



UNIVERSITY
OF WOLLONGONG
AUSTRALIA

University of Wollongong
Research Online

Faculty of Social Sciences - Papers

Faculty of Social Sciences

2016

Australia and other nations are failing to meet sedentary behaviour guidelines for children: implications and a way forward

Leon Straker
Curtin University

Erin Kaye Howie
Curtin University

Dylan Paul Cliff
University of Wollongong, dylanc@uow.edu.au

Melanie T. Davern
University of Melbourne

Lina Engelen
University of Sydney

See next page for additional authors

Publication Details

Straker, L., Howie, E. Kaye., Cliff, D. Paul., Davern, M. T., Engelen, L., Gomersall, S. R., Ziviani, J., Schranz, N. K., Olds, T. & Tomkinson, G. Ryan. (2016). Australia and other nations are failing to meet sedentary behaviour guidelines for children: implications and a way forward. *Journal of Physical Activity and Health*, 13 (2), 177-188.

Research Online is the open access institutional repository for the University of Wollongong. For further information contact the UOW Library: research-pubs@uow.edu.au

Australia and other nations are failing to meet sedentary behaviour guidelines for children: implications and a way forward

Abstract

Background: Australia has joined a growing number of nations that have evaluated the physical activity and sedentary behavior status of their children. Australia received a "D minus" in the first Active Healthy Kids Australia Physical Activity Report Card. Methods: An expert subgroup of the Australian Report Card Research Working Group iteratively reviewed available evidence to answer 3 questions: (a) What are the main sedentary behaviors of children? (b) What are the potential mechanisms for sedentary behavior to impact child health and development? and (c) What are the effects of different types of sedentary behaviors on child health and development? Results: Neither sedentary time nor screen time is a homogeneous activity likely to result in homogenous effects. There are several mechanisms by which various sedentary behaviors may positively or negatively affect cardiometabolic, neuromusculoskeletal, and psychosocial health, though the strength of evidence varies. National surveillance systems and mechanistic, longitudinal, and experimental studies are needed for Australia and other nations to improve their grade. Conclusions: Despite limitations, available evidence is sufficiently convincing that the total exposure and pattern of exposure to sedentary behaviors are critical to the healthy growth, development, and wellbeing of children. Nations therefore need strategies to address these common behaviors.

Keywords

forward, way, implications, children, guidelines, other, behaviour, australia, sedentary, meet, failing, nations

Disciplines

Education | Social and Behavioral Sciences

Publication Details

Straker, L., Howie, E. Kaye., Cliff, D. Paul., Davern, M. T., Engelen, L., Gomersall, S. R., Ziviani, J., Schranz, N. K., Olds, T. & Tomkinson, G. Ryan. (2016). Australia and other nations are failing to meet sedentary behaviour guidelines for children: implications and a way forward. *Journal of Physical Activity and Health*, 13 (2), 177-188.

Authors

Leon Straker, Erin Kaye Howie, Dylan Paul Cliff, Melanie T. Davern, Lina Engelen, Sjaan R. Gomersall, Jenny Ziviani, Natasha K. Schranz, Tim Olds, and Grant Ryan Tomkinson

1 **Title:** Australia and other nations are failing to meet sedentary behaviour guidelines for children:
2 implications and a way forward

3 **Running Title:** Failure to meet sedentary guidelines for children

4 **Keywords:** Screen time, child health, well-being, sedentary behaviour, indicators

5 **Corresponding Author:** Leon M. Straker (L.Straker@curtin.edu.au)
6 School of Physiotherapy and Exercise Science, Curtin University, Perth, Western Australia, Australia
7 Phone: 61 8 9266 3634 Fax: 61 8 9266 3699

8
9 Erin K. Howie (erin.howie@curtin.edu.au)
10 School of Physiotherapy and Exercise Science, Curtin University, Perth, Western Australia, Australia

11
12 Dylan P. Cliff (dylanc@uow.edu.au)
13 Early Start Research Institute, Faculty of Social Sciences, School of Education, University of Wollongong,
14 Wollongong, New South Wales, Australia

15
16 Melanie T. Davern (mdavern@unimelb.edu.au)
17 McCaughey VicHealth Centre for Community Wellbeing, School of Population and Global Health,
18 University of Melbourne, Melbourne, Victoria, Australia

19
20 Lina Engelen (Lina.engelen@sydney.edu.au)
21 Prevention Research Collaboration, School of Public Health, University of Sydney, Sydney, New South
22 Wales, Australia

