Adherence to 24-Hour Movement Guidelines in Low-Income Brazilian Preschoolers and Associations with Demographic Correlates

Martins, C, Lemos, L, Neco de Souza Filho, A, Bezerra , TA, Soares, I, Mota, J, Bandeira, P, Mota, J, Tassitano, R & Duncan, M

DOI 10.1002/ajhb.23519
ISSN 1042-0533

Publisher: Wiley

Adherence to 24-Hour Movement Guidelines in Low-Income Brazilian Preschoolers and Associations with Demographic Correlates

24-Hour Movement Brazilian Preschoolers

Clarice Maria de Lucena Martins[1], Luis Filipe Gomes Barbosa Pereira Lemos[1], Anastácio Neco de Souza Filho[1], Thaynã Alves Bezerra[1], Ivina Andréa Aires Soares[2], Jéssica Gomes Mota[1], Paulo Felipe Ribeiro Bandeira[3], Jorge Augusto Pinto Silva Mota[4], Rafael Miranda Tassitano[5], Michael Joseph Duncan[6]

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

[2] Education Department of Ceará State, Brazil

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

[4] Research Center on Physical Activity, Health and Leisure, Faculty of Sport, University of Porto, Porto, Portugal

[5] Department of Physical Education, Federal Rural University of Pernambuco, Dom Manoel de Medeiros, Pernambuco, Brazil

[6] Centre for Applied Biological and Exercise Sciences, Coventry University, Coventry, United Kington.

Abstract

Background: The importance of movement behaviours for health is well known, although few studies have examined the adherence to movement guidelines in low-income preschoolers from a middle-income country, as Brazil. This study reports the proportion of preschoolers meeting the 24-hour movement guidelines and investigates its associations with demographic correlates in Brazilian low-income preschoolers. Methods: Two hundred and seventy preschoolers (132 boys, means age = 3.97 ± 0.80) provided physical activity (PA) data (Actigraph wGT3X). Sleep duration, screen time, and social correlates were parent-reported. Preschoolers were classified as compliant/not compliant with the 24-hour movement guidelines. Relationships between compliance with movement behaviours guidelines and demographic correlates were calculated using a network analysis (Mplus 8.0; Rstudio). Results: Preschoolers were active (273.52 ± 62.08 minutes/day of total PA), though moderate-to-vigorous physical activity (MVPA) time was below the guideline (58.68 ± 22.51 minutes/day); spent more than the recommended 60minutes/day on screen time (169.91 ± 97.07minutes/day); and slept less than 10 hours per night (9.44 ± 1.12 hours/day). Only 3% of the sample complied with the guidelines. PA showed the highest compliance (43%), compared to sleep duration (35%) and screen time (15%). Male sex was related to adherence to MVPA recommendations, while female sex, with adherence to total PA recommendations. Child´s primary caregivers was the most important centrality indicator in the network. Conclusion: Only 3% of the assessed preschoolers are compliant with the 24-hour movement behaviours guidelines. Strategies to promote adherence to movement behaviours among low-income preschoolers should consider child´s primary caregivers to support movement behaviours.

Keywords: 24-hour movement behaviours, sleep, physical activity, screen time, preschoolers, low-income

1. Introduction

There has been increasing interest in public health research and practice related to physical activity (PA), sedentary behavior and sleep time throughout the day, as research has shown that these combined behaviors are related to health (Chastin, Palarea-Albaladejo, Dontje, & Skelton, 2015). The most recent World Health Organization (WHO) 24-Hour guidelines on Movement behaviours for the Early Years (WHO, 2019) recommend that, for preschoolers up to 4 years-old, a healthy 24-h during the day includes: i) ≥180 minutes of PA, including at least 60 minutes of moderate-to-vigorous physical activity (MVPA), ii) ≤1 hour of sedentary screen time, and iii) between 10 and13 hours of good quality sleep. For the 5 years-old children, Tremblay et al., (2016) stated that besides PA, a healthy 24-h day should include less that 2 hours of sedentary screen time, and between 9 and 11 hours of good quality sleep.

Although the importance of these movement behaviours for health is evident, results from high-income countries have shown that less than 15% of preschool aged-children are compliant with the three recommendations of the guidelines (Chaput et al., 2017; Cliff et al., 2017; De Craemer, McGregor, Androutsos, Manios, & Cardon, 2018). Even considering there is some country to country differences, similar low adherence to the movement guidelines has been observed. For example, a study from Canada reported that 12.7% of preschool children adhered to the 24-h movement behaviour recommendations, with a high proportion meeting the sleep duration and the PA recommendations, and only a limited percentage meeting the screen time recommendation (Chaput et al., 2017). For Australian preschoolers, similar results were observed, and 14.9% of children met all three guidelines (Cliff et al., 2017). Craemer et al. (2018) showed lower compliance values for Belgian preschool-aged children, according to week and weekend days (10.1% and 4,3%, respectively), with the lowest compliance seen for the PA recommendations. Conversely, a recent systematic review with South-American preschoolers reported that a great number of studies has presented moderate PA levels exceeding 60 minutes per day, and a high exposure to screen time, though almost half of the studies used subjective measures of PA, and the adherence to the combined recommendations have not been assessed (Guerra et al., 2020).

Young children from low-income families are less likely to be engaged in structured PA opportunities (Chang & Kim, 2017), spend a great ammount of sedentary time (Santana et al., 2017), and compared to those from high-income contexts, engage in significantly more weekly screen time (Carson, Spence, Cutumisu, & Cargill, 2010). Moreover, sedentary behaviors in low-income families are at an all-time high, with startling levels of screen time documented at young ages (Yang-Huang et al., 2017) . Indeed, TV watching has been seen as integral to family life, including watching during meals and using TV to occupy children (Lindsay, Sussner, Greaney, & Peterson, 2009).

