Associations between South African preschoolers' routine physical activity, self-regulation and psychosocial well-being

Mental Health and Physical Activity 20 (2021) 100383

Contents lists available at ScienceDirect

Mental Health and Physical Activity

journal homepage: www.elsevier.com/locate/menpa

Associations between South African preschoolers' routine physical activity, self-regulation and psychosocial well-being

Cook Cj [a,b,*], Howard Sj [c], Scerif G [d], Twine R [e], Kahn K [e], Norris Sa [b], Draper Ce [b,a]

[a] Division of Exercise Science and Sports Medicine, Department of Human Biology, University of Cape Town, Cape Town, South Africa
[b] SAMRC Developmental Pathway for Health Research Unit, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa
[c] Early Start Research Institute, Faculty of Social Sciences, University of Wollongong, Wollongong, NSW, Australia
[d] Department of Experimental Psychology, University of Oxford, Oxford, United Kingdom
[e] MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt), Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa

ARTICLE INFO

Keywords:
Sociability
Externalising
Low-income
Accelerometry
Early childhood

ABSTRACT

Physical activity (PA) is an essential health behaviour with a wide range of benefits, including the potential for a beneficial association with self-regulation and psychosocial well-being. However, evidence for this relationship remains scarce in the preschool age-group and in low-income countries. Therefore, this study aimed to examine the relationship between self-regulation and psychosocial well-being on the one hand and objectively measured, free-living PA in 119 preschool children (M_{age} = 50.7 months, SD = 8.4) on the other from low-income settings in South Africa. PA was objectively measured using accelerometry and teacher-report ratings of self-regulation and psychosocial well-being were collected. Results revealed that time spent in both TPA ($B = -0.233$, $p = 0.005$) and MVPA ($B = -0.181$, $p = 0.039$) was negatively associated with self-regulation skills. Additionally, time spent in TPA ($B = 0.180$, $p = 0.034$) was positively (detrimentally) associated with externalising behaviour problems. This study suggests a negative association between self-regulation as well as externalising behaviour and PA, but also highlights the need for more comprehensive and longitudinal research in low and middle-income countries, taking into consideration the nature and context of free-living PA in these settings in order to better understand these relationships and their potential confounds.

1. Introduction

It has been well established that physical activity (PA) is an essential health behaviour with a wide range of benefits (Janssen & Leblanc, 2010; Warburton, Nicol, & Bredin, 2006), and that PA habits from as early as preschool often track through childhood into adulthood (Telama, 2009; Telama et al., 2014). PA guidelines for preschool-aged children (Catherine E. Draper et al., 2020; Okely et al., 2017; Tremblay et al., 2012; World Health Organization, 2019) recommend that, for optimal health and development benefits, children aged 3–5 years engage in 3 h of PA per day, including at least 1 h of moderate-to vigorous-intensity PA (MVPA). There is growing recognition of the potential for early PA to not only influence health and physical development trajectories, but also aspects of cognitive development (Donnelly et al., 2016; Tomporowski, Davis, Miller, & Naglieri, 2008), and psychological well-being (Lubans et al., 2016; Rodriguez-Ayllon et al., 2019). This includes a potential association with self-regulation – the ability to regulate attention, behaviours and emotions in a goal-driven manner (Rothbart, Ellis, & Posner, 2004) – and psychosocial well-being (i.e., higher levels of PA are associated with higher levels of sociability and prosocial behaviours, and less internalising and externalising problems; Hinkley et al., 2014). Aspects of both self-regulation and psychosocial well-being have themselves been found to have a profound influence on development through their influence on lifespan neurodevelopmental trajectories (Robson, Allen, & Howard, 2020; Sylva, Melhuish, Sammons, Siraj-Blatchford, & Taggart, 2004).

In preschool children, there is some evidence – mostly from high-income countries – that indicates a beneficial effect of PA on self-regulation (Ludwig & Rauch, 2018; Mullen & Hall, 2015) and factors contributing to self-regulation, such as executive function and other aspects of cognition (Carson et al., 2015; Donnelly et al., 2016; Tandon, Hassairi, Soderberg, & Joseph, 2018). A potential bi-directional

* Corresponding author. Division of Exercise Science and Sports Medicine, Department of Human Biology, University of Cape Town, Cape Town, South Africa.
E-mail address: caylee.cook@wits.ac.za (C. Cj).

https://doi.org/10.1016/j.mhpa.2021.100383
Received 22 September 2020; Received in revised form 12 January 2021; Accepted 14 January 2021
Available online 20 January 2021

relationship between PA and self-regulation, however, is suggested by evidence that children with high self-regulation are more likely to engage in regular PA (Howard, Vella, & Cliff, 2018; Piché, Fitzpatrick, & Pagani, 2015). Indeed, one study with preschool children (Piché et al., 2015) showed a positive reciprocal relationship: compared to participation in structured, non-athletic activities, participation in structured PA in preschool had a beneficial effect on later self-regulation. Furthermore, good self-regulation in preschool led to increased participation in structured PA (Piché et al., 2015).

There is also evidence for a positive association between PA and higher levels of psychosocial well-being (and lower levels of psychological ill-being; Rodriguez-Ayllon et al., 2019). While there appears to be conclusive evidence for the association between PA and psychosocial well-being in adolescents (Rodriguez-Ayllon et al., 2019), evidence for preschool children is almost non-existent. Similarly, an older review that looked at the associations between PA and psychosocial well-being in preschool-age children found some evidence to indicate a beneficial association, but emphasised that there were too few studies to draw concrete conclusions (Hinkley et al., 2014). Of this limited evidence for preschool-age children, one study found that participation in PA in the form of outdoor play was positively associated with psychosocial well-being (specifically social skills; Hinkley, Brown, Carson, & Teychenne, 2018). The authors hypothesised that this association might be driven by opportunities for peer interactions during outdoor play.