23
24 Sjaan R. Gomersall (s.gomersall1@uq.edu.au)
25 Centre for Research on Exercise, Physical Activity, and Health, School of Human Movement Studies,
26 University of Queensland, Brisbane, Queensland, Australia

27
28 Jenny Ziviani (j.ziviani@uq.edu.au)
29 School of Health and Rehabilitation Sciences, The University of Queensland, and Children's Health
30 Queensland, Brisbane, Queensland, Australia

31
32 Natasha K. Schranz (natasha.schranz@mymail.unisa.edu.au)
33 Alliance for Research in Exercise, Nutrition and Activity (ARENA), Sansom Institute for Health Research,
34 University of South Australia, Adelaide, Australia

35
36 Tim S. Olds (tim.olds@unisa.edu.au)
37 Alliance for Research in Exercise, Nutrition and Activity (ARENA), Sansom Institute for Health Research,
38 University of South Australia, Adelaide, Australia

39
40 Grant R. Tomkinson (grant.tomkinson@unisa.edu.au)
41 Alliance for Research in Exercise, Nutrition and Activity (ARENA), Sansom Institute for Health Research,
42 University of South Australia, Adelaide, Australia

43

1 **Abstract** (200 words)

2 **Background:** Australia has joined a growing number of nations which have evaluated the physical
3 activity and sedentary behaviour status of their children. Australia received a 'D minus' in the first Active
4 Healthy Kids Australia Physical Activity Report Card.

5 **Methods:** An expert subgroup of the Australian Report Card Research Working Group iteratively
6 reviewed available evidence to answer three questions: 1) What are the main sedentary behaviours of
7 children?, 2) What are the potential mechanisms for sedentary behaviour to impact on child health and
8 development? and, 3) What are the effects of different types of sedentary behaviours on child health
9 and development?

10 **Results:** Neither sedentary time nor screen time are homogeneous activities likely to result in
11 homogenous effects. There are several mechanisms by which various sedentary behaviours may
12 positively or negatively affect cardiometabolic, neuro-musculoskeletal, and psycho-social health, though
13 the strength of evidence varies. National surveillance systems, and mechanistic, longitudinal and
14 experimental studies are needed for Australia and other nations to improve their grade.

15 **Conclusions:** Despite limitations, available evidence is sufficiently convincing that the total exposure and
16 pattern of exposure to sedentary behaviours are critical to the healthy growth, development and
17 wellbeing of children. Nations therefore need strategies to address these common behaviours.

18

19

1 **Australia and other nations are failing to meet sedentary behaviour guidelines for children**

2 In May 2014, 15 countries gathered in Toronto, Canada for the Global Summit on Physical Activity of
3 Children in response to international concern over the physical inactivity of the world's children. Using
4 expert consensus panels, countries reviewed their respective available data and weighed the evidence
5 to assign a grade for nine core indicators in national Physical Activity Report Cards. The core indicators
6 were related to individual behaviours that contributed to overall physical activity levels, as well as
7 sources of influence and strategies and investments. One of the core behavioural indicators was
8 sedentary behaviour which was operationalised as the proportion of children and young people meeting
9 the recommended national screen time guidelines. For Australia, this is spending no more than one
10 hour per day for 2-4 year olds and less than two hours per day for 5-17 year olds viewing an electronic
11 screen for leisure purposes .¹ Currently there are no national data for children less than 2 years of age
12 to determine what percentage are complying with the national guideline of no screen time.

13 Australia received a grade of 'D minus(-)' for sedentary behaviours, with only 29 % of 5 to 17
14 year olds meeting screen time recommendations.^{2,3} Fewer Australian teenagers met the
15 recommendations (19 %of 15-17 year olds) than younger school children (41 % of 5-8 year-olds and 24%
16 of 9-14 year-olds) or pre-schoolers (26 % of 2 -4 year-olds).³ Australia is not alone, with four other
17 countries rated below Australia with a 'Fail' and four more with a 'D' in sedentary behaviour. The
18 highest grade achieved was a 'B', by Ghana and Kenya, followed by New Zealand and Ireland which both
19 received grades of 'C' (See Table 1). While the metrics used to assign grades varied between countries,
20 the grades assigned raise the question: *What can countries do to improve their grades?*

