

Table A.1.g. Cognitive outcomes and physical activity, children and adolescents

Questions: What is the association between **physical activity** and health-related outcomes? Is there a dose response association (volume, duration, frequency, intensity)?

Does the association vary by type or domain of PA?

Population: Children aged 5-under 18 years of age

Exposure: Greater volume, duration, frequency, or intensity of physical activity

Comparison: No physical activity or lesser volume, duration, frequency, or intensity of physical activity

Outcome: Cognitive outcomes (e.g., academic performance, executive function)

***Importance:** CRITICAL

Black font is from original GRADE Evidence Profiles from Australian 24-Hour Movement Guidelines for Children (5-12 years) and Young People (12-17 years).(26) **Red font denotes additions based on WHO update using review of existing systematic reviews.**

No. of studies/ Study design	Quality Assessment					Summary of findings	Certainty	US PAGAC evidence (27)
	Risk of bias	Inconsistency	Indirectness	Imprecision	Other			
The range of mean ages was 7.8 to 16.9 years. Data were collected by RCT, non-randomized intervention trial, cross-sectionally and up to 6 years of follow-up. Cognitive Development / Academic Achievement were assessed by: WIAT-III, TEA-Ch, CDR, computerized cognitive assessment system, d2 Test of Attention, Letter Digit Substitution Test, BAS, Trail Making Test, Stroop Color and Word Test, Verbal Fluency Test, WISC-IV, WAI, OSPAN, The Tower of London, school records and GPA, and state or national level standardized tests. Mathematics Engagement was assessed using School Engagement Measure. On-task Behaviour was assessed through systematic direct observation. All outcomes were measured objectively.								
4 RCTs n=2,847	Serious risk of bias	No serious inconsistency	Serious indirectness	No serious imprecision	<p>Possibility of publication bias</p> <p>Most trials did not address higher level EF measures</p>	<p>Xue et al. 2018 (24) (19 RCTs; n = 5,038): Exercise interventions with multiple sessions per week for 6 weeks or longer were associated with greater change in overall EF (SMD 0.20 [95% I, 0.09 to 0.30], $p<0.05$), inhibitory control (SMD 0.26 [95% CI, 0.08 to 0.45], $p<0.01$), working memory (SMD 0.10 [95% CI, -0.05 to 0.25], $p<0.02$), and cognitive flexibility (SMD 0.14 [95% CI, -0.03 to 0.31], $p<0.04$) compared with no exercise interventions. There was no evidence of an effect on planning. Effects of exercise interventions was comparatively larger on populations with higher versus lower BMIs.</p> <p>Martin et al. 2017 (16): (3 RCTs, 2 NRTs; n=2,204): Mixed effects of classroom-based PA vs. no PA on measures of learning, reasoning, math, reading, fluid intelligence social studies, and math, science, and English.</p> <p>On-task behaviour 3 studies found positive effects of PA intervention on on-task behaviour (Bartholomew et al. 2018; Riley et al. 2016; Grieco et al. 2016).</p> <p>Cognition 1 study found no difference between PA intervention and control groups for content recall (Norris et al. 2015).</p> <p>Academic achievement 1 study found no change on mathematical test performance following the PA intervention (Riley et al. 2016).</p>	MODERATE ^m	<p>9 ESRs</p> <p>Moderate evidence indicates an effect of both acute and long-term moderate-to-vigorous physical activity interventions on brain, cognition, and academic outcomes (e.g., school performance, psychometric profile of memory and executive function) in preadolescent children ages 5 to 13 years.</p> <p>PAGAC Grade: Moderate.</p> <p>Insufficient evidence is available to determine whether a relationship</p>