It is clear that more research is needed to evaluate these relationships in preschool-age children and across diverse contexts, and including low- and middle-income country (LMIC) settings given that findings from 'western, educated, industrialised, rich and democratic' (WEIRD) countries do not unconditionally transfer to LMIC contexts. This is likely due to unique contextual factors such as specific cultural and religious norms and practices, family structure and parenting style, and individual responses to psychological stress (Obradović & Willoughby, 2019). Therefore, rather than adopting findings, recommendations and interventions that are derived from highly discrepant HIC contexts, a better understanding is needed of how these developmental factors interact in diverse LMIC settings.

In South Africa, a LMIC, studies with preschoolers have found that children in this age group, and particularly amongst those from low-income settings, are typically exceeding the recommended PA at this age (Cook, Draper, Scerif, & Howard, 2019; Draper et al., 2017; Tomaz et al, 2019, 2020). However, the nature of PA differs as well; children from these low-income settings generally do not have access to extra-mural, sports or structured activities at school or after school (Klingberg, van Sluijs, & Draper, 2020), meaning that this PA is most likely to be free-living PA. Empirical evidence characterising South African children's free-living physical activity in this age group is limited. However, available evidence from previous studies conducted in the same or similar settings (Draper et al., 2017; Klingberg et al., 2020) has highlighted that much of children's physical activity takes place outdoors (in the yard if available and if not, in the street), as there is often minimal space for active play indoors. This has been described by parents as 'running around' in the neighbourhood and is largely unstructured and unsupervised play, despite concerns about safety (Klingberg et al., 2020). While it has not been formally observed and documented (Draper, et al., 2019), this play generally entails activities that do not involve formal equipment and play structures, and rather requires children to improvise and be creative with the space and equipment that have available. Furthermore, while screens are becoming more ubiquitous in South Africa, compared to children in high-income settings, children in lower income settings are less likely to have their own devices (such as mobile phones, tablets), and therefore, spend less time indoors on screens (Klingberg et al., 2020; Tomaz et al., 2020). While previous research has reported on the association between PA and cognitive function in preschool children from the current sample (Cook, Howard, et al., 2019), the relationships between PA, self-regulation and psychosocial well-being have not yet been investigated in these settings.

Therefore, the aim of this study was to examine the relationship between self-regulation and psychosocial well-being with objectively measured, free-living PA in preschool children from low-income settings in South Africa. We hypothesised that self-regulation and favourable components of psychosocial well-being (sociability, prosocial behaviours) would be positively associated with higher amounts and intensities of PA, while unfavourable components of psychosocial well-being (internalising behaviours, externalising behaviours) would be not associated or negatively associated with higher amounts and intensities of PA.

2. Methods

2.1. Study sites

Data were collected from urban and rural low-income settings in South Africa so as to include a diversity of low-income settings. Both settings have a number of challenges that are inherent to low-income areas in South Africa, including: high levels of unemployment (27.7% of the population are unemployed; Statistics South Africa, 2017), and poor educational outcomes (50% of students drop out before final year of school; Spaull, 2015). The low-income urban setting consisted of two preschools in Soweto, Johannesburg. The urban study setting is classified as an urban informal area, or 'township' (Statistics South Africa, 2003). These townships, historically, were situated outside of the city limits for housing the black migrant labour force (enforced by the Group Areas Act during apartheid; Maharaj, 1997). In Soweto, where the predominant ethnicity is black African, the population density is 6357.29 per km^2 (Statistics South Africa, 2011) and the household density is 1776.42 people per km^2. At least 10 of the 11 South African languages are spoken in this area due to the large proportion of migration from rural areas around South Africa (Collinson, Tollman, & Kahn, 2007). Of these, isiZulu and Sesotho are the two most widely spoken languages, followed by Setswana and Xitsonga. Most of Soweto is comprised of both formal and informal housing. Service delivery remains poor in townships, and common issues include overcrowding, high levels of crime and violence (Biersteker, 2010; Winton, 2004). Preschools and early childhood development (ECD) centres in Soweto are typically small, with limited classroom space and almost no outdoor space or outdoor play equipment.

The low-income rural setting consisted of three preschools in the Bushbuckridge sub-district of Mpumalanga Province. The rural study setting is classified as a rural tribal setting, meaning it is an area that falls within the domain of a tribal authority (Statistics South Africa, 2003). The predominant ethnicity in this district is Black African 99.7%, with Xitsonga being spoken by 94.7% of the population (Statistics South Africa, 2011). Population density is much lower than the urban setting, at 610 people per km^2, although extreme poverty is similarly pervasive. The district has a slow rate of infrastructure development and very few tarred roads. Typical living conditions include household plots with a small area to support home-grown crops. Electricity is available in the village; however, most households have no electricity in the home due to its high cost, and therefore rely on open fires for cooking. Additionally, many households have only limited access to running water and rudimentary sanitation with 85% of households having pit toilets (Kahn et al., 2012). Typically, preschools in the area have ample space inside the classrooms and outdoors, including outdoor play equipment. However, the infrastructure of these buildings is generally poor, with limited access to electricity, running water and sanitation. Many preschools (as well as primary and secondary schools) cook food for the children over open fire on the school property.

The preschools in both settings were selected based on an existing relationship with the research units and/or the PI of the study. This meant that the preschools were familiar with research practices however, the participants included in the current study (parents/caregivers and children) had not been involved in any previous research studies.

The preschools were registered for a government stipend. However, this stipend only covers the very basic meals provided to the children during the school day (breakfast and lunch). It does not cover any costs for facilities, equipment, educational resources or staff salaries.