21

1 Australia's sedentary behaviour grade was based on the percentage of children meeting the
2 recommendations for daily screen time, as it generally was for other nations (though the exact
3 definitions varied). The Active Healthy Kids Australia Physical Activity Report Card focused on screen
4 time sedentary behaviour for a number of reasons. Firstly, national guidelines recommend a dose
5 specifically for screen-based sedentary behaviours¹ and the best nationally representative data
6 available in Australia were for compliance with screen time guidelines rather than all sedentary
7 behaviours. Secondly, the Research Working Group (24 experts in the field of physical activity and health
8 from around Australia who evaluated the evidence and assigned a grade by consensus) had more
9 confidence in reported screen time than other self- or proxy- report measures of sedentary behaviours.⁴
10 Thirdly, there was stronger evidence that screen time, particularly television (TV) watching, was
11 associated with detrimental outcomes (see Question 3 section for further details⁵). However, basing the
12 grade solely on meeting screen time guidelines is a limitation for multiple reasons: 1) much of childhood
13 sedentary behaviour is not screen-based; 2) overall sedentary behaviour, in addition to screen time,
14 potentially has detrimental effects;^{6,7} and 3) screen time itself is varied and changing rapidly.

15

16 **Methods approach**

17 The following is a discussion of key evidence that resulted from a critical review by an expert
18 subgroup of the Australian Report Card Research Working Group The Research Working Group had been
19 collecting and evaluating literature and data related to the Report Card generation. To conduct the
20 present review, the first two authors conducted a further literature search of primary databases to
21 capture recently published evidence. The critical analysis followed an iterative process by the expert
22 sub-group where additional literature was considered and all evidence was synthesized. The experts
23 reviewed the literature in reference to three general questions about sedentary behaviours as seen in

1 Figure 1. A better understanding of the answers to these three questions will help inform strategies to
2 reduce sedentary behaviours among children and thus improve the grade.

3

4 **Question 1: What are the main sedentary behaviours of children?**

5 Sedentary behaviour is defined as any waking behaviour with a low energy expenditure (<1.5 METS) and
6 a sitting or reclined posture⁸ and is part of a spectrum of 'activity' of various energy expenditure
7 intensities ranging from sedentary, through light (typically ≥ 1.5 –<3 METS), to moderate (≥ 3 –<6 METS)
8 and vigorous (≥ 6 METS). Although there has been debate on the specific MET cutpoints used for
9 children,⁹ research in young children suggests that 1.5 METS is consistent with the energy cost of
10 sedentary activities.¹⁰ Thus each child's 24-hour day can be divided into sleep and wake 'activity', with
11 'activity' further divided by intensity into sedentary, light, moderate and vigorous time. The most
12 common measures of sedentary behaviour are self-report and accelerometry, which both have
13 limitations.¹¹ Self- or proxy- report questionnaires and recalls are subject to recall bias and some
14 continue to show limited validity compared to device based or objective measures, and accelerometers
15 do not distinguish between types of sedentary behaviours or provide context. Inclinometers have been
16 increasingly used to measure sedentary time as they better distinguish between postures of sedentary
17 behaviours (ie lying, sitting, standing), but still do not provide context or type of behaviour.
18 Accelerometers can yield widely discrepant estimates of sedentary time according to device placement
19 and analytical decisions around non-wear time, operationalisation of sleep, epoch length and intensity
20 cut-offs. This is only a brief description of some of the issues surrounding the measurement of sedentary
21 behaviours in children, a topic which warrants further discussion beyond this review.

22 Being sedentary is seen as different to not attaining recommended daily amounts of moderate
23 to vigorous physical activity (MVPA) as a child can spend a large portion of their day in sedentary
24 behaviour but still meet daily MVPA recommendations of at least 60 minutes.¹² Further the health

1 effects of accumulating too little physical activity or too much sedentary time may differ ¹³⁻¹⁵, although
2 the research evidence in children is still building. ¹⁶⁻¹⁹

3 The largest proportion of a child's waking day is spent in sedentary behaviour. For example,
4 accelerometer data on Australian 10-12 year olds showed that 63 % of their waking day was spent
5 engaged in sedentary activities, as shown in Figure 2. ²⁰ While objective surveillance of Australian
6 children's physical activity is limited, studies suggest that preschool-aged children, ^{21,22} primary school
7 aged children ²³ and young adolescents ²⁴ spend at least 60 % of wake time in sedentary behaviours,
8 which is consistent with data from 39 countries. ²⁵ These data also suggest that the proportion of the
9 waking day spent sedentary increases with age across childhood, although the evidence for young
10 children and how sedentary behaviour tracks throughout childhood into adulthood is limited. ²⁶