This is also compounded by the fact that children from low-income families go to bed later (Blair et al., 2012), and are at risk for insufficient sleep (Bagley, Kelly, Buckhalt, & El-Sheikh, 2015), once poverty has been highlighted as a risk for short sleep duration (Armstrong, Covington, Hager, & Black, 2019). One explanation for these findings could be related to the family environment, where demographic factors may affect preschooler´s movement behaviours. Factors such as parenting practices and expectations, family routines, cultural preferences, and child care schedules can all influence sleep (Crabtree & Williams, 2009).

Indeed, examining the adherence to 24-h movement behavior in children from low-income families is a complex challenge that comprises three main theoretical attributes: the first is related to the various factors involved, of different levels and scales; the second is related to the non-linear relationship between those variables that can affect 24-hour movement behavior; and the third aspect is related to the several research areas, aims and perspectives that are related to movement behaviours. Thus, movement behaviors are complex and occur nonlinearly in the real world. In this sense, the relationship between 24-h movement behaviours adherence and its demographic correlates should be addressed from the paradigm of complex adaptive systems (CAS) (Carmichael & Hadžikadić, 2019).

To date, the possible relationships between 24-h movement behaviours adherence with demographic correlates, such as mother´s educational level, presence of siblings at home, parent's unemployment, and primary caregivers, as a CAS, where the emerging pattern allows the identification of the most important variables to maintain a desirable theoretical pattern of the system (Schmittmann et al., 2013), remains an unexplored area. This approach is particularly important to understand the network effects of all related variables on movement behaviours and, consequently, to better plan interventions and public policies. Moreover, it is important to investigate the proportion of low-income preschool children complying with the established guidelines to inform researchers which percentage of preschoolers already engage in healthy 24-h days. To our knowledge, no study in Brazil has explored the compliance with the 24-h movement behaviours guidelines in preschool-aged children, especially those preschoolers in low-income contexts, and how demographic correlates may be associated with this compliance. Brazil is a middle-income country with extreme social inequalities, characterized by an abyss between life conditions of the riches and the poorest families. Brazilian low-income preschoolers are exposed to precarious basic life indicators, such as housing structure, health care access, education, and security conditions, that could restrict their opportunities to health movement behaviours. Therefore, this study aims to report the proportion of Brazilian low-income preschoolers meeting the 24-hour movement guidelines and investigates associations with demographic correlates through a network perspective.

2. Methods

2.1 Setting and Population Characteristics

For this cross-sectional study, preschool children aged 3- to 5-year-old, of both sexes, and registered in early education childhood centers (EECC) of João Pessoa were eligible. João Pessoa is a large seaside city in the northeast of Brazil, with a mixture of low to middle income, and formal, as well as informal housing. The preschool public education zone is organized in nine districts, where eighty-six EECC are located, and fifty institutions have 3-to-5 years registered students. From the ten institutions that are located in deprived zones, six EECC were randomly selected and included in the study.

At these deprived low-income areas, the majority (62.5%) of mothers or fathers were unemployed. Over 45% of the mothers and 54% of the fathers had finished the 9th grade or less. The Human Development Index (HDI) for the EECC´s areas range from 0.4 to 0.5 (low). The sample size estimation was conducted (prevalence of 50%; 95% confidence interval; 5% maximum of tolerance error; design effect of 1.0), and the minimum required sample size was 230 preschoolers; 20% more children were included to account for potential loss (drop out and hardware failure). All children aged 3 to 5 years-old attending the 6 schools (322) were invited for assessments.

2.2. Procedures

All the preschools' staff and parents were informed about the research's goals, protocols, and procedures in meetings with the project coordinator (one session in each school) and agreed to participate in the present study. Trained physical education teachers and graduate students conducted the assessments. The school administration provided all socio-demographic data (children's age, birth date, parent's contact, and address). Parents / caregivers were invited for a meeting at school and were interviewed individually. The interview was conducted with different children´s caregivers (5.4% fathers, 76.2% mothers, 2.0% older brothers, 8.8% grandparents, 2.2% uncle, 5.4% others). Demographic information, and screen and sleep time were collected during this interview.

Assessments were conducted during a four-month period (November / December, 2019, and February / March, 2020). Anthropometric data were assessed at preschools, and the accelerometer was placed in the participating children, who used it during 7 consecutive days. Accelerometer measurements were obtained from 270 children who provided valid measurements based on the data reduction criteria.

2.3. Measurements

2.3.1. Anthropometric Measures

Height (cm) and body mass (kg) were assessed using a *Holtain* stadiometer, and weighting scale (Seca 708, Germany), while the participant was lightly dressed and barefoot. Two measures were taken, if they differed, the average value was adopted. BMI was calculated by dividing body weight with the squared height in meters (kg/m^2) (Cadenas-Sanchez et al., 2016), and children were classified according to the WHO cut-offs (de Onis, Garza, Onyango, & Rolland-Cachera, 2009).

2.3.2. Physical Activity

PA was objectively assessed using accelerometer (Actigraph, model WGT3-X, Florida), a valid instrument for measuring PA in preschoolers (Bornstein, Beets, Byun, & McIver, 2011). The preschool teachers received training (verbal and written instructions) for the correct use of the accelerometer, including placement, and the proper positioning. The participants were instructed to wear the accelerometer on the right hip 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). During preschool time, accelerometers were removed by teachers around 11 am for children´s bath and attached properly after it. Parents were also instructed to remove the belt during night and attach when children woke up.

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 and using a 15-s epoch length (Cliff, Reilly, & Okely, 2009), and data were reintegrated in 60-s epochs for analysis. Periods of ≥ 20 min of consecutive zero counts were defined as non-wear time and removed from the analysis (Esliger, Copeland, Barnes, & Tremblay, 2005). The first day of accelerometer data was omitted from analysis to avoid subject reactivity (Esliger et al., 2005). Valid data were considered for a minimum of 8 h of wear time, during at least three days (one weekend day and two weekdays), as done in previous study with similar sample (Montgomery et al., 2004). The mean wear time was 10.9 hours (SD ± 1.4h of wear time between children).

