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Abstract

Introduction: Adequate gross motor coordination is essential for children participating in age-related physical activities and has an important role in maintaining sufficient physical activity levels during the life course **Aim:** To examine the association between moderate and vigorous physical activity and gross motor coordination in early infancy (ages 3–6). **Methods** The sample comprised 209 children aged 3–6 years. Gross motor coordination was assessed according to the Movement Assessment Battery for Children (MABC-2). The battery to assess gross motor coordination comprised the aiming & catching and balance components. Moderate and vigorous physical activity was measured by accelerometery worn for 7 consecutive days (Monday to Sunday). **Results:** Our data indicated that 31.3% of the sample had low, 32.3% medium and 36.0% high gross motor coordination. Multiple linear regression analysis showed that moderate and vigorous physical activity was positively associated with gross motor coordination, adjusted for gender and sedentary behavior. **Conclusions:** Preschoolers with high gross motor coordination spend more time in moderate and vigorous physical activity. Gross motor coordination development should therefore be a key strategy in childhood interventions aiming to promote long-term physical activity.

Keywords: Preschoolers, gross motor coordination, moderate vigorous physical activity, and accelerometer.

Introduction

Gross motor coordination is a specific aspect of general the motor competence, defined as gross motor skill competency, encompassing fundamental movement skills and motor coordination. Gross motor coordination is often specified in terms of proficiency in a variety of fundamental motor skills involving object control, such as grasping with the hand or striking a ball with the feet, and locomotor, such as walking and hopping to describe goal-directed human movement (Barnett, Salmon, & Hesketh, 2016; Sanchez et al., 2017), that are ideally learned during preschool and early school years (Barnett, Salmon, et al., 2016) and which are associated with the practice of PA (Loprinzi et al., 2015). The relevance of CMG in the early years of life is central as it provides the basis for children to develop sequences of more specific movements in different sports (eg, cycling and swimming) (Hulteen et al., 2015). Impairment of motor development starts in preschool age (Logan, Robinson, Wilson, & Lucas, 2012) and becomes more intensive at primary school age(Lopes, Santos, Pereira, & Lopes, 2012). Thus, the acquisition of adequate gross motor coordination (GMC) is an essential requirement in childhood. Since, adequate GMC is essential for children participating in age-related physical activities and has an important role in maintaining sufficient physical activity levels during the life course (Laukkanen, Pesola, Havu, Saakslahti, & Finni, 2014b; Sanchez et al., 2017). GMC is considered an important element of a child's motor skills, and their cognitive and psychological behaviours (Gallahue & Ozmun, 2011). Motor coordination has been reported to be positively associated with preschool children's PA behaviour (Olesen, Kristensen, Korsholm, & Froberg, 2013). PA has important psychological and physical implications in all age groups (Biddle & Asare, 2011; Timmons et al., 2012), including preschoolers (Tucker, 2008) and being physically active is an important lifestyle habit that tracks into adulthood (Brown et al., 2009).

Consequently, PA guidelines have been established for preschool children. According to the guidelines, preschoolers should accumulate 180 min of total PA throughout the day. In addition, the Canadian guidelines also recommend that preschool children accumulate at least 1 h of moderate to vigorous PA (MVPA) daily (Tremblay et al., 2012). These recommendations go on to explain that children can accumulate PA intermittently throughout the day, and can include light-intensity activities such as standing, moving around and active play as well as moderate-to-vigorous intensity activities such as brisk walking, running and climbing (Australian Governmental Departament of Health, 2010; Tremblay et al., 2012). The majority of evidence indicates that a substantial proportion of preschool aged children do not meet the recommendation of at least 60 min of MVPA per day (Hnatiuk, Salmon, Hinkley, Okely, & Trost, 2014), but rather spend most of their waking hours engaged in sedentary behaviour (SB) (Kelly et al., 2007; Reilly et al., 2004). SB is referred as any waking behaviour characterized by an energy expenditure ≤1.5 METs while in a sitting or reclining posture) (Tremblay et al., 2017). Further, SB seems to have an inverse relationship with motor coordination in pre-schoolers (Lopes et al., 2012; Sanchez et al., 2017). One important determinant of childhood physical activity and sedentary behavior may be that of motor development in infancy and childhood (Sanchez et al., 2017). Insufficient MVPA levels and high amounts of sedentary time are associated with poor motor skills (Iivonen et al., 2013).