11 Sedentary behaviour can be thought to occur in four main domains of children's lives –
12 education/school/child care, transport, self care/domestic chores, and leisure/play, . For school-aged
13 children, a main 'occupation' is that of being a student in which the majority of time at school is
14 sedentary. ²⁰ Educational tasks are also completed away from school, which contributes to additional
15 sedentary time. Most Australian 4-5 year old children (85%) who are not yet in school attend preschool.
16 ²⁷ A recent review found estimates of screen time use during childcare ranges from 0.1 to 2.4 hours per
17 day. ²⁸ Sedentary transport tasks include sitting in buses, trains and cars to get to and from school and
18 other destinations. Sedentary self-care tasks include eating and some grooming. Leisure and play
19 sedentary behaviours include reading from a book or an electronic screen. With such a diversity of tasks
20 and differential time spent in each task, it is likely that not all sedentary behaviours are equal in terms of
21 their impact on healthy growth, development and wellbeing. ^{29,30}

22 Sedentary behaviours are often classified as being either based around an electronic screen or
23 not. ^{23,31} Screen time sedentary behaviours were initially TV, then included video games and
24 desktop/laptop computers and now include touch screen tablets and smart phones. Currently data on

1 the use of new touch screen devices by children are very limited, and the development of smart devices
2 has decoupled device and content—children no longer need a TV to watch ‘TV’. Non-screen sedentary
3 behaviours of children typically include class time at school, commuting, reading from paper, talking and
4 eating, though with multitasking and the growing integration of technology into daily life, each of these
5 examples could also involve screen time. Figure 3 shows nationally representative Australian data from
6 2007 and illustrates that total daily sitting time is high from age 9 to 17 years and is composed of around
7 3.5 hours of screen time and 6 hours of non-screen time.²⁶ Thus whilst screen time is often the focus, it
8 does not constitute the majority of sedentary behaviour for most children.

9 In summary, children spend a large proportion of their waking hours in sedentary behaviours for
10 a range of reasons. Childhood sedentary behaviour is varied in aspects potentially important to child
11 health and development and given the high exposure and varied nature of sedentary behaviour, it is
12 critical to understand the impact of sedentary behaviours on healthy growth, development and
13 wellbeing.

14
15 **Question 2: What are the potential mechanisms for sedentary behaviours to impact on child health**
16 **and development?**

17 There are a number of mechanisms by which sedentary behaviours may impact on child health and
18 development, as illustrated in Figure 1.

19
20 ***Disruption of metabolism*** – Sedentary behaviours could potentially influence energy expenditure,
21 energy intake and energy metabolism which could impact on adiposity and other cardiometabolic
22 outcomes.

23 Sedentary behaviours may directly decrease energy expenditure. Prolonged low energy
24 expenditure during sedentary behaviours could result in lower daily energy expenditure via low levels of

1 muscle activity and thus decreased energy expenditure. Children typically have low levels of energy
2 expenditure (<1.5 METs) during common sedentary activities.^{10,32} Sedentary behaviours also may
3 displace higher energy expenditure activities, which have clear metabolic health effects. Moderate to
4 vigorous physical activity is known to have positive effects on cardiometabolic outcomes in children
5 including increased myocardial function, improved cholesterol, and decreased blood pressure.^{6,33}
6 Therefore, children that spend too much time in sedentary behaviours may be in double jeopardy, as
7 they may be impacted by the negative effects of sedentary behaviours and not benefit from the positive
8 effects of the more vigorous activities that could have been engaged in for some of that time.

9 Some sedentary behaviours, or activities during sedentary behaviours, may directly increase
10 energy intake and thus impact on cardiometabolic outcomes. For example, children consumed more
11 calories during a meal while watching TV than while playing with computers or video games.³⁴
12 Additionally, some sedentary behaviours, or exposure to content during sedentary behaviours, may
13 indirectly increase later energy intake. For example, increased intake of junk food may result from
14 seeing sugar-sweetened beverage sponsorship signs whilst watching a sporting event either live or on
15 TV, or viewing fast food advertisements during social media use.^{35,36}