2.2. Participants

To be eligible for participation, children had to: be enrolled at a participating preschool; be aged 3- to 6-years; provide signed consent from a parent or caregiver; and attend preschool on the day of testing. All parents and caregivers of eligible children in the recruited preschools were invited to an information meeting at the respective schools, during which they were given both written and verbal information about the study. Written information sheets and consent forms were available in English, Xitsonga (for the rural group), Sesotho and isiZulu (for the urban group). Verbal information was provided, and the consent forms were explained in the preferred language of the group, with the assistance of a local fieldworker. Thereafter, parents and caregivers were given the opportunity to ask any questions and voice any concerns. Those who were unable to attend the meeting were given the written information, and contact details of the PI and field worker, in case they had any questions. Parents and caregivers were given up to five days to sign and return the consent forms to the preschool, the forms were then collected by the ECD practitioners who then handed them over to the researchers. Regarding the caregivers/participants who did not provide signed consent, no concerns about research participation were communicated to the educators or research team. Instead, they simply did not respond to the invitation to participate.

This yielded an eligible sample of 187 children. Eligible children for whom consent was not given by their parents/caregivers ($n = 51$) did not significantly differ in age ($p = 0.32$) or sex ($p = 0.13$) from the consented sample. Children who expressed unwillingness to participate were excluded before testing. Additional missing data was due to participants being absent on testing days or not meeting wear time criteria for PA measure (explained below). This final sample subjected to analysis was comprised of 119 children ($M_{age} = 50.7 \pm 8.4$, 52% female).

Ethical approval was obtained from the University of Cape Town Human Research Ethics Committee (Ref: 053/2015), and the Human Research Ethics Committee (Medical) at the University of the Witwatersrand (Ref: M160534), and permission given by the Mpumalanga Provincial Department of Health Research Committee. This study adheres to the guidelines explained in the Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects. Parents provided written informed consent for each participant.

2.3. Procedure and measures

Data collection was conducted by researcher who was trained by experts in accelerometry within the department and received training for the EYT from the creator of the tool. The researcher then spent two days training a local fieldworker from each setting who assisted with data collection and could communicate in participants' home language. All children were fluent enough to complete the testing in one of the three main languages (Sotho, Zulu and Xitsonga) and the field worker was generally able to converse in other languages when needed. All testing took place at the preschools during school hours.

Self-regulation and psychosocial well-being. The Early Years Toolbox (EYT) Child Self-Regulation & Behaviour Questionnaire (CSBQ; Howard & Melhuish, 2017) was selected to index self-regulation and aspects of psychosocial well-being. The CSBQ, which was reported by each child's preschool educator, comprises 33 questions about the typicality of everyday self-regulatory behaviours. It includes subscales of cognitive self-regulation (CSR), behavioural self-regulation (BSR) and emotional self-regulation (ESR). It also yields positive (sociability and prosocial) and negative (externalising and internalising problems) aspects of psychosocial well-being. The typicality of these behaviours is rated on a scale from 1 (not true) to 5 (certainly true). Examples of the items for each subscale are; BSR: waits their turn in activities; good at following instructions; CSR: persists with difficult tasks, does not need much help with tasks; ESR: is calm and easy going, gets over being upset quickly; sociability: chosen as a friend by others, plays easily with other children; prosocial: happy to share, helps others; externalising: aggressive to children, shows wide mood swings internalising: most days distressed or anxious, most days says feeling unwell.

CSBQ has shown good convergent validity with Strengths and Difficulties Questionnaire (SDQ) subscales with *r*s for analogous CBSQ and SDQ susbscales: Externalising r = .91; Internalising r = 0.78; Prosocial = .85. CSBQ subscales without direct analogues were compared to the nearest-comparison SDQ subscale: Sociability r = 0.91 (with the prosocial behaviours subscale); BSR r = 0.81; ESR r = 0.66; CSR r = 0.70 (with hyperactivity). The CSBQ has not been validated for use in South African settings, however, the tool has excellent psychometric properties (Howard & Melhuish, 2017; Howard, Neilsen-Hewett, de Rosnay, Vasseleu, & Melhuish, 2019). In addition, no other questionnaires assessing self-regulation have been validated for use in South African settings. The use of the CSBQ in this study therefore provides novel data on the suitability of this measure for this setting.

Consistent with prior studies in Western contexts that found high reliability of CSBQ subscales (Howard, Cook, et al., 2019; Howard & Melhuish, 2017), the current data showed sufficient reliability of these subscales – Cronbach alphas for individual subscales in the current study were: BSR = 0.82; CSR = 0.84; ESR = 0.60; externalising = 0.76; internalising = 0.68; sociability = 0.70; prosocial = .84. There was also evidence of convergent validity, such that the CSR subscale correlated with EF measures in the current data (reported in Cook, Draper, et al., 2019; CSR with inhibition r = 0.26, p = 0.005; CSR with working memory r = 0.22, p = 0.01), and discriminant validity shown by variable correlations between CSBQ subscales (ranging from r = 0.10 to 0.77). Subscale means were also consistent with published preliminary norms for this scale (Howard & Melhuish, 2017).

The CSBQ was administered by a trained researcher who went through the questions with each educator. The educators were able to speak and understand English however, if there were any uncertainties, the fieldworker helped to explain in their home language.

Physical activity. PA was measured objectively using hip-worn ActiGraph GT3× + accelerometers, which participants wore for 24 h on seven consecutive days. Participants, their parents and caregivers and the teachers received verbal and written information in their home language explaining what the device was, how to wear it and how to look after it. Participants were instructed to only remove the device during water activities such as swimming or bathing. A smiley face sticker was placed on the device to remind the participant how to orientate the device.