The reciprocal relationship between motor coordination and PA is very important, especially in preschoolers, PA seems to be positively correlated with object control, locomotor skill competence and motor coordination in children, and negatively correlated with SB (Iivonen et al., 2013; Laukkanen, Pesola, Havu, Saakslahti, & Finni, 2014a), however, few studies have examined the association between MVPA and motor coordination in preschool children (Iivonen et al., 2013). Considering that GMC is essential for children to maintain a sufficient physical activity level throughout the lifecourse it is important for public health and education professionals to understand the

associations between PA and GMC to target the most effective ways to enhance preschoolers' motor competence and PA.

Therefore, this study aimed to examine the association between MVPA and GMC among preschoolers.

Material and Methods

Participants and data collection

Participants in this study were preschool-aged children enrolled in the Preschool Physical Activity, Body Composition and Lifestyle Project (PRESTYLE). A sample of children, aged 2–6 years, was recruited from public kindergartens located in the metropolitan area of Porto, Portugal. For this analysis, we included only children aged three to six years with seven days of accelerometer data, had information about GMC, MVPA height, and body mass available were included in the sample. The final sample this cross-sectional study included two hundred and nine preschoolers met these inclusion criteria (n=109; 52.1% girls). All classes of kindergartens that participated in this study had one physical education class per week, with a duration of 60min. Data collection took place between April 2013 and November 2014. Written informed consent was obtained from parents and school supervisors. Study procedures were approved by the Portuguese Foundation for Science and Technology and by the Scientific Board of Physical Activity and Health PhD program.

Anthropometric measures

Body mass and height were measured by standard anthropometric methods. Body mass was measured to the nearest 0.10kg, with participants lightly dressed (underwear and t-shirt only) using a portable digital scale (Tanita Inner Scan BC 532, Tokyo, Japan). Height was measured to the nearest millimetre in bare or stocking feet with children standing upright against a Holtain portable stadiometer (Tanita).

Gross motor coordination

GMC was assessed using the Movement Assessment Battery for Children (MABC-2) (Henderson, Sugden, & Barnett, 2007). This test battery was developed as a means of identifying those at risk of motor impairment and has been widely adopted for this purpose (Smits-Engelsman, Niemeijer, & van Waelvelde, 2011). The MABC-2 is designed for children from 3 to 16 years and assesses manual dexterity, aiming & catching and balance components. The MABC is composed for: age band 1 (3-6years); age band 2 (7-10years) and age band 3 (11-16 years)(Henderson et al., 2007). Manual dexterity data were not assessed in this study as the focus of the current work was on gross motor coordination (aiming & catching and balance components). The child's performance on each of these tasks (a score for either accuracy or completion time) was summed, producing area scores, and converted to normative scores (taking age in months into considerations, age adjusted) according the MABC–2 test manual (Henderson et al., 2007). The sum of both components of GMC was subsequently converted to Zscores.

Moderate vigorous physical activity and Sedentary behavior

Moderate vigorous physical activity (MVPA) and sedentary behavior (SB) were measured during 7 consecutive days (Monday to Sunday using the ActiGraph GT1M accelerometer (Pensacola, FL, USA). This accelerometer provides output in activity counts, which provides information about the intensity of PA (Janz, 1994). Alternatively, accelerometer output can be interpreted using specific cut-points, which identify time in different intensities of PA. Data reduction, cleaning and analysis of accelerometer data were performed using a specially written program described and used previously (Purslow, Hill, Saxton, Corder, & Wardle, 2008; Sardinha, Baptista, & Ekelund, 2008) Data were analyzed using specific pediatric cut-points, which have been validated for young children: ≥1680 cpm for MVPA, as already been used in several studies (Byun,

Beets, & Pate, 2015; Byun, Dowda, & Pate, 2011; O'Connor et al., 2014; Pate et al., 2015) and SB was calculated using a cut-point of ≤ 100 cpm (Trost, Loprinzi, Moore, & Pfeiffer, 2011). For the purpose of this study, the epoch duration was set to 5 seconds, which has been shown to be more accurate for the assessment of the preschoolers' spontaneous and intermittent activities (Vale, Santos, Soares-Miranda, Silva, & Mota, 2009). To process the data we used *Actilife*® software (Pensacola, Florida), which automatically scaled the 15-second cut-point to the 5-second epoch interval. A minimumwear time of 10 hours per day was considered valid for inclusion in data analysis (Rich et al., 2013). Non-wear time was defined as a period of at least 60 consecutive minutes of zero counts. Parents were instructed to attach the accelerometer when the child awoke and to remove it when they went to bed. The accelerometer was firmly adjusted at the child's hip by an elastic waist belt under their clothing. All children participated in their normal activities with their classmates during the monitoring period.

