Table A.1.c. Bone health 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: Bone health
***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.

	Quality Assessment							
No. of studies/ Study design **No. of participants**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other**	**Summary of findings**	**Certainty**	**US PAGAC evidence *(27)***
The range of mean ages was 5.2 to 17.7 years. Data were collected by RCT, cross-sectionally, and up to 12 years of follow-up. Measures included: BMD, BMC, scanned area, cross-sectional area, total skeletal area, section modulus, bone stress index, femur and tibia bone strength index, strength-strain index, polar moment of inertia, cross-sectional moment of inertia, periosteal and endosteal circumference, cortical thickness, cortical BMC, cortical bone area, BMD ratios (femoral neck to trochanter, femoral neck to intertrochanter, trochanter to intertrochanter). All outcomes were measured objectively by DXA or peripheral quantitative CT.								
2 RCTs[a] N = 73 **No eligible reviews identified.**	No serious risk of bias	No serious inconsistency	Serious indirect-ness[b]	No serious imprecision	None	In both groups, **BMD** increased more during periods of physical training than during periods of no physical training (Gutin et al. 1999).	MODERATE[c]	10 ESRs Strong evidence demonstrates that children and youth who are more physically active than their peers have higher bone mass, improved bone structure, and greater bone strength. **PAGAC Grade: Strong**.
7 Longitudinal[d] N = 948 **No eligible reviews identified.**	No serious risk of bias	No serious inconsistency	No serious indirect-ness	No serious imprecision	None	*Total PA* **1 study** reported that baseline *total PA* predicted follow-up **BMC** at the **hip, trochanter, spine** and **whole body** in *boys* and at the **trochanter** and **whole body** in *girls* (data not shown). **Total PA** explained 1-2% of the variability in **BMC** (Janz et al. 2006). Children who maintained **high levels of PA** over the 3-yr period (≥50th percentile) accrued, on average, 14% more **trochanteric BMC** and 5% more **whole-body BMC** relative to peers maintaining **low levels of PA** (<50th percentile) (Janz et al. 2006). **1 study** found that spending a higher proportion of total PA in MPA-VPA relative to LPA was favourably associated with **BMC, BMD** and **bone area** (Heidemann et al. 2013). *VPA* **Hip** and **spine BMC:** mixed (favourable and null) associations (**2/2 studies;** Janz et al. 2014a; Francis et al. 2014). *MVPA*	MODERATE[e]	

						Whole body, spine and **hip BMC:** mixed (favourable and null) associations (**3/3 studies;** Janz et al. 2010; Francis et al. 2014; Janz et al. 2014b); **Hip BMD:** mixed (favourable and null) associations (**1/1 studies;** Janz et al. 2014b). **Femoral neck cross-sectional area** and **section modulus:** mixed (favourable and null) associations (**2/2 studies;** Janz et al. 2007; Janz et al. 2014b); **Measures of bone strength** (**bone stress index** and **polar moment of inertia**): mixed (favourable and null) associations (**1/1 studies;** Janz et al. 2014b).		
14 Cross-sectional[f] N = 6,520 **No eligible reviews identified.**	No serious risk of bias	No serious inconsistency	No serious indirect-ness	No serious imprecision	None	*Meeting/Not Meeting Guidelines (≥60 min/day MVPA)* **1 study** reported that meeting guidelines had no association with **BMC** (whole body, hip, lumbar spine, trochanter, intertrochanter, femoral) (Gracia-Marco et al. 2011a). **1 study** reported that meeting guidelines had mixed favourable, null, and unfavourable associations with **BMC** of at least 1 anatomical region (**whole body, upper limb, lower limb)** (Gracia-Marco et al. 2011b). **1 study** reported that meeting guidelines had mixed favourable (girls) and null (boys) associations (**lumbar spine**) or null associations (**whole body, hip, trochanter, intertrochanter** or **femoral neck**) with **BMD** (Gracia-Marco et al. 2011a). *Total PA* *Total PA and BMC:* **Whole body BMC:** associations were favourable (**1/2 studies;** Gracia-Marco et al. 2012), or mixed (favourable in boys, null in girls; **1/2 studies**; Janz et al. 2001); **Hip BMC:** favourable associations (**2/2 studies;** Janz et al. 2001; Gracia-Marco et al. 2012); **Spine BMC:** favourable association (**1/1 studies;** Janz et al. 2001). *Total PA and BMD:* **Whole body BMD:** null associations (**1/1 studies;** Janz et al. 2001); **Hip BMD:** favourable associations (**1/1 studies;** Janz et al. 2001); **Spine BMD:** mixed (null in boys, favourable in girls) associations (**1/1 studies;** Janz et al. 2001); **Calcaneal** and **distal forearm BMD:** favourable associations (**1/1 studies;** Hasselstrom et al. 2007). *Total PA and Area and strength:* **Total skeletal area:** favourable associations (**1/1 studies;** Janz et al. 2001). **Femur** and **tibia strength index/strength-strain index:** mixed (favourable and null) associations (**1/1 studies;** Farr et al. 2011). *VPA* *VPA and BMC:* **Whole body BMC:** associations were favourable (**1/1 studies;** Tobias et al. 2007) or mixed (favourable in boys, null in girls; **1/1 studies;** Janz et al. 2001); **Whole body BMC adjusted for bone area:** null associations (**1/1 studies;** Tobias et al. 2007);	LOW[g]	