Time spent in the commonly defined intensity domains light, moderate and vigorous was estimated using the cut-points proposed by Butte et al. (2014) 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 ≥ 6.112 counts. The amount of time spent sedentary was set at 819 counts. For the statistical analysis, Total physical activity (TPA), Light physical activity (LPA) and MVPA was considered.

2.3.3. Sleep Time

Parents reported children's usual daily sleep hours. Parents 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 night?" and "On weekend days, how many hours of sleep does your child usually have during the night?". Separate questions were asked for weekdays and weekend days and were subsequently merged for analysis. Overall sleep hours were calculated as follows: ((Sleep on weekdays x 5) + (Sleep on weekend days x 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). This approach has been validated against estimates from sleep logs and objective actigraphy in young children (Goodlin-Jones, Sitnick, Tang, Liu, & Anders, 2008)

2.3.4. Screen Time

Parents were also asked to recall the total average duration their child watched TV, used the computer, smartphones, and videogames. The questions were made separately for weekdays and weekend days and reunited to analyzes (Cronbach's $\alpha = 0.87$). For screen time the questions were: "How many hours during a week day does your child usually watch TV, use computer, smartphones or electronics games?" and "How many hours during a weekend day does your child usually watch TV, use computer, smartphones or electronics game?". Then, the same procedure used for sleep hours was applied.

2.3.5. Demographic Correlates

Mother´s educational level, presence of siblings at home, parents´ unemployment, and child´s primary caregivers were reported by children´s parents/ guardians.

Considering that the Brazilian Institute of Geography and Statistics defined mother´s education as a socio-economic status indicator (IBGE, 2010), as there is a strong correlation between mothers' education and family income and social status, this variable was used in the study. Response categories for mother's educational level were: 1) illiterate; 2) incomplete elementary school; 3) completed elementary school; 4) incomplete high school; 5) completed high school; 6) incomplete higher education; 7) completed higher education or more. For analysis purpose, data were dichotomized in: 1) incomplete high school or less; 2) completed high school or more.

Presence of siblings at home were answered as a continuous number and dichotomized in: 1) yes; 2) no. The same dichotomization was used for parent´s unemployment. Response categories for child´s primary caregivers were: 1) parents; 2) family member (grandparents, aunts/uncles); 3) others. For analysis purpose, data were dichotomized in: 1) parents; 2) others. Family income was categorized as: 1) up to a minimum salary; 2) more than a minimum salary.

2.4. Statistical Procedures

All variables were checked for normality using Kolmogorov–Smirnov tests. Descriptive analyses for continuous variables and frequency analyses for categorical variables were performed. The statistical differences between age groups were tested using ANOVA - analysis of variance, with Bonferroni's post hoc comparisons. A two-sided student's T-test and Cohen's d effect size were used to compare continuous mean values between sexes. Children were classified as compliant with movement behaviours guidelines by age, when: a) PA: TPA ≥ 180 min/day, including MVPA ≥ 60 min/day); b) screen time: ≤ 60 min/day for 3 and 4 years-old children, and ≤ 120 min/day for 5 years-old children; and c) sleep time: 10 ≥ 13h/day for 3 and 4 years-old children, and 9 ≥ 11h/day for 5 years-old children (WHO, 2019; Tremblay et al., 2016). The level of significance was set at alpha level of 0.05. Data were analyzed using SPSS Windows v 20.0 (SPSS Inc, Chicago, Illinois).

To analyze the association between guidelines adherence and demographic correlates, The Network Analysis Machine Learning technique was used, which aims to establish interactions between variables from a graphical representation. The "Fruchterman-Reingold" algorithm was applied so, data were presented in the relative space in which variables with stronger associations remain together, and the less strongly associated variables were repelled from each other (Fruchterman & Reingold, 1991). The least absolute contraction and selection operator was used to obtain regularization and to make the model less sparse (Friedman, Hastie, & Tibshirani, 2007). The EBIC parameter was adjusted to 0.25 to create a network with greater parsimony and specificity (Foygel & Drton, 2010).

To quantify the importance of each node (variable) in the network, we calculated the betweenness, closeness and strength centrality indices: (1) betweenness centrality, estimated from the number of times that a node is part of the shortest path among all other pairs of nodes connected to the network, is important to identify the variables that are most sensitive to interventions; (2) closeness centrality, determined from the inverse of the distances from one node to all others, is a variable that will be quickly affected by changes in any part of the network, and will also spread the effect in other parts of the network (3) strength centrality, which is the sum of all the weights of the paths that connect a node to the others. Each of these indices were normalized (mean = 0, and standard deviation (SD) = 1), so that an index value of > 1 indicates that it is > 1 SD from the mean. The red colors indicated negative associations and the blue positive relationships between the variables. The thickness and intensity of the color are related to the intensity of the associations. Analyses were performed in the qgraph package of the Rstudio program.

2.5 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. 2.727.698).

3. Results

A total of 322 eligible children were invited to participate, of which 52 (16%) did not provide consent, did not validate accelerometer data, or parents did not participate in the interview. The final sample included 270 preschool children with complete movement behaviour data. The majority (67.4%) of children were classified as normal weight, 10% as underweight, and 22.6% as overweight/obese. On average preschoolers had more than the recommended 180 minutes / day physically active (273.52 ± 62.08 minutes/day), but spent less that the recommended 60 minutes/day on MVPA (58.68 ± 22.51minutes/day), spent a greater amount of time on screen (169.91± 97.07 minutes/day) and slept less than 10 hours per night (9.44±1.12 hours/day). A statistically significant difference in MVPA was observed between sex, being boys more active and had more sleep time than girls, and between 3 and 5 years-old children MVPA ($p \leq 0.05$) (Table 1).

**************************Insert Table 1 ********************************

Compliance with each single movement behaviours recommendation by age is presented in Table 2. The higher percentage of children compliant with PA, screen, and sleep time recommendations was seen for the 5 years-old children (54.2%, 24.1%, and 71.1%, respectively).