16 Prolonged sedentary behaviour can also alter energy metabolism. Laboratory studies in adults
17 ^{37,38} have demonstrated changes in glucose metabolism, however a similar study in children was not able
18 to demonstrate a similar effect.³⁹ In addition to changes in glucose metabolism, prolonged low energy
19 expenditure may also result in changes in the partitioning of fat and decreased muscle protein synthesis
20 rates⁷ with effects on metabolism occurring beyond time spent in sedentary behaviours. Both the
21 timing and patterns of sedentary behaviour may have important influences on energy metabolism.⁴⁰

22
23 **Limited neuromuscular activity** – Sedentary behaviours may impact gross motor control, bone and
24 muscle development via low levels of movement and muscle activity and/or the displacement of

1 movement activities with appropriate loading. Lack of practice of gross motor skills could result in
2 reduced motor capacity.⁴¹ Forces exerted during sedentary behaviour are typically insufficient to
3 stimulate bone growth, compared with activities such as jumping and skipping.^{42,43} Muscle development
4 similarly requires sufficient loading to stimulate growth, strength development and flexibility and
5 sedentary behaviours may not provide sufficient stimulus,⁴⁴ compared with MVPA and strength
6 training.^{45,46} Some sedentary behaviours may have a positive impact on fine motor skill development,
7 for example, drawing and playing electronic games.⁴⁷

8

9 ***Prolonged, awkward postures or repetitive motions*** – Sedentary behaviours could have an impact on
10 musculoskeletal outcomes via prolonged or repetitive stress on tissues. Inflammation of tendons and
11 surrounding connective tissue can be caused by highly repetitive movements, such as video games
12 which require frequent button activation⁴⁷ or playing a piano.⁴⁸ However, these activities may
13 positively impact fine motor skills.⁴⁹ Joint and muscle discomfort can be caused by sustained postures,
14 particularly when the posture is awkward (greater anti-gravitational load or near to the end of joint
15 range of motion in one or more planes), such as writing on paper or watching a video on a smart phone
16 or tablet held close to the body. These activities require positions near to the end range of neck flexion,
17 which may cause neck pain.⁵⁰

18

19 ***Socio-emotional experiences*** – Sedentary behaviours could have an impact on emotional health and
20 social well-being via exposure to anti-social material and displacement or provision of positive social
21 interaction.⁵¹ Increased access to the internet adds another avenue for children to be exposed to
22 inappropriate anti-social content and negative social interactions such as cyber-bullying.⁵² Sedentary
23 behaviours may also displace or negatively influence useful intrapersonal interactions where children
24 learn social and life skills. Virtual social interactions do not provide all the cues available in face-to-face

1 interactions and thus excessive virtual interaction to the exclusion or even as part of face-to-face
2 interactions, may impede a child's social skills.⁵³ Similarly, other non-social non-screen sedentary
3 behaviours, such as reading books, may have negative developmental psychosocial outcomes.⁵⁴
4 However sedentary behaviours such as playing a musical instrument, talking on the phone or video-
5 conferencing with friends and family, and multiplayer board and electronic games can provide positive
6 socio-emotional experiences.⁵⁵

7
8 **Cognitive experiences** - Sedentary behaviours could have an impact on cognitive development and
9 academic achievement by exposure to poor or beneficial cognitive experiences, by displacement of
10 more productive sedentary behaviours, and also displacement of MVPA. Some sedentary behaviours
11 encourage passive, rather than active cognitive engagement. Active engagement has shown to have
12 beneficial effects on cognitive development compared to passive activities.⁵⁶ Increased technology use
13 with specific content (e.g. content that is hyper-stimulating and fast-paced) may have negative effects
14 on children's attention and cognitive performance.⁵⁷ Productive experiences such as school homework
15 may be displaced by other sedentary behaviour with limited useful cognitive impact.^{29,30} Additionally,
16 sedentary behaviours displace MVPA which has been shown to have a positive influence on cognitive
17 performance and academic achievement.⁵⁸ More positively, sedentary behaviours such as appropriate
18 reading, writing, paper and electronic games may have the ability to improve cognitive development
19 and academic achievement.⁵⁹

20
21 **Other mechanisms** - Sedentary behaviours could have an impact on other aspects of health via a
22 number of mechanisms. Prolonged close vision, for example reading from a book or tablet, could result
23 in increased short-sightedness.⁶⁰ Sleep quantity and quality could be impacted by bedroom screen time
24 and blue light from some electronic screens altering chrono-hormone levels.⁶⁰

