Lubans D (2018) Development of foundational movement skills: a conceptual model for physical activity across the lifespan. Sports Med 48:1533–1540
11. Jones D, Innerd A, Giles EL, Azevedo LB (2020) Association between fundamental motor skills and physical activity in the early years: a systematic review and meta-analysis. J Sport Health Sci 6: 542–5552
12. Figuerola W, Ribeiro S (2013) Sono e plasticidadeneural. Rev USP 28:17
13. Martins C, Clark C, Ribeiro Bandeira P, Mota J, Duncan M (2020) Association between compliance with the 24-hour movement guidelines and fundamental movement skills in preschoolers: a network perspective. Int J Environ Res Public Health 17:5443
14. Mota JA-O, Clark CA-O,Bezerra TA-O,Lemos LA-O,ReuterCAO,MotaJA-O,DuncanMA-O,Martins CA-O (2020) Twenty-fourhour movement behaviours and fundamental movement skills in preschool children: a compositional and isotemporal substitution analysis. J Sports Sci 38:2071–2079
15. Stodden D, GoodwayJ, LangendorferS,RobertonMA,Rudisill M, Garcia C, Garcia L (2008) A developmental perspective on the role of motor skill competence in physical activity: an emergent relationship. Quest 60:290–306
16. Bornstein D, Beets M, Byun W, McIver K (2011) Accelerometerderived physical activity levels of preschoolers: a meta-analysis. J Sci Med Sport 14:504–511

17. Butte N, Wong W, Lee J, Adolph A, Puyau M, Zakeri I (2013) Prediction of energy expenditure and physical activity in preschoolers. Med Sci Sports Exerc 46:1216
18. Goodlin-Jones B, Sitnick S, Tang K, Liu J, Anders T (2008) The Children's Sleep Habits Questionnaire in toddlers and preschool children. J Dev Behav Pediatr 29:82–88
19. Valentini N (2012) Validity and reliability of the TGMD-2 for Brazilian children. J Mot Behav 44:275–280
20. Ulrich DA, Sanford CB (2000) Test of Gross Motor Development : examiner's manual. Pro-Ed, Austin
21. Hu Lt BPM (1999) Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct Equ Model Multidiscip J 6:1–55
22. Browne MW, Cudeck R (1992) Alternative ways of assessing model fit. Sociol Methods Res 21:230–258
23. Barnett L, Hinkley T, Okely AD, Salmon J (2013) Child, family and environmental correlates of children's motor skill proficiency. J Sci Med Sport 16:332–336
24. Vitor L, Lisa B, Luís R (2016) Is there an association among actual motor competence, perceived motor competence, physical activity, and sedentary behaviorinpreschool children?J MotorLearn Dev4: 129–141
25. Sugawara SK, Tanaka S, Tanaka D, Seki A, Uchiyama HT, Okazaki S, Koeda T, Sadato N (2014) Sleep is associated with offline improvement of motor sequence skill in children. PLoS ONE 9:e111635
26. Kwon S, O'Neill M (2020) Socioeconomic and familial factors associated with gross motor skills among US children aged 3–5 years: the 2012 NHANES National Youth Fitness Survey. Int J Environ Res Public Health 17:4491
27. Limburg K, Jung NH, Mall V (2016) Chapter 2 - Assessing normal developmental neurobiology with brain stimulation. In: Kirton A, Gilbert DL (eds) Pediatric brain stimulation. Academic Press, Oxford, pp 23–43
29. Carson V, Kuzik N, Hunter S, Wiebe S, Spence J, Friedman A, Tremblay M, Slater L, Hinkley T (2015) Systematic review of sedentary behavior and cognitive development in early childhood. Prev Med 78:115–122
30. Morgan PJ, Barnett LM, Cliff DP, Okely AD, Scott HA, Cohen KE, Lubans DR (2013) Fundamental movement skill interventions in youth: a systematic review and meta-analysis. Pediatrics 132: e1361
31. Tononi G, Cirelli C (2014) Sleep and the price of plasticity: from synaptic and cellular homeostasis to memory consolidation and integration. Neuron 81:12–34
32. Spencer RMC, Campanella C, de Jong DM, Desrochers P, Root H, Cremone A, Kurdziel LBF (2016) Sleep and behavior of preschool children under typical and nap-promoted conditions. Sleep Health 2:35–41
33. Bentler P, Yuan K-H (1999) Structural equation modeling with small samples: test statistics. Multivar Behav Res 34:181–197