************************** Insert Table 2 **********************************

Regardless of sex, only 3% of the entire sample complied with the overall 24-h movement behaviours recommendations, and 16% or less complied the combination of at least two movement behaviours. PA was the behavior with higher compliance (43%) compared to sleep time (35%) and screen time (15%). Furthermore, our data also showed a higher percentage of girls who were not compliant with any of the recommendations (Figure 1a-c).

********************** **Insert Figure 1** **********************************

The network configuration showed that children´s compliance with sleep recommendations was related to being female, and to compliance with MVPA, and screen recommendations. Conversely, children not being compliant with sleep recommendations was associated with higher BMI, and having parents as primary caregivers. Male sex was related to adherence to MVPA recommendations, while female sex, with adherence to TPA recommendations. Moreover, sex, child´s primary caregivers, and adherence to MVPA, TPA, and sleep time recommendations were located closely in the network. Conversely, BMI, screen adherence, age and mother´s educational level were positioned in peripheral regions of the network (Figure 2; Supplementary file 1).

************************** **Insert Figure 2** ******************************

The network configuration can be explained from the centrality indicators (Table 3). Adherence to TPA recommendations, child´s primary caregivers and sex showed greater strength, which indicates that the strongest relationships were established with these variables in the current network format. The variables with the highest betweenness were TPA adherence, sleep adherence, and child´s primary caregivers. These variables act as hubs, as the connection between variables of the two clusters goes through these three variables (see Figure 2). For the closeness indicator, adherence to TPA recommendations, sex and child´s primary caregivers showed the highest values.

**************************** **insert Table 3******************************

4. Discussion

The purpose of this study was to evaluate the proportion of preschool children (3 to 5 years-old) that adhere the 24h movement behaviors guidelines, and investigate the association with demographic correlates in low-income children from a middle-income country. Although prior studies have examined the adherence to the integrated 24-h movement behaviours guidelines (Chaput et al., 2017; Cliff et al., 2017; De Craemer et al., 2018; Vale & Mota, 2020) in preschool children from high-income countries, few studies have examined low-income samples, specially from a middle-income country, and none have examined the association with demographic correlates, according to a network approach.

The majority of children from our study had a healthy BMI z-score and high levels of PA. The average amount of objectively measured TPA (273.5 min/day) is in excess of the recommended 180 min/day. The average amount of MVPA was almost 59 min/day, which is nearly the recommended 60min/day, and close to the objectively measured time reported by Guerra et al (2020) in a systematic review with South-American preschoolers. Nonetheless, only 3% of the entire sample complied with the combined PA, screen time and sleep time recommendations, which is considerably lower than the prevalence observed in children from high-income countries (10 to 15%) (Chaput et al., 2017; Cliff et al., 2017; De Craemer et al., 2018), and in children from a pilot study conducted in urban and rural areas from South Africa (26%) (Catherine et al., 2020), a middle-income country as Brazil. Of note, for a single behaviour, our children are proportionally less active (43%) than those from Canada (Chaput et al., 2017) and Australia (Cliff et al., 2017) (61.8% and 93%, respectively), more active (43%) than those from Portugal (Vale & Mota, 2020) and Belgium (De Craemer et al., 2018) (28.6% and <20%, respectively); spend more time in screen activities (15% of compliance) than preschoolers from Canada (24.4%), Australia (17.3%) and Belgium (61%); and fewer had adequate sleep (35% of compliance) than the Portuguese, Canadian, Australian and Belgian preschoolers (45% 83.9%, 88.7%, and >90%, respectively). It is also important to highlight that when analyzing the single movement behaviours, the PA recommendation was the one our children had the highest adherence, irrespective of sex (53% and 33% for boys and girls, respectively). Even so, compared to the low-income South African preschoolers (Catherine et al., 2020), whose cultural contexts are more similar to ours, the assessed low-income Brazilian children are less active (43% vs. 84%). This difference may be due to the mixed sample of

African children assessed, who came from urban and rural areas, where PA opportunities are quite different.

Even accounting for the different instruments employed in previous studies, such as accelerometer brands (i.e. in the current study, the Australian, the Portuguese, the Belgium, and the South African studies assessed PA with Actigraph accelerometer, while the Canadian study used the Actical), and different cut-points to determine PA intensities (Butte et al., 2014; Evenson, Catellier, Gill, Ondrak, & McMurray, 2008; Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006; Reilly et al., 2003), the above mentioned studies have placed the device on the same position (hip), and up to some point, the results are comparably different of those from the current study.

In these aforementioned previous studies, a large proportion of preschoolers meet the sleep duration guidelines (approximately 94.3% for Belgians, 88.7% for Australians, 83.9% for Canadians, and 66% for South Africans). In our low-income sample, the adherence to sleep time recommendations was only 35%, which along with screen time, were the major reasons for the low proportion of children adhering to the 24-h recommendations. A study with low-income urban South-African preschoolers showed nocturnal sleep duration similar to ours (9.28 ± 0.80 hours/day) (Tomaz et al., 2019), and the observed night sleep time adherence was similar to that objectively observed by Armstrong et al. (2019) in a low-income American toddlers' sample, who also reported poverty as a risk factor for adverse behavioral outcomes, including short sleep duration.

Due to its proximity to the Equator line, João Pessoa has a warm climate, with high temperatures throughout the year (~ 27º C), and the sun rises between 4:30 am and 5:30 am all year round. The lack of structure in the houses of the assessed children, such as no curtains on the windows and no cooling system, besides the usually overcrowded sleep environment, in somehow, may compromise children´s sleep hours, as discussed by Tomaz et al., 2019, when analyzing a similar population from urban areas. However, as few studies has produced such findings, this explanation is presented only as a possibility. Indeed, children from low-income families go to bed later (Blair et al., 2012), which can lead to an even greater concern about current results, as parent-reported sleep measures may overestimate sleep time in a low-to-middle income preschoolers´ sample, when compared to objective measures (Tomaz et al., 2019).