						Hip BMC: favourable associations (**2/2 studies;** Janz et al. 2001 and 2014a); **Spine BMC:** associations were favourable (**2/3 studies;** Janz et al. 2001 and 2014a) or null (**1/3 studies;** Francis et al. 2014). **Upper limb *absolute* BMC:** favourable associations (**1/1 studies;** Tobias et al. 2007); **Lower limb *absolute* BMC:** null associations (**1/1 studies;** Tobias et al. 2007); **Upper** and **lower limb *areal* BMC:** null associations (**1/1 studies;** Tobias et al. 2007); **Cortical BMC:** favourable associations (**1/1 studies**; Sayers et al. 2011). *VPA and BMD:* **Whole body BMD:** associations were favourable (**1/2 studies;** Tobias et al. 2007) or null (**1/2 studies**; Janz et al. 2001); **Whole body *areal* BMD:** favourable associations (**1/1 studies;** Tobias et al. 2007); **Hip BMD:** favourable associations (**1/1 studies;** Janz et al. 2001); **Spine BMD:** mixed (null in boys, favourable in girls) associations (**1/1 studies;** Janz et al. 2001); **Calcaneal** and **distal forearm:** favourable associations (**1/1 studies;** Hasselstrom et al. 2007); **Upper limb *absolute*** or ***areal* BMD:** favourable associations (**1/1 studies;** Tobias et al. 2007); **Lower limb *absolute*** or ***areal* BMD:** null associations (**1/1 studies;** Tobias et al. 2007); **Femoral neck, trochanter** and **intertrochanter BMD:** favourable associations (**1/1 studies;** Cardadeiro et al. 2012); **Cortical BMD:** unfavourable associations (**1/1 studies;** Sayers et al. 2011); **BMD ratios:** null (femoral neck to intertrochanter, trochanter to intertrochanter) or mixed (null in boys, negative in girls; femoral neck to intertrochanter) associations (**1/1 studies;** Cardadeiro et al. 2012). *VPA and Area and strength:* **Total skeletal area:** favourable association (**1/1 studies;** Janz et al. 2001); **Cortical bone area:** favourable association (**1/1 studies;** Sayers et al. 2011); **Periosteal circumference of the tibia:** positive association (**1/1 studies;** Sayers et al. 2011); **Endosteal circumference of the tibia:** negative association (**1/1 studies;** Sayers et al. 2011); **Cross-sectional area** and **section modulus** of **narrow neck, intertrochantic** and **shaft** regions of **femur:** favourable associations (**1/1 studies;** Janz et al. 2004). <u>*MVPA*</u> *MVPA and BMC:* **Whole body BMC:** mixed (favourable and null) associations (**1/1 studies;** Janz et al. 2008); **Hip BMC:** favourable associations (**2/2 studies;** Janz et al. 2008; Janz et al. 2014a); **Spine BMC:** mixed (favourable in boys, null in girls) associations (**2/3 studies;** Janz et al. 2008; Janz et al. 2014a), or null associations (**1/3 study;** Francis et al. 2014).		

						MVPA and BMD: **Femoral neck, trochanter** and **intertrochanter BMD:** null associations (**1/1 studies;** Cardadeiro et al. 2012); **BMD ratios:** null (femoral neck to trochanter, trochanter to intertrochanter) or mixed (null in boys, positive in girls; femoral neck to intertrochanter) associations (**1/1 studies;** Cardadeiro et al. 2012). <u>*MPA*</u> *MPA and BMC:* **Whole body *absolute* or *areal* BMC:** favourable associations (**1 /1 studies;** Tobias et al. 2007); **Upper limb *absolute* or *areal* BMC:** null associations (**1/1 studies;** Tobias et al. 2007); **Lower limb *absolute* or *areal* BMC:** favourable associations (**1/1 studies;** Tobias et al. 2007); **Cortical BMC:** null associations (**1/1 studies**; Sayers et al. 2011). *MPA and BMD:* **Whole body *absolute* or *areal* BMD:** favourable associations (**1/1 studies;** Tobias et al. 2007); **Upper limb *absolute* or *areal* BMD:** null associations (**1/1 studies;** Tobias et al. 2007); **Lower limb *absolute* or *areal* BMD:** favourable associations (**1/1 studies;** Tobias et al. 2007); **Femoral neck, trochanter, intertrochanter BMD:** null associations (**1/1 studies;** Cardadeiro et al. 2012); **Cortical BMD:** null associations (**1/1 studies;** Sayers et al. 2011); **BMD ratios:** null (femoral neck to trochanter, femoral neck to intertrochanter, trochanter to intertrochanter; **1/1 studies;** Cardadeiro et al. 2012). *MPA and Area and strength:* **Cortical bone area:** favourable association (**1/1 studies;** Sayers et al. 2011); **Periosteal** and **endosteal circumference of the tibia:** null associations (**1/1 studies;** Sayers et al. 2011); **Cross-sectional area** of **femoral shaft:** favourable associations (**1/1 studies;** Janz et al. 2004); **Section modulus** of **femoral shaft:** mixed (null in boys, favourable in girls) associations (**1/1 studies;** Janz et al. 2004); **Cross-sectional area** and **section modulus** of **narrow neck** and **intertrochantic** regions of **femur:** mixed (null in boys, favourable in girls) associations (**1/1 studies;** Janz et al. 2004). <u>*LPA*</u> *LPA and BMC:* **Whole body *absolute* or *areal* BMC:** null associations (**1/1 studies**; Tobias et al. 2007); **Upper** or **lower limb *absolute* BMC:** favourable associations (**1/1 studies;** Tobias et al. 2007); **Upper** or **lower limb *areal* BMC:** null associations (**1/1 studies;** Tobias et al. 2007); **Cortical BMC:** null associations (**1/1 studies**; Sayers et al. 2011)**.**		