Statistical analysis

Means and standard deviation (SD) were calculated to describe children's main characteristics by gender. Multiple linear regression was employed as it provides an indication of the amount of variance in MVPA explained by GMC after adjusting for gender and SB. Statistical analysis was performed using the SPSS 24.0 software (SPSS Inc., Armonk, NY). The level of significance was set at $p < 0.05$.

Results

Table 1 shows descriptive characteristics of the sample according to gender. Boys had lower body mass (p=0.04) and were more active than girls (p=0.01), boys also had less SB than girls (p=0.01). The girls had better performance on total scores for GMC compared to boys (p=0.01). No other statistical significant differences were found.

Table I. Preschool children`s characteristics.

Gender Total Girls Boys Variable (n=109) (n=100)			(n=209)	
				***P*-Value**
Age (years)	4.73±0.74	4.72±0.72	4.74±0.74	0.69
Weight (Kg)	20.73±3.91	21.22±4.21	20.12±3.42	0.04*
Height (cm)	109.01 ± 6.12	110.51±6.32	109.12±5.81	0.09
BMI (kg/m^2)	17.03±1.96	17.17±2.14	16.87±1.73	0.15
SB (min/day)	67.07±6.19	68.40±5.98	65.61±6.10	0.01*
MVPA (min/day)	92.29 ±25.72	85.44±24.99	99.86±24.43	0.01*
GMC	42.91 ±10.73	44.06 ±9.71	41.71 ±11.62	0.01*

Abbreviations: BMI, body mass index; SB, Sedentary behavior; MVPA, Moderate vigorous physical activity; GMC, Gross Motor Coordination. ,*P<0.05.

Multiple linear regression analysis (Table 2) showed that MVPA was positively associated with GMC and negatively associated with SB, adjusted for gender.

Table II - Association between moderate vigorous physical activity and gross motor coordination in preschoolers

		MVPA		
Variables	Beta	95%CI	P	R^2
ZGMC	0.12	0.63; 3.10	0.01	
SB	-0.81	-3.73; -3.03	0.01	0.69

Multiple linear regression model: MVPA; moderate vigorous physical activity, ZGMC; zscore gross motor coordination, SB; sedentary behavior. The association was adjusted for age and gender,*P<0.05.

Discussion

This study examined the association between MVPA and GMC in preschool children. MVPA was positively associated with GMC and negatively associated with SB,

irrespective of gender. This is the key novel finding of this study and is worth highlighting because preschoolers with low GMC tend to be less physically active than their counterparts with high GMC.

Our data also shows that 31.7% of the children had low levels of GMC, 32.3% had medium and 36.0% a high level of GMC. The children with high GMC undertook greater levels of MVPA than their counterparts with low levels of GMC. The preschoolers with high SB also had low MVPA. This finding supports previous studies indicated that the total amount of PA, and MVPA positively, and sedentariness negatively, with the level of gross motor skills in children.(Burgi et al., 2011; Fisher et al., 2005; Laukkanen et al., 2014a; Williams et al., 2008; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). In longitudinal designs, the level of gross motor skills was only weakly or moderately associated with level of PA (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009b; Lopes, Rodrigues, Maia, & Malina, 2011).

The present results also agree with some studies that mentioned that overall PA seems to be positively correlated with object control, locomotor skill competence and motor coordination in children.(Barnett, Lai, et al., 2016; Barnett, Salmon, et al., 2016) Available evidence suggests that preschoolers' motor skill performance seems to be positively associated with the time spent in health-related PA (Fisher et al., 2005). For instance, fundamental movement skills (FMS) proficiency was associated with overall PA during childhood (Iivonen et al., 2013). Likewise, previous research has indicated evidence that motor skills performance in preschool children can be improved and maintained by an appropriate physical activity in 4- to 5- year-old boys and girls (Roth et al., 2015). The level of motor coordination appears to be one of the main factors contributing to an active lifestyle.