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

Research supports a link between sedentary behaviour and poor health outcomes in adults. One of the pathways that sedentary behaviour may influence health is by tracking of the behaviour into adulthood. Total sedentary behaviour may track better from childhood to adolescence than physical activity.^{61,62} Total screen time behaviours track moderately from childhood to adolescence.⁶³ TV was more stable than video games from age 5 to 13,⁶⁴ and levels of TV in childhood track into TV in adulthood.⁶⁵

In summary, there are multiple potential mechanisms for various aspects of sedentary behaviours to impact on multiple health and development outcomes. Whilst some mechanisms are specific to certain types of sedentary behaviours, many may result from a variety of sedentary behaviours. The actual mechanisms are complex and the interactions and cumulative effects are not fully understood. However given the considerable exposure of children to sedentary behaviours it is critical that these relationships are better understood.

Question 3: What are the effects of different types of sedentary behaviours on child health and development?

Sedentary behaviour in children has the potential to influence health and development through different types of sedentary behaviour and different mechanisms as seen in Figure 1. This section provides a brief synthesis of the available evidence for different sedentary behaviours to have effects on multiple components of child health and development including cardiometabolic, neuromusculoskeletal, psychosocial, and relevant other outcomes. The focus of this brief review is on children, though where the evidence for children is limited,⁶⁶ evidence in adults has been included⁷. Given the differences in types of sedentary behaviour, this brief synthesis is arranged by types of sedentary behaviour and

1 includes: screen time, TV, other screens (excluding TV), non-screen sedentary behaviour, and any
2 sedentary time.

3

4 ***Screen time sedentary behaviours***

5 The Australian Physical Activity Report Card grades were assigned based on compliance with screen time
6 guidelines, as screen time has been given particular attention for having unique effects on children's
7 health.⁵¹ Common limitations to the evidence, however, include cross-sectional designs and that many
8 of the observed associations have a high risk of residual confounding due to sedentary behaviours being
9 related to other lifestyle and socio-economic factors.

10

11 *Cardiometabolic-* The two most commonly studied cardiometabolic outcomes have been obesity and
12 cardiorespiratory fitness. A longitudinal study of Danes found that increased TV and total screen time
13 from adolescence to adulthood was associated with increased body mass index (BMI).⁶⁷ A cross-
14 sectional study of 9 to 16 year olds found that BMI was more strongly inversely associated with general
15 screen time than physical activity.⁶⁸ Cross-sectional studies have also shown a negative relationship
16 between screen time and cardiorespiratory fitness that is independent of physical activity.^{69,70}

17

18 *Neuro-musculoskeletal-* The majority of studies examining musculoskeletal effects of screen time have
19 examined specific types of screens and will thus be discussed in following sections. However, in one
20 cross-sectional study, overall screen time was not associated with bone structure in 9 to 20 year old
21 children when adjusted for physical activity and other factors.⁴²

22

23 *Psychosocial-* Compared to other types of sedentary behaviour, screen time has a unique potential to
24 influence psychosocial outcomes due to the content viewed. While the assumption is that screen time

1 negatively affects psychosocial outcomes, few studies have empirically evaluated this relationship. Two
2 cross-sectional studies found increased screen time to be detrimentally associated with depression
3 scores and psychological difficulty, independent of physical activity.^{71 72} Additionally, evidence supports
4 the transmission of aggressive behaviours from violent media including TV, movies, video games and
5 internet.⁷³ Specific uses of technology such as for educational purposes, can, nevertheless, improve
6 psychosocial outcomes and these are discussed in later sections.

7

8 *Other-* Unique characteristics of screen time behaviour have also led to the investigation of other
9 outcomes from screen time including sleep and vision. Among adults, screen time, not total sedentary
10 time, was associated with sleep problems.⁷⁴ A review found that increased screen time among children
11 adversely affected sleep, but the effects largely depended on type of screen exposure, age, gender, and
12 day of the week.⁷⁵ Screen time may also adversely affect vision. Among university students, sustained
13 periods of close screen work and lack of a screen filter was associated with a greater report of vision
14 problems including dry and tired eyes as well as headache.⁷⁶

15

16 ***Television Watching***

17 While many of the Physical Activity Report Cards assessed children's exposure to sedentary behaviours
18 based on meeting guidelines for total screen time, it is acknowledged that different types of screen
19 devices, used for different purposes, may have differential effects on child health and development. The
20 majority of the evidence supports a detrimental effect of TV on multiple child outcomes.