It is also plausible to speculate that less sleep time and longer awake time may also provide children with greater screen exposure, which is widespread in middle and low-income families. This scenario may, at least in part, explain the low compliance to screen time recommendations observed in the current study (15%), which is lower than the observed in other low-to-middle income contexts (Catherine et al., 2020; Kracht, Webster, & Staiano, 2019). The assessed children spend ten daily waking hours at preschool settings, where screen time is not allowed. When they leave preschools, there is no sunlight, and the neighborhood environment is not attractive or safe for outdoor activities, what predisposes to sedentary activities at home, and may contribute to an increasing screen exposure. Therefore, intervention strategies should focus on these environment aspects.

Our results from the networking analysis emphasized TPA, sex, and specifically the child´s primary caregivers with the greater centrality indicators, reflecting the role of this variable in the emerging pattern of the network. The strength indicator provides information about which variables present the strongest connections in the current network pattern. Children's health behaviours are formed at an early age, under the influence of their parents (Tucker, van Zandvoort, Burke, & Irwin, 2011). Indeed, both parents and active childcare providers may be positive example, facilitating the engagement of young children in PA (Hesketh, Lakshman, & van Sluijs, 2017), though the family unit is particularly important for the development of young children's activity-related attitudes, and behaviours (French, Story, & Jeffery, 2001), besides parental control over children's behaviours. Therefore, parental role modeling and the home environment are important influences on the PA behaviours of preschool-aged children (Tucker et al., 2011), though future studies should focus on the contribution of grandparents for example, as PA of older people may contribute to a family culture of PA (Palmer, 2018). Moreover, variables with a high closeness value will be quickly affected by changes in any part of the network and may also affect other parts. This is particularly interesting in relation to TPA, which is primarily composed of light PA, and may be more easily changed than MVPA. In this sense, interventions to promote structured MVPA in preschool environment or social PA programs should be encouraged.

The network analysis also showed that sex, child´s primary caregivers, and adherence to TPA and sleep time recommendations were closely related. Indeed, the close relationship between movement behavious is expected, as these behaviours are co-dependent (Chastin et al., 2015). Child´s primary caregivers and adherence to TPA and sleep recommendations showed the highest betweenness. These variables act as hubs, as the connection between movement behaviors (TPA, MVPA and sleep) and the demographic correlates as income and unemployment, for example, goes through these variables. Thus, the network analysis highlighted that parents´ conditions, such as employment status, and amount of income support, may act in TPA, sleep time and child´s primary caregivers, and consequently in all those variables that are closely located in the network, changing the entire network configuration to a more theoretically desirable format. All of these aforementioned variables are related in a complex system, and allows us to hypothesize that a greater parents income condition may facilitate families´ access to healthy movement opportunities. Moreover, BMI and screen time, for example, are peripherally located in the network. This doesn´t mean that these variables are not important, but that in this specific context, these variables did not provide sufficient influence for the analyzed network.

The overarching strength of the present study is in reporting, for the first time, the combined adherence to all the three 24-hour movement behaviours in low-income Brazilian preschoolers. Data concerning adherence to 24-hour movement behaviours have, to date, only been presented in relation to high-income countries, where social contexts are extremely different from that of developed countries. As a consequence, the data presented in the current study extends understanding of movement behaviours in the broad context of preschoolers. In addition, the use of a network approach to consider the associations between adherence to movement behaviours recommendations and demographic correlates is a unique aspect of the current study.

Our study does have limitations that should be highlighted. The low external validity and lack of generalizability should be highlighted. Nonetheless, this study covers a specific low-income sample, which demographic characteristics are quite similar to those of children from other low-income regions in Brazil. As there are no prior published studies that the authors are aware of, which have addressed the 24-hour movement behaviours adherence in Brazilian low-income preschoolers, direct comparisons with other studies are difficult to make. However, this clearly highlights the need for further examinations of the nature of movement across ethnic and geographic locations, according to specific contexts. Moreover, children, particularly those that are younger, may nap at preschool settings and this period was not considered in this study. The number of persons living in the same house is another important correlate that should be assessed in future studies with similar low-income sample. Finally, the use of parents reported sleep and screen times is a limitation and may be considered an area to adapt or refine for future research. Nonetheless, while parent-report is a notable limitation, it is also worth mentioning that there is no validated method of assessing screen time in preschool-aged children. The procedure used to individually interview parents across the education spectrum, to negate the potential for error in parent-report via questionnaire, is a considerable asset, when the illiteracy is noted.

5. Conclusion

The present study showed that very few low-income preschoolers in Brazil (3%) are compliant with movement behaviours recommendations. Strategies and programs to promote adherence to sleep, screen time and PA guidelines among low-income preschool children are warranted, and should be focused on actions considering the importance of child´s primary caregivers to support movement behaviours.

Acknowledgments

Clarice Martins was supported by Brazilian Federal Foundation for Support and Evaluation of Graduate Education - CAPES (CAPES-PRINT - 88887.369625/2019-00).

Authors' contributions

Clarice Martins: responsible for conception, design, written, and analysis and interpretation of data.

Luís Lemos: have made substantial contributions to accelerometer analysis and written.

Anastácio Neco: have made substantial contributions to data acquisition and network analysis.

Thaynã Bezerra: have made substantial contributions to data acquisition and network analysis.

Ívina Soares: have made substantial contributions to acquisition of data.

Jéssica Mota: have made substantial contributions to acquisition of data.

Paulo Bandeira: have made substantial contributions to interpretation of data and network analysis.

Jorge Mota: have reviewed the manuscript critically for important intellectual content.

Rafael Tassitano: have made substantial contributions to design, and interpretation of data.

Michael Duncan: have reviewed the manuscript critically for important intellectual content and have given final approval of the version to be published.

Competing Interest

The authors declare that they have no competing interests.