Data were included for participants who had a minimum of three valid days (two week and one weekend day). Accelerometry counts were recorded at 15-s epochs. Non-wear time was defined as 10 min of consecutive zeros, and a valid day included at least 7 h of wear time (Cliff, Reilly, & Okely, 2009). Accelerometry data was analysed using ActiLife version 6 software (ActiGraph, Pensacola, FL, USA). Age-appropriate cut points were used to calculate PA intensities (Janssen et al., 2013). These included light-intensity physical activity (LPA; 37–419 counts.15s-1), moderate-intensity physical activity (MPA; ≥420–841 counts.15s-1) and vigorous-intensity physical activity (VPA; ≥842 counts.15s-1). Duration of time (in minutes) spent per day in LPA, MPA and VPA total physical activity (TPA; sum of LPA, MPA and VPA) and moderate and vigorous-intensity PA (MVPA; sum of MPA and VPA; >420 counts per 15 s) were then generated based on these cut points.

2.4. Statistical analysis

All analyses were conducted using IBM SPSS Statistics version 25 for Mac (IBM Corp, Armonk, NY). Descriptive statistics were used to

compute mean and standard deviation for self-regulation and PA variables for the full sample. Five multiple linear regressions were conducted to determine whether TPA accounted for significant variance in self-regulation (average score, to reduce the number of multiple regression analyses included) and psychosocial well-being while adjusting for age, sex and setting (urban and rural). Five additional regressions were carried out to determine the effect of different intensities of PA (LPA and MVPA) on self-regulation and psychosocial well-being. LPA and MVPA were included in the same linear regression as no multicollinearity assumptions were violated. Regression results are presented as standardised beta coefficients and significance was set at $p < 0.05$.

3. Results

Participant characteristics of the total sample are reported in Table 1. Participants averaged over 7.5 h (M = 445.68 min/day) of TPA, and just less than 2 h of MVPA (110.05 min/day). Mean totals for the CSBQ subscales all fell within the 'normal' range (according to Australian preliminary norms: Howard & Melhuish, 2017).

Linear regression results for the associations between objectively measured PA with self-regulation and psychosocial well-being are presented in Table 2. Time spent in both TPA ($B = -0.233$, $p = 0.005$) and MVPA ($B = -0.181$, $p = 0.039$) was negatively associated with self-regulation. Effect sizes were large for both TPA (Cohen's d = 0.471) and MVPA (Cohen's d = 0.49). In other words, children who spent more time in TPA and MVPA had lower ratings of self-regulation. Additionally, time spent in TPA ($B = 0.180$, $p = 0.034$) was positively (detrimentally) associated with externalising behaviour with a large effect size (Cohen's d = 0.374). Dissimilarly, the association between sociability and LPA ($B = 0.199$, $p = 0.065$) did not reach statistical significance, but trended in the opposite direction with a medium effect size (Cohen's d = 0.111), such that there might be a beneficial association between time spent in LPA and sociability.

4. Discussion

The current study sought to investigate the relationship between self-regulation, psychosocial well-being and objectively measured, free-living PA in preschool children from low-income settings in South Africa. Results revealed that amount and intensity of PA were associated with self-regulation and some aspects of psychosocial well-being in preschool children from these settings. Specifically, time spent in TPA and MVPA was negatively associated with self-regulation, while time spent in TPA was positively (i.e., detrimentally) associated with externalising behaviours. Internalising behaviour, prosocial behaviour and sociability did not show significant associations with PA at any intensity. However, in contrast to the detrimental associations mentioned above, sociability trended towards a positive (beneficial) association with LPA.

The high volumes of PA reported in the current study builds further on the evidence on South African preschool-aged children in low-income settings (Draper, et al., 2019; Tomaz et al, 2019, 2020). These studies have attributed the high volumes of PA largely to active transport (such as walking to school) and spending a large proportion of their day outdoors playing (Craig, Bland, & Reilly, 2013; Draper et al., 2017; Klingberg et al., 2020; Tomaz et al., 2019).

Overall, teacher-ratings of self-regulation and psychosocial well-being fell within the 'normal' range based on Australian norms (Howard & Melhuish, 2017). Furthermore, teachers put around 80% of children in the top half of the scale – suggesting strong self-regulatory skills in the current sample. This would be consistent with the high levels of executive function found in children from the current sample (Cook, Howard, et al., 2019) and other similar local settings (Howard, Cook, et al., 2019) as executive function is known to contribute to self-regulatory skills. Further examples of this has been found in both recent studies of young children from low-income settings in Africa (Nweze, Nwoke, Nwufo, Aniekwu, & Lange, 2020; Willoughby, Piper, Kwayumba, & McCune, 2018; Wolf & McCoy, 2019) and in cross cultural studies (Ellefson, Ng, Wang, & Hughes, 2017; Steven J. Howard, Cook, et al., 2019; Lamm et al., 2018) in which children from low-income settings or LMIC's are showing significantly stronger executive function skills than expected or compared to their higher-income counterparts. Additionally, literature on models of resilience (Aburn, Gott, & Hoare, 2016) and hidden talents (Ellis et al., 2020) in people who live in or have experienced adversity provides some insight into other mechanisms that might be driving the strong EF and self-regulatory skills found in the current sample. Both models place focus on the strengths and adaptive capabilities that stem from chronic and acute adversity as opposed to the deficits. More specifically, the resilience model refers to the ability of people to develop well despite exposure to adversity (Aburn et al., 2016). The hidden talents model takes this further by suggesting that people can develop specialised skills because of their exposure to adversity (Ellis et al., 2020). Considering that children living in low-income settings may face more challenges than children from high-income settings (such as poverty, food insecurity, and safety concerns; Klingberg et al., 2020), it is possible that low-income environments present more opportunities for children to exercise their executive function and self-regulation skills. On the other hand, it is possible that self-regulatory ratings could be biased by teacher perceptions of 'typical' self-regulation in these settings, however that explanation would not account for the convergent validity with objective measures or discriminant validity across the subscales. Further research is required to provide evidence for these potential explanations.