						LPA and BMD: **Whole body BMD:** favourable associations (**1/1 studies;** Tobias et al. 2007); **Whole body *areal* BMD:** null associations (**1/1 studies;** Tobias et al. 2007); **Upper** and **lower limb *absolute* or *areal* BMD:** favourable associations (**1/1 studies;** Tobias et al. 2007); **Cortical BMD:** unfavourable association (**1/1 studies;** Sayers et al. 2011). *LPA and Area and strength:* **Cortical bone area:** null association (**1/1 studies**; Sayers et al. 2011); **Periosteal circumference of the tibia:** positive association (**1/1 studies;** Sayers et al. 2011); **Endosteal circumference of the tibia:** null association (**1/1 studies;** Sayers et al. 2011). *Other (impact measured by g-band)* **1/1 studies** (Deere et al. 2012) found both favourable (higher impacts) and null (lower impacts) associations between impact and **BMD** (femoral neck, hip), **hip structure** (femoral neck width, cross-sectional area, cortical thickness) and **predicted strength** (cross-sectional moment of inertia). A dose-response gradient was found for higher impact activity and **BMD** (femoral neck, total hip).		

Abbreviations: BMC = bone mineral content; BMD = bone mineral density; CSA = cross sectional area; CT = computer tomography; DXA = dual-energy x-ray absorptiometry; LPA = light intensity physical activity; MPA = moderate physical activity; MVPA = moderate-and-vigorous physical activity; PA = physical activity; VPA = vigorous physical activity.

[*] As determined by WHO

[a] Includes **1 randomized-controlled trial** (Gutin et al. 1999).

[b] Serious indirectness. Differences in intervention: the RCT examined a training program that 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.

[c] The quality of the evidence from the randomized study was downgraded from "high" to "moderate" due to serious indirectness of the intervention being assessed.

[d] Includes **7 longitudinal studies** (Janz et al. 2006; Janz et al. 2007; Janz et al. 2010; Heidemann et al. 2013; Francis et al. 2014; Janz et al. 2014a; Janz et al. 2014b) from **2 unique samples**. **Six studies** reported data from the Iowa Bone Development Study (Janz et al. 2006; Janz et al. 2007; Janz et al. 2010; Francis et al. 2014; Janz et al. 2014a; Janz et al. 2014b) and **1 study** reported data from the CHAMPS study sample (Heidemann et al. 2013). Results are reported separately, and participants are only counted once.

[e] The quality of evidence from longitudinal studies was upgraded from "low" to "moderate" due to no serious risk of bias.

[f] Includes **14 cross-sectional studies** (Janz et al. 2001; Janz et al. 2004; Hasselstrom et al. 2007; Tobias et al. 2007; Janz et al. 2008; Sayers et al. 2011; Farr et al. 2011; Gracia-Marco et al. 2011a; Gracia-Marco et al. 2011b; Cardadeiro et al. 2012; Gracia-Marco et al. 2012; Deere et al. 2012; Francis et al. 2014; Janz et al. 2014a), from **6 unique samples**. **Five** studies reported data from the Iowa Bone Development Study (Janz et al. 2001; Janz et al. 2004; Janz et al. 2008; Francis et al. 2014; Janz et al. 2014a), **3 studies** from the ALSPAC (Tobias et al. 2007; Sayers et al. 2011; Deere et al. 2012), **3 studies** from HELENA (Gracia-Marco et al. 2011a; Gracia-Marco et al. 2011b; Gracia-Marco et al. 2012), and **1 study** from each of CoSCIS (Hasselstrom et al. 2007), EYHS (Cardadeiro et al. 2012), and Jump-In: Building Better Bones (Farr et al. 2011). Results are reported separately, and participants are only counted once.

[g] The quality of the evidence from cross-sectional studies remained rated as "low" as there were no serious limitations across studies or reasons to upgrade.