References

Armstrong, B., Covington, L. B., Hager, E. R., & Black, M. M. (2019). Objective sleep and physical activity using 24-hour ankle-worn accelerometry among toddlers from low-income families. *Sleep Health, 5*(5), 459-465. doi:10.1016/j.sleh.2019.04.005

Association, W. M. (2013). World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA, 310*(20), 2191-2194. doi:10.1001/jama.2013.281053

Bagley, E. J., Kelly, R. J., Buckhalt, J. A., & El-Sheikh, M. (2015). What keeps low-SES children from sleeping well: the role of presleep worries and sleep environment. *Sleep Medicine, 16*(4), 496-502. doi:10.1016/j.sleep.2014.10.008

Blair, P. S., Humphreys, J. S., Gringras, P., Taheri, S., Scott, N., Emond, A., . . . Fleming, P. J. (2012). Childhood sleep duration and associated demographic characteristics in an English cohort. *Sleep, 35*(3), 353-360. doi:10.5665/sleep.1694

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

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. doi:10.1249/mss.0000000000000209

Cadenas-Sanchez, C., Martinez-Tellez, B., Sanchez-Delgado, G., Mora-Gonzalez, J., Castro-Piñero, J., Löf, M., . . . 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. doi:10.1016/j.jsams.2016.02.003

Carmichael, T., & Hadžikadić, M. (2019). The Fundamentals of Complex Adaptive Systems. In T. Carmichael, A. J. Collins, & M. Hadžikadić (Eds.), *Complex Adaptive Systems: Views from the Physical, Natural, and Social Sciences* (pp. 1-16). Cham: Springer International Publishing.

Carson, V., Spence, J. C., Cutumisu, N., & Cargill, L. (2010). Association between neighborhood socioeconomic status and screen time among pre-school children: a cross-sectional study. *BMC Public Health, 10*, 367. doi:10.1186/1471-2458-10-367

Catherine, D., Simone, A. T., Caylee, J. C., Sasha, S. J., Candice, R., Sahba, B., . . . Anthony, D. O. (2020). Understanding the influence of 24-hour movement behaviours on the health and development of preschool children from low-income South African settings: the SUNRISE pilot study. *South African Journal of Sports Medicine, 32*(1). doi:10.17159/2078-516X/2020/v32i1a8415

Chang, S. H., & Kim, K. (2017). A review of factors limiting physical activity among young children from low-income families. *Journal of exercise rehabilitation, 13*(4), 375-377. doi:10.12965/jer.1735060.350

Chaput, J. P., Colley, R. C., Aubert, S., Carson, V., Janssen, I., Roberts, K. C., & Tremblay, M. S. (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*(Suppl 5), 829. doi:10.1186/s12889-017-4854-y

Chastin, S. F., Palarea-Albaladejo, J., Dontje, M. L., & Skelton, D. A. (2015). 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, 10*(10), e0139984. doi:10.1371/journal.pone.0139984

Cliff, D. P., McNeill, J., Vella, S. A., Howard, S. J., Santos, R., Batterham, M., . . . 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*(Suppl 5), 857. doi: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. *Journal of Science and Medicine in Sport, 12*(5), 557-567. doi:10.1016/j.jsams.2008.10.008

Crabtree, V. M., & Williams, N. A. (2009). Normal sleep in children and adolescents. *Child and Adolescent Psychiatric Clinics, 18*(4), 799-811.

De Craemer, M., McGregor, D., Androutsos, O., Manios, Y., & Cardon, G. (2018). Compliance with 24-h Movement Behaviour Guidelines among Belgian Pre-School Children: The ToyBox-Study. *International Journal of Environmental Research and Public Health, 15*(10). doi:10.3390/ijerph15102171

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. doi:10.1016/j.arcped.2008.10.010

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 and health, 2*(3), 366-383.

Evenson, K. R., Catellier, D. J., Gill, K., Ondrak, K. S., & McMurray, R. G. (2008). Calibration of two objective measures of physical activity for children. *Journal of Sports Sciences, 26*(14), 1557-1565. doi:10.1080/02640410802334196

Foygel, R., & Drton, M. (2010). *Extended Bayesian information criteria for Gaussian graphical models.* Paper presented at the Advances in Neural Information Processing Systems.

French, S. A., Story, M., & Jeffery, R. W. (2001). Environmental influences on eating and physical activity. *Annual Review of Public Health, 22*, 309-335. doi:10.1146/annurev.publhealth.22.1.309

Friedman, J., Hastie, T., & Tibshirani, R. (2007). Sparse inverse covariance estimation with the graphical lasso. *Biostatistics, 9*(3), 432-441. doi:10.1093/biostatistics/kxm045

Fruchterman, T. M. J., & Reingold, E. M. (1991). Graph drawing by force-directed placement. *Software: Practice and Experience, 21*(11), 1129-1164. doi:10.1002/spe.4380211102

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. *Journal of Developmental and Behavioral Pediatrics, 29*(2), 82-88. doi:10.1097/DBP.0b013e318163c39a

Guerra, P. H., Barbosa Filho, V. C., Almeida, A., Silva, L. S., Pinto, M. T. V., Leonel, R. M., . . . Florindo, A. A. (2020). SYSTEMATIC REVIEW OF PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOR INDICATORS IN SOUTH-AMERICAN PRESCHOOL CHILDREN. *Rev Paul Pediatr, 38*, e2018112. doi:10.1590/1984-0462/2020/38/2018112

Hesketh, K. R., Lakshman, R., & van Sluijs, E. M. F. (2017). Barriers and facilitators to young children's physical activity and sedentary behaviour: a systematic review and synthesis of qualitative literature. *Obesity Reviews, 18*(9), 987-1017. doi:10.1111/obr.12562

IBGE. (2010). Instituto Brasileiro de geografia e Estatística. *Censo demográfico, 2010*.

Kracht, C. L., Webster, E. K., & Staiano, A. E. (2019). Sociodemographic Differences in Young Children Meeting 24-Hour Movement Guidelines. *J Phys Act Health, 16*(10), 908-915. doi:10.1123/jpah.2019-0018

Lindsay, A. C., Sussner, K. M., Greaney, M. L., & Peterson, K. E. (2009). Influence of social context on eating, physical activity, and sedentary behaviors of Latina mothers and their preschool-age children. *Health Education and Behavior, 36*(1), 81-96. doi:10.1177/1090198107308375

Montgomery, C., Reilly, J. J., Jackson, D. M., Kelly, L. A., Slater, C., Paton, J. Y., & Grant, S. (2004). Relation between physical activity and energy expenditure in a representative sample of young children. *American Journal of Clinical Nutrition, 80*(3), 591-596. doi:10.1093/ajcn/80.3.591

Palmer, V. J. (2018). Grandparents’ contribution to a family culture of physical activity. *Gerontologie et societe, 40*(2), I-XVI.