5 NRTs ^a n=547	Serious risk of bias ^b	No serious inconsistency	Serious indirectness ^c	No serious imprecision	NR	<p>On-task behaviour 2/3 studies showed positive effects of PA intervention on on-task behaviour (Goh 2017; Mullender-Wijnsma et al. 2015); 1/3 studies showed no effects of PA intervention on on-task behaviour (Wilson et al. 2016).</p> <p>Cognition 2 studies showed no effects of PA intervention on sustained attention or executive function text performance (processing speed, selective attention) (Wilson et al. 2016; van den Berg et al. 2016).</p> <p>Academic Achievement GPA increased in both groups, but there were no between-group differences (Shore et al. 2014).^d</p>	VERY LOW ^e	exists between moderate-to-vigorous physical activity and cognition in adolescents ages 14 to 18 years. PAGAC Grade: Not assignable.
9 Longitudinal f n=15,460 No reviews limited to longitudinal studies identified.	Serious risk of bias ^g	No serious inconsistency	No serious indirectness	No serious imprecision	NR	<p>Academic Achievement School Grades %MVPA at age 11 yr was favourably associated with English (but not Math or Science), and with academic attainment at age 13 and 16 in boys and girls (association also significant for Science in girls at age 16 yr) (Booth et al. 2014). 1 study found null association between MVPA and Grade based points (Corder et al. 2015).</p> <p>Standardized tests 1 study found PA index was favourably associated with writing score, but not reading or numeracy (Telford et al. 2012b). 1 study found that changes in MVPA had mixed favourable (in girls) and null (in boys) associations with changes in NAPLAN test scores (Owen et al. 2018). 1 study found null associations between <i>total PA (cpm)</i> or <i>% time in MVPA</i> with numeracy, reading and English (Aadland et al. 2017).</p> <p>Cognition Executive function tests (CDR): 1 study found no association between <i>total PA</i> or <i>% time in MVPA</i> at age 11 yr and test speed or accuracy at age 13. In boys, %MVPA (adjusted for total PA) was favourably associated with accuracy, but not speed. In girls, no association with speed or accuracy (Booth et al. 2013). 1 study found no associations between <i>total PA (cpm)</i> or <i>% time in MVPA</i> with inhibition, working memory and cognitive flexibility (Aadland et al. 2017). 1 study found unfavourable associations between LPA and verbal reasoning and verbal knowledge, while mixed unfavourable and null associations for MVPA (Aggio et al. 2016). 1 study found mixed unfavourable (in girls) and null (in boys) associations between LPA and fluid intelligence; and mixed unfavourable (in boys) and null (in girls) associations between VPA and inhibitions (Wickel et al. 2017). 1 study found null associations between LPA with inhibition and working memory, between MPA or MVPA with inhibition, working memory and fluid intelligence; and between VPA with working memory and intelligence (Wickel et al. 2017)</p>	LOW ^h	

						<p>Mathematics Engagement 1 study found that changes in <i>MVPA</i> had null association with changes in mathematics engagement (Owen et al. 2018a). 1 study found null associations between <i>LPA</i>, <i>MPA</i>, <i>VPA</i> and <i>MVPA</i> with mathematics engagement. (Owen et al. 2018b) 1 study found mixed favourable associations between <i>MPA</i> and cognitive engagement, and null associations with behavioural, emotional and overall school engagement. (Owen et al. 2018b)</p>		
6 Cross-sectional ^f n=11,996	Serious risk of bias ^j	Serious inconsistency ^k	No serious indirectness	No serious imprecision		<p>Marques et al. 2016 (15) (41 cross-sectional studies, 2 RCTs, and 8 longitudinal studies; n = NR): There was no consistent evidence of a relationship between objectively-measured PA and academic outcomes (4/11 studies found statistically significant positive association; 1/11 study found an inverse relationship; 6/11 studies reported no relationship). 12/18 studies reported statistically significant associations between self-reported PA and academic measures and 6/18 studies found no relationship.</p> <p>Academic Achievement Standardized tests Total PA 2/2 studies reported no association between <i>total PA</i> and WIAT-III (Lambourne et al. 2013; Hansen et al. 2014).</p> <p>MPA, MVPA, VPA 1/3 studies reported mixed unfavourable and null associations between <i>MVPA</i> and state Math test performance with inconsistencies occurring across samples (Young et al. 2014). 1/3 studies reported mixed favourable and null associations, with %<i>MVPA</i> favourably associated with English (but not Math or Science) scores in boys, and English and Science (but not Math) scores in girls (Booth et al. 2014). School Grades 1/3 studies found <i>MPA</i>, <i>MVPA</i> and <i>VPA</i> were unfavourably associated with Math and Language scores, and GPA (Esteban-Cornejo et al. 2014).</p> <p>Cognition Total PA and MVPA Executive function tests (TEA-Ch, CDR) 1/1 studies reported mixed null and favourable associations between <i>total PA</i> or %<i>MVPA</i> and test speed and accuracy (Booth et al. 2013).</p>	VERY LOW ^f	