Results from the current study suggest that children who were more physically active were more likely to have lower ratings of self-regulation. Similarly, those who were more physically active at higher intensities were also more likely to exhibit externalising behaviours. Although this finding is inconsistent with evidence presented in PA intervention studies that show cognitive and psychosocial benefits, specifically at higher intensities (Carson et al., 2017), these results are in line with a growing number of studies reporting a detrimental association between objectively measured PA and behavioural disorders such as externalising behaviour (McNeill, Howard, Vella, Santos, & Cliff, 2018; Page, Cooper, Griew, & Jago, 2010), and hyperactive/inattention problems (Ebenegger et al., 2012). When you consider that highly active children often exhibit poor self-regulatory or externalising behaviours, the limitations of assigning directionality to cross sectional studies becomes clear. Longitudinal data will be necessary to assess the

Table 1
Participant characteristics for the total sample.

	Total (n = 119)
Age	50.7 ± 8.4
BSR	3.78 ± 0.91
CSR	3.68 ± 1.13
ESR	4.02 ± 0.86
SR average score	3.81 ± 0.83
Sociability	3.90 ± 0.67
Prosocial	4.15 ± 1.00
Externalising	1.89 ± 0.94
Internalising	2.27 ± 0.92
LPA (min/day)	353.13 ± 55.49
MPA (min/day)	85.61 ± 21.04
VPA (min/day)	24.45 ± 10.81
TPA (min/day)	455.68 ± 91.18
MVPA (min/day)	110.05 ± 30.08

Data is presented as mean ± standard deviation. BSR = behavioural self-regulation, CSR = cognitive self-regulation, SR = self-regulation, ESR = emotional self-regulation, LPA = light-intensity physical activity, MPA = moderate-intensity physical activity, VPA = vigorous-intensity physical activity, TPA = total physical activity, MVPA = moderate- and vigorous-intensity physical activity.

Table 2
Standardised beta for associations between objectively measured PA, self-regulation and psychosocial well-being.

	Self-regulation			Psychosocial well-being											
	Average score			Sociability			Prosocial			Externalising			Internalising		
	B	***p***	**R^2**	***B***	p	**R^2**	***B***	***p***	**R^2**	***B***	***p***	**R^2**	***B***	***p***	**R^2**
TPA	−0.233	0.005*	0.320	0.146	0.123	0.900	−0.140	0.110	0.218	0.180	0.034*	0.272	0.091	0.289	0.236
LPA	−0.110	0.234	0.329	0.199	0.065	0.100	−0.050	0.615	0.222	0.087	0.363	0.275	0.166	0.090	0.248
MVPA	−0.181	0.039*		−0.041	0.687		−0.128	0.175		0.136	0.134		0.091	0.289	

Note: Linear regression models adjusted for age, sex and setting (urban and rural). BSR = behavioural self-regulation, CSR = cognitive self-regulation, ESR = emotional self-regulation, LPA = light-intensity physical activity, TPA = total physical activity, MVPA = moderate- and vigorous-intensity physical activity. *p < 0.05.

directionality of these relationships.

Furthermore, when it comes to free-living PA, it is more likely that a child's self-regulation or psychosocial traits might influence their participation in PA compared to PA interventions that specifically target these factors. This trend is seen between other aspects of cognitive development and PA, such as executive function, in which beneficial associations are only or especially apparent in PA with specific contexts and characteristics (Diamond, 2012, 2015; Diamond & Ling, 2016). It is possible that largely unsupervised (Klingberg et al., 2020), free-living PA in these low-income South African settings may not be a context that engages, extends and thus fosters self-regulatory skills at this age. Instead, it may be that spending such extended amounts of time (±7.5 h) in predominantly outdoor free play may limit other opportunities to learn and practice self-regulation. For example, in structured PA or teacher-led activities, children are required to listen to and follow instructions despite what they would prefer to be doing whereas in free play, children tend to follow their desires and impulses.

Indeed, evidence for associations between PA and psychosocial well-being have been mixed. However, the review by Hinkley et al. (2014) found some evidence for beneficial associations between PA and psychosocial well-being. While the current study did not show significant associations between PA and internalising, prosocial behaviour or sociability subscales, interestingly, sociability was the only subscale to trend toward a beneficial association with LPA, a trend that requires further replication in these settings. One study that did specifically include a sociability scale found no significant associations with objectively measured PA in Canadian preschool children (Irwin, Johnson, Vanderloo, Burke, & Tucker, 2015). However, that study only recorded PA during school hours whereas the current study measured PA over the full day. It is possible that PA outside of school hours, particularly in these South African settings where substantial PA occurs outside of the school setting (Tomaz et al., 2020), might influence sociability behaviours (or be influenced by them, as longitudinal data may clarify).

This is further supported by a study conducted in similar settings in South Africa found that children in low-income settings tended to accumulate the majority of their PA in the afternoon and early evenings, unlike the children from high-income settings, who accumulated the majority of their PA at preschool and were less active and more sedentary in the afternoons (Tomaz et al., 2020). Moreover, a qualitative study that was conducted in similar settings to the urban sample highlighted the idea that the majority of children's play occurs outdoors, as there is no space for play indoors as there might be in a higher-income household (Klingberg et al., 2020). Therefore, it is possible that the high volumes of PA accumulated in the late afternoons and evenings, consists of outdoor play with siblings and neighbours, including children of different ages, which may have a beneficial effect on sociability behaviours. This hypothesis is in line with a study that found a positive association between outdoor time and social skills (Hinkley et al., 2018).