Therefore, our data reinforce these aforementioned studies, suggesting that the implementation of PA into children's everyday life (e.g. in the kindergarten/school settings) are of particular importance since higher levels of PA during childhood are associated with fundamental movement skills (FMS) proficiency and vice versa (Iivonen

et al., 2013). Children without or with low opportunities to gain appropriate FMS levels are in danger to develop motor developmental retardations with a lower chance to successfully participate in an active and healthy sports culture (Stodden *et al*. 2008). As a consequence, children with less developed FMS proficiency are reported to be at a higher risk to develop habitual physical inactivity, higher levels of SB and subsequently poorer adolescent health (Lubans *et al*. 2010). It is possible that limited motor competence may lead to unpleasant experiences in movement activities whereas better motor competence is associated with more favourable experiences, which encourage involvement in PA (Lopes, et al., 2011). Therefore, underlining the importance of developing FMS/GMC during the early years of life.

Our findings show that preschoolers who had high levels of GMC were more active in MVPA than those that had low level of GMC. This is congruent with evidence in the literature that having high fundamental movement skill level may increase options for participation in PA, as well as increased participation leading to further development of motor skills. However, some studies suggest a reciprocal relationship between PA and FMS (Barnett, Morgan, Van Beurden, Ball, & Lubans, 2011; Kambas et al., 2012). Children tend to be physically active during play and it is possible that those who have greater motor competence may be more likely to engage and persist in challenging physically active tasks. If this is so, investing in the improvement of motor proficiency in young children has potentially relevant policy implications related to PA and health.

Despite this, few studies in Europe have reported the prevalence of movement difficulties relative to norm referenced data in preschool children with respect to motor coordination (D'Hondt et al., 2011; Lopes, Stodden, Bianchi, Maia, & Rodrigues, 2012; Toftegaard-stoeckel, Groenfeldt, & Andersen, 2010). As such, the current study extends research knowledge on this topic.

There is considerable evidence to indicate that reduced PA or increased sedentary behaviour are implicated in motor development, or the process by which a child acquires movement patterns and skills, has also been shown to be positively associated with PA

(Cliff, Okely, Smith, & McKeen, 2009; Fisher et al., 2005). Early motor development is important as motor skills are a key factor in the likelihood of participation in various forms of PA during later childhood and adolescence (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009a; Fisher et al., 2005). Knowing that, in early childhood, PA opportunities are essential to develop good GMC levels; and that GMC level differences become more evident between children and may in turn affect their PA participation (Barnett et al., 2009a). Some of studies have given attention to the association between MVPA and gross motor skills (Burgi et al., 2011; Olesen et al., 2013),

The present study adds to the literature by systematically reviewing scientific evidence on the relationship between moderate vigorous physical activity and gross motor coordination among preschoolers 3–5 years of age, a population which has received less attention in the literature than primary and secondary school aged children. As the early years of life are an important period of growth it is important to emphasize early identification and intervention of young children suspected as, or at risk of, having poor GMC (Figueroa & An, 2017).

Although our study identified that MVPA was positively associated with GMC and negatively associated with SB. in pre-schoolers, some limitations should be recognized. The study included preschool children from only one metropolitan area, making it difficult to generalize the findings to other samples. Furthermore, because the study was crosssectional, it is not possible to infer causal relationships. Future longitudinal research would be welcome to understand this latter point. Taking into account that motor development occurs in a specific social context and that each context places particular demands on motor skills and motor coordination, we should have adjusted to our paper data on the composition of the housing cluster as well as the socioeconomic status of aggregate, since they are factors that must be taken into account when evaluating this issue (Venetsanou & Kambas, 2010).

The strengths of this study included the assessment of GMC, which has not been widely measured in preschoolers. Our findings demonstrate some interesting

associations which support the few data available on the topic to date. Further studies are needed to understand which strategies better suit the improvement of GMC and PA in the early years.

Conclusion

The current study demonstrates that MVPA was positively associated with GMC and negatively associated with SB, among Portuguese preschoolers. MVPA and GMC proficiency training seems to be linked and it pre-schoolers should be recommended to engage in activities that stimulate GMC as early as possible. This fact is particularly important since a more active lifestyle during childhood can lead to more developed motor competence during adulthood. Therefore, GMC development should be a key strategy in childhood interventions aiming to promote long-term PA.

Disclosure statement

No potential conflict of interest was reported by the authors.

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