Pate, R. R., Almeida, M. J., McIver, K. L., Pfeiffer, K. A., & Dowda, M. (2006). Validation and calibration of an accelerometer in preschool children. *Obesity (Silver Spring), 14*(11), 2000-2006. doi:10.1038/oby.2006.234

Reilly, J. J., Coyle, J., Kelly, L., Burke, G., Grant, S., & Paton, J. Y. (2003). An objective method for measurement of sedentary behavior in 3- to 4-year olds. *Obesity Research, 11*(10), 1155-1158. doi:10.1038/oby.2003.158

Santana, C. C. A., Azevedo, L. B., Cattuzzo, M. T., Hill, J. O., Andrade, L. P., & Prado, W. L. (2017). Physical fitness and academic performance in youth: A systematic review. *Scandinavian Journal of Medicine and Science in Sports, 27*(6), 579-603. doi:10.1111/sms.12773

Schmittmann, V. D., Cramer, A. O. J., Waldorp, L. J., Epskamp, S., Kievit, R. A., & Borsboom, D. (2013). Deconstructing the construct: A network perspective on psychological phenomena. *New Ideas in Psychology, 31*(1), 43-53. doi:https://doi.org/10.1016/j.newideapsych.2011.02.007

Tomaz, S. A., Prioreschi, A., Watson, E. D., McVeigh, J. A., Rae, D. E., Jones, R. A., & Draper, C. E. (2019). Body Mass Index, Physical Activity, Sedentary Behavior, Sleep, and Gross Motor Skill Proficiency in Preschool Children From a Low- to Middle-Income Urban Setting. *J Phys Act Health, 16*(7), 525-532. doi:10.1123/jpah.2018-0133

Tremblay, M. S., Carson, V., & Chaput, J. P. (2016). Introduction to the Canadian 24-Hour Movement Guidelines for Children and Youth: An Integration of Physical Activity, Sedentary Behaviour, and Sleep. *Applied Physiology, Nutrition, and Metabolism. Physiologie Appliquée, Nutrition et Métabolisme, 41*(6 Suppl 3), iii-iv. doi:10.1139/apnm-2016-0203

Tucker, P., van Zandvoort, M. M., Burke, S. M., & Irwin, J. D. (2011). The influence of parents and the home environment on preschoolers' physical activity behaviours: a qualitative investigation of childcare providers' perspectives. *BMC Public Health, 11*, 168. doi:10.1186/1471-2458-11-168

Vale, S., & Mota, J. (2020). Adherence to 24-hour movement guidelines among Portuguese preschool children: the prestyle study. *Journal of Sports Sciences*, 1-6. doi:10.1080/02640414.2020.1775385

WHO. (2019). Guidelines on Physical Activity, Sedentary Behaviour and Sleep for Children under 5 Years of Age. In *Guidelines on Physical Activity, Sedentary Behaviour and Sleep for Children under 5 Years of Age*. Geneva: World Health Organization 2019.

Yang-Huang, J., van Grieken, A., Moll, H. A., Jaddoe, V. W. V., Wijtzes, A. I., & Raat, H. (2017). Socioeconomic differences in children's television viewing trajectory: A population-based prospective cohort study. *PloS One, 12*(12), e0188363. doi:10.1371/journal.pone.0188363

Tables and figures

Table 1 – Sample´s characteristics and differences by age and sex.

	3 years-old (n=91)	**4 years-old (n=96)**	**5 years old (n=83)**	**Boys (n=132)**	**Girls (n=138)**	**P d**	**TOTAL**
Age (years)	3.63 ± 0.33	4.49 ± 0.28	5.38 ± 0.27	4.49 ± 0.29	4.51 ± 0.30	0.77 0.06	3.97±0.80
Z-BMI	0.09 ± 0.82	-0.03 ± 0.51	-0.06 ± 1.12	-0.03 ± 0.96	0.04 ± 0.67	0.35 0.08	0.00±1.00
TPA (min/day)	266.51 ± 58.19	273.35 ± 63.13	280.24 ± 65.24	271.84 ± 67.41	274.89 ± 56.96	0.66 0.04	273.52±62.08
LPA (min/day)	212.35 ± 49.48	214.02 ± 53.45	217.18 ± 48.91	209.27 ± 54.94	219.76 ± 46.28	0.08 0.20	214.70±50.56
MVPA (min/day)	53.81 ± 18.61	59.33 ± 18.80	63.05 ± 27.34[a]	62.33 ± 22.53	55.12 ± 20.63	0.01* 0.33	58.68±22.51
Screen time (min/day)	171.24 ± 111.46	159.67 ± 83.91	181.08 ± 95.30	178.22 ± 94.04	163.11 ± 99.74	0.17 0.15	169.91±97.07
Sleep time (hours/day)	9.39 ± 1.10	9.30 ± 1.11	9.65 ± 1.08	9.45 ± 1.07	9.43 ± 1.11	0.57 0.01	9.44±1.12

Values are expressed as mean ± standard deviation. One-way ANOVA with Bonferroni´s post-hoc; [a] significant difference between 3 and 5 years-old; Independent t-test; * significant differences between sexes; ($p \leq .05$); Z-BMI = Body mass index z-score; TPA = Total physical activity; LPA = Light physical activity; MVPA = Moderate to vigorous physical activity;

Table 2. Percentage of preschoolers compliant with the guidelines by age

Movement Behaviours	Adherence to 24-h movement behaviours	3 years-old n (%)	4 years-old n (%)	5 years-old n (%)
Physical activity	Compliant (%)	36 (39.6)	33 (34.4)	45 (54.2)
	Non compliant (%)	55 (60.4)	63 (65.6)	38 (45.8)
Screen time	Compliant (%)	13 (14.3)	8 (8.3)	20 (24.1)
	Non compliant (%)	78 (85.7)	88 (91.6)	63 (75.9)
Sleep time	Compliant (%)	17 (18.7)	19 (19.8)	59 (71.1)
	Non compliant (%)	74 (81.3)	77 (80.2)	24 (28.9)

Physical activity (TPA ≥ 180 min/day, including MVPA ≥ 60 min/day); Screen time (≤ 60 min/day for 3 and 4years-old; ≤ 120 min/day for 5 years-old); Sleep time (600 - 780 min/day for 3 and 4years-old; 540 – 660 min/day for 5 years-old).