Alternatively, it may be that the children who are more sociable are more likely spend longer periods of time playing with other children. A review by Rodriguez-Ayllon et al. (2019) concluded that participation in team sports resulted in better psychosocial well-being and attributed this to peer interaction and support involved in team sports. Although children in these settings do not have access to after-school (structured) activities and would not be participating in team sports at this age, it is possible that the mechanisms may be the same, meaning that they are receiving similar positive peer interaction and support while being active. Again, longitudinal data will clarify the directionality of these relationships.(Cook, Draper, et al., 2019),()Draper, Tomaz, Bassett, et al., 2019,()Howard, Cook, et al., 2019.

4.1. Strengths and limitations

It is possible that teachers' ratings of children may be influenced by their individual interpretations of children and may be more inclined to rate children that are highly active as having behaviour problems. This highlights one of the limitations with the use of subjective ratings of self-regulation and psychosocial well-being. However, previous studies have shown that teacher-report measures are typically more predictive and highly correlated with objective measures of self-regulation compared to parent-report measures, emphasising the a strength in the current study (Howard, Neilsen-Hewett, et al., 2019). Nevertheless, future studies should aim to include both objective and subjective measures of self-regulation to replicate these results. A strength of this study is the contribution of research from a largely understudied population from and LMIC to the literature. The lack of previous research in this population means that very few psychological measures (including CSBQ) are validated for this particular sample, or for any African sample. This limits the interpretation of such a measure in a novel sample and is therefore a limitation of the current study. Furthermore, without directly assessing the context of the PA along with the objective measurement, it is difficult to determine the mechanisms behind the associations found. Given the exploratory nature of this study, an a priori power analysis was not performed.

5. Conclusions

This is the first study to investigate associations of psychosocial well-being and self-regulation with PA, in a sample of preschool children from low-income settings in South Africa. This is important as many other studies have focused on the effects or organised or structured PA programmes on self-regulation and psychosocial well-being (Howard et al., 2018; McNeill et al., 2018; Piché et al., 2015), findings of which do not necessarily extend to LMIC settings (where, for instance, PA levels are high and the nature of PA often differs). The current study contributes to the limited available evidence on development of preschool children in LMICs, and factors potentially influencing this development. Specifically, this study suggests a negative association between self-regulation as well as externalising behaviour and PA but also highlights the need for more comprehensive and longitudinal research in LMICs, taking into consideration the nature and context of free-living PA in these settings. This is preferable to simply attempting to apply findings from high-income countries to LMICs, which can lead to misaligned priorities and policy actions.

Declaration of competing interest

None.

Acknowledgements

Funding support for this research was received British Academy for the Humanities and Social Sciences, through a Newton Advanced Fellowship awarded to C Draper. For Caylee J. Cook, the support of the DST-NRF Centre for Excellence in Human Development at the University of Witswatersrand, Johannesburg, in the Republic of South Africa towards this research is hereby acknowledged. The authors would like to thank local field workers, Rachel Setlhafuno and Nonhlanhla Mashaba, as well as Audrey Khosa and Jackson Mabasa for facilitating community engagement in the respective study sites. The authors are also grateful to the preschools, parents/caregivers and children for their cooperation and participation.

References

Aburn, G., Gott, M., & Hoare, K. (2016). What is resilience? An integrative review of the empirical literature. *Journal of Advanced Nursing, 72*(5), 980–1000. https://doi.org/10.1111/jan.12888

Biersteker, L. (2010). *Scaling-up early child Development in South Africa: Introducing a reception year (grade R) for children aged five years As the first Year of schooling (wolfensohn center for development at brookings)*. Cape Town: Global Economy and Development at Brookings.

Carson, V., Hunter, S., Kuzik, N., Wiebe, S. A., Spence, J. C., Friedman, A., et al. (2015). Systematic review of physical activity and cognitive development in early childhood. *Journal of Science and Medicine in Sport, 19*(7), 573–578. https://doi.org/10.1016/j.jsams.2015.07.011

Carson, V., Lee, E.-Y., Hewitt, L., Jennings, C., Hunter, S., Kuzik, N., et al. (2017). Systematic review of the relationships between physical activity and health indicators in the early years (0-4 years). *BMC Public Health, 17*(S5), 854. https://doi.org/10.1186/s12889-017-4860-0

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. https://doi.org/10.1016/j.jsams.2008.10.008

Collinson, M. A., Tollman, S. M., & Kahn, K. (2007). Migration, settlement change and health in post-apartheid South Africa: Triangulating health and demographic surveillance with national census data. *Scandinavian Journal of Public Health, 35* (SUPPL. 69), 77–84. https://doi.org/10.1080/14034950701356401

Cook, C., Draper, C., Scerif, G., & Howard, S. J. (2019). *Executive function and physical activity in preschool children from low-income settings in South Africa. University of Cape Town*.

Cook, C. J., Howard, S. J., Scerif, G., Twine, R., Kahn, K., Norris, S. A., et al. (2019). Associations of physical activity and gross motor skills with executive function in preschool children from low-income South African settings. *Developmental Science, 22*(5), 1–13. https://doi.org/10.1111/desc.12820

Craig, E., Bland, R., & Reilly, J. (2013). Objectively measured physical activity levels of children and adolescents in rural South Africa: High volume of physical activity at low intensity. *Applied Physiology Nutrition and Metabolism, 38*(999), 81–84. https://doi.org/10.1139/apnm-2012-0115

Diamond, A. (2012). Activities and programs that improve children's executive functions. *Current Directions in Psychological Science, 21*(5), 335–341. https://doi.org/10.1177/0963721412453722

Diamond, A. (2015). Effects of physical exercise on executive functions: Going beyond simply moving to moving with thought. *Ann Sports Med Res, 2*(1), 1–6.