Note: CDR = Cognitive Drug Research; EF = executive function; GPA = grade point average; MPA = moderate intensity physical activity; MVPA = moderate-to-vigorous physical activity; NR = not reported; NRT = non-randomized trial; PA = physical activity; SMD = standardized mean difference; TEA-Ch = Test of Everyday Attention for Children; VPA = vigorous intensity physical activity; WIAT-III = Weschler Individual Achievement Test of oral language, written language and mathematics-Third Edition.

^fAs determined by WHO

^a Includes 1 non-randomized trial (Shore et al. 2014).

^b Serious risk of bias. No inclusion/exclusion criteria established; inadequate reporting of recruitment, allocation concealment, and blinding; large unexplained loss to follow-up (36.5% retention) and unknown if follow-up differed by group allocation (Shore et al. 2014).

^c Serious indirectness. Differences in intervention: studies examined PE class content and provided indirect evidence bearing on the potential effectiveness of different intensities and durations of PA. Indirect comparisons: different durations and intensities of PA were not compared within individual studies.

^d The intervention group increased steps/day (baseline to post-intervention: 9692 to 12307) more than the control group (9420 to 10608) (Shore et al. 2014).

^e The quality of evidence from the non-randomized study was downgraded from "low" to "very low" due to: (1) a serious risk of bias that diminished the level of confidence in the observed effects, and (2) serious indirectness of the intervention and the comparison being assessed.

^fIncludes **3 longitudinal studies** (Telford et al. 2012b; Booth et al. 2013; Booth et al. 2014) from **2 unique samples**. **Two studies** reported data from the ALSPAC sample (Booth et al. 2013; Booth et al. 2014); results are reported separately, and participants are only counted once.

^gSerious risk of bias. Validity and reliability of outcomes unknown (Telford et al. 2012b; Booth et al. 2013; Booth et al. 2014).

^h**The quality of evidence from the longitudinal studies was not upgraded from "low" to "moderate" due to serious risk of bias.**

ⁱIncludes **6 cross-sectional studies** (Lambourne et al. 2013; Booth et al. 2013; Esteban-Cornejo et al. 2014; Young et al. 2014; Booth et al. 2014; Hansen et al. 2014) from **5 unique samples**. **Two studies** reported data from the ALSPAC sample (Booth et al. 2013; Booth et al. 2014); results are reported separately, and participants are only counted once.

^jSerious risk of bias. Valid PA data missing for 41.5% of the sample (Hansen et al. 2014). Validity and reliability of outcomes unknown (Booth et al. 2013 and 2014; Esteban-Cornejo et al. 2014; Young et al. 2014).

^kSerious inconsistency. **Two studies** found unfavourable associations [between PA (MPA, MVPA, VPA) and GPA (Esteban-Cornejo et al. 2014), and between MVPA and state Math test performance (Young et al. 2014)], **2 studies** found no associations [between total PA and WIAT-III (Lambourne et al. 2013; Hansen et al. 2014)], and **2 studies** found no or favourable associations [between PA (total, %MVPA) and executive function tests (Booth et al. 2013); and between %MVPA and national English, Math and Science test scores (Booth et al. 2014)].

^lThe quality of evidence from cross-sectional studies was downgraded from "low" to "very low" due to: (1) a serious risk of bias in five studies that diminished the level of confidence in the observed effects, and (2) large unexplained inconsistency among the findings.

^mThe quality of evidence from the RCT was downgraded from "high" to "moderate" due to: (1) a serious risk of bias that diminished the level of confidence in the observed effects, and (2) serious indirectness of the intervention and the comparison being assessed.