Table 3. Centrality measures of the network analysis between movement behaviours, BMI, and demographic correlates.

Variables	Betweenness	Closeness	Strength
TPA	**1.135**	**1.090**	**1.252**
MVPA	-0.657	0.834	0.705
Screen	-0.478	-0.708	-1.206
Sleep	**1.135**	0.718	0.780
Sex	-0.657	**1.225**	**1.022**
Age	-0.657	-1.375	-1.244
BMI	-0.657	-1.213	-1.452
Mother Education	-0.478	-0.643	-0.523
Sibilings	-0.119	-0.286	-0.196
Child Primary	**2.389**	**1.455**	**1.305**
Income	-0.657	-0.655	-0.395
Unemployment	-0.299	-0.443	-0.047

BMI = Body Mass Index; TPA = Total Physical Activity; MVPA = Moderate – to – vigorous physical activity

Figure 1a-c – Venn diagrams showing the percentage of preschoolers compliant and not compliant with 24-hour movement behaviours, and the combinations of these guidelines for the overall sample and by sex.

Figure 2: Associations between movement behaviours and demographic correlates. Positive associations are expressed by blue the blue color, and negative associations by the red color. The thickness of the graph indicates the weight of the ratio.

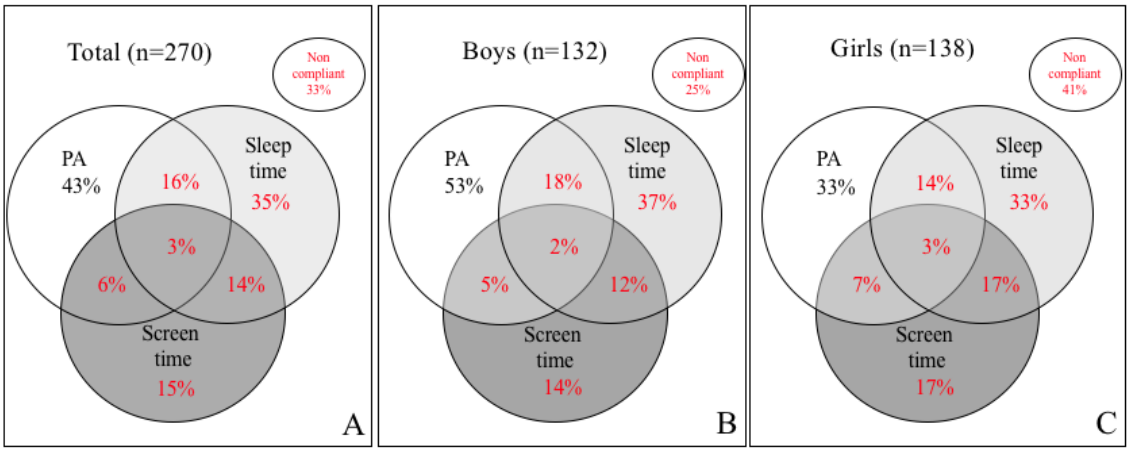

Figure 1a-c – Venn diagrams showing the percentage of preschoolers compliant and not compliant with 24-hour movement behaviours, and the combinations of the recommendations for the overall sample, and by sex.

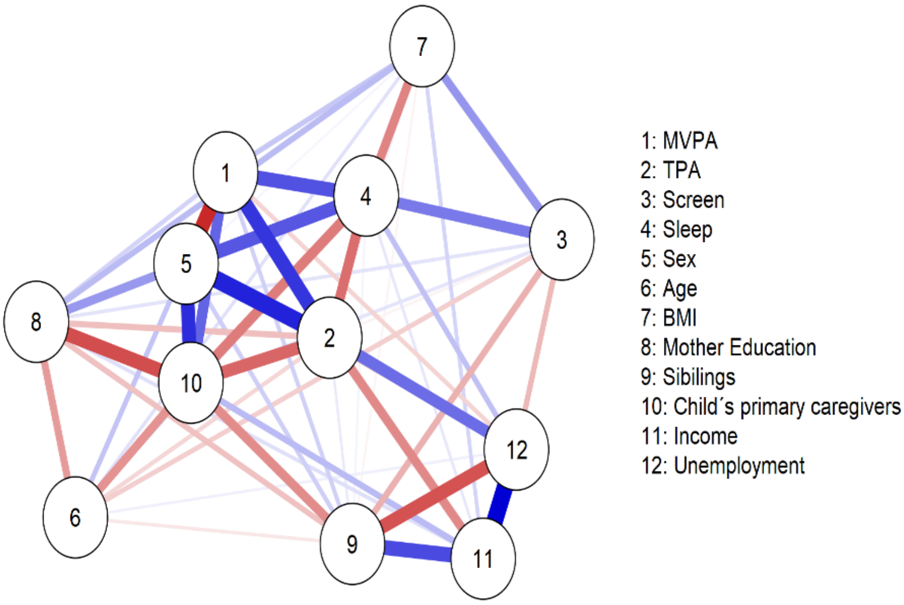

Figure 2: Associations between movement behaviours and demographic correlates. Positive associations are expressed by blue the blue color, and negative associations by the red color. The thickness of the graph indicates the weight of the ratio