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

Draper, C. E., Tomaz, S. A., Bassett, S. H., Harbron, J., Kruger, H. S., Micklesfield, L. K., et al. (2019a). Results from the healthy active kids South Africa 2018 report card. *SAJCH South African Journal of Child Health, 13*(3), 130–136. https://doi.org/10.7196/SAJCH.2019.v13.i3.1640

Draper, C. E., Tomaz, S. A., Biersteker, L., Cook, C. J., Couper, J., De Milander, M., et al. (2020). The South African 24-hour movement guidelines for birth to 5 years: An integration of physical activity, sitting behavior, screen time, and sleep. *Journal of Physical Activity and Health, 17*(1), 109–119. https://doi.org/10.1123/jpah.2019-0187

Draper, C. E., Tomaz, S. A., Jones, R. A., Hinkley, T., Twine, R., Kahn, K., et al. (2019b). Cross-sectional associations of physical activity and gross motor proficiency with adiposity in South African children of pre-school age. *Public Health Nutrition, 22*(4), 614–623. https://doi.org/10.1017/s1368980018003579

Draper, C. E., Tomaz, S. A., Stone, M., Hinkley, T., Jones, R. A., Louw, J., et al. (2017). Developing intervention strategies to optimise body composition in early childhood in South Africa. *BioMed Research International*. https://doi.org/10.1155/2017/5283457

Ebenegger, V., Marques-Vidal, P. M., Munsch, S., Quartier, V., Nydegger, A., Barral, J., et al. (2012). Relationship of hyperactivity/inattention with adiposity and lifestyle characteristics in preschool children. *Journal of Child Neuropsychology, 27*(7), 852–858.

Ellefson, M. R., Ng, F. F. Y., Wang, Q., & Hughes, C. (2017). Efficiency of executive function: A two-generation cross-cultural comparison of samples from Hong Kong and the United Kingdom. *Psychological Science, 28*(5), 555–566. https://doi.org/10.1177/0956797616687812

Ellis, B. J., Abrams, L. S., Masten, A. S., Sternberg, R. J., Tottenham, N., & Frankenhuis, W. E. (2020). Hidden talents in harsh environments. *Development and Psychopathology, 1–19*. https://doi.org/10.1017/S0954579420000887

Hinkley, T., Brown, H., Carson, V., & Teychenne, M. (2018). Cross sectional associations of screen time and outdoor play with social skills in preschool children. *PloS One, 13*(4), 1–15.

Hinkley, T., Teychenne, M., Downing, K. L., Ball, K., Salmon, J., & Hesketh, K. D. (2014). Early childhood physical activity, sedentary behaviors and psychosocial well-being: A systematic review. *Preventive Medicine, 62*, 182–192. https://doi.org/10.1016/j.ypmed.2014.02.007

Howard, S. J., Cook, C. J., Everts, L., Melhuish, E., Scerif, G., Norris, S., et al. (2019). Challenging socioeconomic status: A cross-cultural comparison of early executive function. *Developmental Science*. , Article e12854. https://doi.org/10.1111/desc.12854

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

Howard, S. J., Neilsen-Hewett, C., de Rosnay, M., Vasseleu, E., & Melhuish, E. (2019). Evaluating the viability of a structured observational approach to assessing early self-regulation. *Early Childhood Research Quarterly, 48*, 186–197. https://doi.org/10.1016/j.ecresq.2019.03.003

Howard, S. J., Vella, S. A., & Cliff, D. P. (2018). Children's sports participation and self-regulation: Bi-directional longitudinal associations. *Early Childhood Research Quarterly, 42*, 140–147. https://doi.org/10.1016/j.ecresq.2017.09.006

Irwin, J. D., Johnson, A. M., Vanderloo, L. M., Burke, S. M., & Tucker, P. (2015). Temperament and objectively measured physical activity and sedentary time among Canadian preschoolers. *Preventive Medicine Reports, 2*, 598–601. https://doi.org/10.1016/j.pmedr.2015.07.007

Janssen, X., Cliff, D. P., Reilly, J. J., Hinkley, T., Jones, R. A., Batterham, M., et al. (2013). Predictive validity and classification accuracy of ActiGraph energy expenditure equations and cut-points in young children. *PloS One, 8*(11), 1–9. https://doi.org/10.1371/journal.pone.0079124

Janssen, I., & Leblanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity, 7*, 40. https://doi.org/10.1186/1479-5868-7-40

Kahn, K., Collinson, M. A., Xavier Gómez-olivé, F., Mokoena, O., Twine, R., Mee, P., et al. (2012). Profile: Agincourt health and socio-demographic surveillance system. *International Journal of Epidemiology, 41*(4), 988–1001. https://doi.org/10.1093/ije/dys115

Klingberg, S., van Sluijs, E. M. F., & Draper, C. E. (2020). Parent perspectives on preschoolers' movement and dietary behaviours: A qualitative study in Soweto, South Africa. *Public Health Nutrition*. https://doi.org/10.1017/S1368980020003730, 2013.

Lamm, B., Keller, H., Teiser, J., Gudi, H., Yovsi, R. D., Freitag, C., et al. (2018). Waiting for the second treat: Developing culture-specific modes of self-regulation. *Child Development, 89*(3), e261–e277. https://doi.org/10.1111/cdev.12847

Lubans, D., Richards, J., Hillman, C., Faulkner, G., Beauchamp, M., Nilsson, M., et al. (2016). Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. *Pediatrics, 138*(3), Article e20161642. https://doi.org/10.1542/peds.2016-1642

Maharaj, B. (1997). Apartheid, urban segregation, and the local state: Durban and the group Areas Act in South Africa. *Urban Geography, 18*(2), 135–154. https://doi.org/10.2747/0272-3638.18.2.135

McNeill, J., Howard, S. J., Vella, S. A., Santos, R., & Cliff, D. P. (2018). Physical activity and modified organized sport among preschool children: Associations with cognitive and psychosocial health. *Mental Health and Physical Activity, 15*(July), 45–52. https://doi.org/10.1016/j.mhpa.2018.07.001

Nweze, T., Nwoke, M. B., Nwufo, J. I., Aniekwu, R. I., & Lange, F. (2020). Working for the future: Parentally deprived Nigerian children have enhanced working memory ability. *The Journal of Child Psychology and Psychiatry and Allied Disciplines*. https://doi.org/10.1111/jcpp.13241

Obradović, J., & Willoughby, M. T. (2019). Studying executive function skills in young children in low- and middle-income countries: Progress and directions. *Child Development Perspectives, 13*(4), 227–234. https://doi.org/10.1111/cdep.12349

Okely, A. D., Ghersi, D., Hesketh, K. D., Santos, R., Loughran, S. P., Cliff, D. P., et al. (2017). A collaborative approach to adopting/adapting guidelines - the Australian 24-hour movement guidelines for the early years (birth to 5 years): An integration of physical activity, sedentary behavior, and sleep. *BMC Public Health, 17*(5), 869. https://doi.org/10.1186/s12889-017-4867-6

Page, A. S., Cooper, A. R., Griew, P., & Jago, R. (2010). Children's screen viewing is related to psychological difficulties irrespective of physical activity. *Pediatrics, 126*(5). https://doi.org/10.1542/peds.2010-1154

Piché, G., Fitzpatrick, C., & Pagani, L. S. (2015). Associations between extracurricular activity and self-regulation: A longitudinal study from 5 to 10 years of age. *American Journal of Health Promotion, 30*(1), e32–e40. https://doi.org/10.4278/ajhp.131021-QUAN-537

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

Rodriguez-Ayllon, M., Cadenas-Sánchez, C., Estévez-López, F., Muñoz, N. E., Mora-Gonzalez, J., Migueles, J. H., et al. (2019). Role of physical activity and sedentary behavior in the mental health of preschoolers, children and adolescents: A systematic review and meta-analysis. *Sports Medicine, 49*(9), 1383–1410. https://doi.org/10.1007/s40279-019-01099-5

Rothbart, M., Ellis, L., & Posner, M. (2004). *Temperament and self regulation. Handbook of self regulation: Research, theory, and applications*.

Spaull, N. (2015). Schooling in South Africa: How low quality education becomes a poverty trap. *South African Child Gauge*, (12), 34–41, 2015.

Statistics South Africa. (2003). *Investigation into appropriate definitions of urban and rural areas for South Africa: Discussion document. Statistics South Africa. Pretoria*.

Statistics South Africa. (2011). *Census 2011. Pretoria*.

Sylva, K., Melhuish, E., Sammons, P., Siraj-Blatchford, I., & Taggart, B. (2004). The effective provision of pre-school education project: Findings from the pre-school period. *Revista Portuguesa de Pedagogia, 38*, 203–219, 1,2e3.

Tandon, P., Hassairi, N., Soderberg, J., & Joseph, G. (2018). The relationship of gross motor and physical activity environments in child care settings with early learning outcomes. *Early Child Development and Care*, 1–10. https://doi.org/10.1080/03004430.2018.1485670, 0(0).

Telama, R. (2009). Tracking of physical activity from childhood to adulthood: A review. *Obesity Facts, 2*(3), 187–195. https://doi.org/10.1159/000222244

Telama, R., Yang, X., Leskinen, E., Kankaanpaa, A., Hirvensalo, M., Tammelin, T., et al. (2014). Tracking of physical activity from early childhood through youth into adulthood. *Medicine & Science in Sports & Exercise, 46*(5), 955–962. https://doi.org/10.1249/MSS.0000000000000181

Tomaz, S. A., Hinkley, T., Jones, R. A., Twine, R., Kahn, K., Norris, S. A., et al. (2020). Objectively measured physical activity in South African children attending preschool and grade R: Volume, patterns, and meeting guidelines. *Pediatric Exercise Science*.

Tomaz, S. A., Prioreschi, A., Watson, E. D., McVeigh, J. A., Rae, D. E., Jones, R. A., et al. (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. *Journal of Physical Activity and Health, 16*(7), 525–532. https://doi.org/10.1123/jpah.2018-0133

Tomporowski, P. D., Davis, C. L., Miller, P. H., & Naglieri, J. A. (2008). Exercise and children's intelligence, cognition, and academic achievement. *Educational Psychology Review, 20*(2), 111–131. https://doi.org/10.1007/s10648-007-9057-0

Tremblay, M. S., LeBlanc, A. G., Carson, V., Choquette, L., Connor Gorber, S., Dillman, C., et al. (2012). Canadian physical activity guidelines for the early years (aged 0–4 years). *Applied Physiology Nutrition and Metabolism, 37*(2), 345–356. https://doi.org/10.1139/h2012-018

Warburton, D. E. R., Nicol, C. W., & Bredin, S. S. D. (2006). Health benefits of physical activity: The evidence. *Canadian Medical Association Journal: Canadian Medical Association Journal, 174*(6), 801. https://doi.org/10.1503/cmaj.051351

Willoughby, M. T., Piper, B., Kwayumba, D., & McCune, M. (2018). Measuring executive function skills in young children in Kenya. *Child Neuropsychology*, 1–20. https://doi.org/10.1080/09297049.2018.1486395, 00(00.

Winton, A. (2004). Urban violence: A guide to the literature. *Environment and Urbanization, 16*(2), 165–184. https://doi.org/10.1177/095624780401600208

Wolf, S., & McCoy, D. C. (2019). The role of executive function and social-emotional skills in the development of literacy and numeracy during preschool: A cross-lagged longitudinal study. *Developmental Science, 22*(4), 1–18. https://doi.org/10.1111/desc.12800

World Health Organization. (2019). Guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age. Retrieved from https://apps.who.int/iris/handle/10665/311664.