21

22 *Cardiometabolic-* Several cross-sectional studies support an inverse relationship between TV and
23 cardiometabolic risk in children independent of physical activity.⁷⁷⁻⁸⁰ These studies have varied in age
24 group and how they have accounted for physical activity.

1 Additional cross-sectional studies have examined the relationship between TV and BMI, but few
2 studies have tested causal relationships. In a worldwide study of children aged 5 to 15 years there was a
3 positive association between TV and BMI, but the relationship was not adjusted for physical activity.⁸¹ In
4 a longitudinal study in the Netherlands, an increase in TV from adolescence to adulthood was associated
5 with increased BMI in adulthood.⁶⁷

6 There is a lack of evidence to support a relationship between TV and cardiorespiratory fitness in
7 children. A longitudinal study found that increased TV was associated with decreased cardiorespiratory
8 fitness over 2 years from age 7, but this was not adjusted for physical activity.⁸² In female adults, TV was
9 negatively associated with cardiorespiratory fitness, but this was mostly mediated by PA and percent
10 body fat.⁸³

11 Independent of total sedentary and screen time, TV may have additional harmful effects on
12 energy balance due to its relationship with energy intake. Several cross-sectional studies have found an
13 association between increased TV and a poorer diet.⁸⁴⁻⁸⁶ An experimental study found that energy
14 intake increased while watching TV among 9 to 13 year olds.³⁴ Advertising during TV may also lead to
15 subsequent increased energy intake as shown in experimental studies.^{35,36}

16
17 *Neuro-musculoskeletal-* The evidence for the effects of TV on neuro-musculoskeletal outcomes in
18 children is inconclusive. While one study has found that TV and back pain were positively related,⁸⁷ two
19 others have found that TV was not related to back pain⁸⁸ or neck and back pain.⁸⁹

20
21 *Psychosocial-* A large number of studies have examined relationships between TV and various
22 psychosocial effects, however many of them have been cross-sectional and unable to discern causality.
23 The majority have found negative associations between increased TV and psychosocial outcomes.
24 Research suggests that children who watch more TV are more likely to have behavioural difficulties, but

1 a variety of measures and definitions of behaviour have been used.^{72,90,91} In a longitudinal study of
2 preschoolers aged 2 to 3years, TV was positively associated with externalising problems.⁹² Other
3 psychological outcomes have been found to have cross-sectional associations with TV, without
4 adjustment for physical activity, including psychological distress,⁹³ self-esteem,⁹⁴ criminal conviction,
5 antisocial personality disorder, and aggressive traits.⁹⁵ While an association between TV and aggressive
6 behaviour has been suggested, the evidence is unclear.⁹⁶ Cross-sectional associations suggest that
7 children who watch more TV have poorer cognitive performance including executive function,⁹⁷
8 communication and language development⁹⁸ and hyperactivity/inattention.⁹⁹

9
10 *Other-* Both vision and sleep seem to be negatively affected by increased TV. Television (and computer
11 use) was associated with poorer vision in children aged 6 to 18years.¹⁰⁰ Increased TV has been
12 associated with poorer sleep in two longitudinal studies including shorter sleep time unadjusted for
13 physical activity in a longitudinal study of children from 6 months to 7 years¹⁰¹ and from ages 2 to 4 and
14 6 to 9 when adjusted for parent-reported PA.¹⁰²

16 ***Other screens (not TV)***

17 There have been few studies to isolate other screens (not including TV), with most of them examining
18 computer use or electronic video games.

19
20 *Cardiometabolic-* Saunders et al. found that leisure time computer/video game play in boys (TV in girls)
21 was associated with poorer cardiometabolic profiles among 8 to 11 year olds when adjusted for
22 accelerometer determined physical activity.⁷⁹ Another cross-sectional study reported computer game
23 use was positively associated with overweight status in 6 to 14 year old children but not in highly active
24 children.¹⁰³

1

2 *Neuromusculoskeletal*- The associations between technology and low back and neck/shoulder pain have
3 been inconsistent. Cross-sectional surveys of adolescents have found computer and laptop use, greater
4 than two hours, were associated with low back and neck/shoulder pain.^{100 101} However, another cross-
5 sectional study of adolescents found that neck/shoulder pain was not related to computer use when
6 adjusted for physical activity.¹⁰² Among children, neck pain was related to increased computer use⁵⁶
7 and repetitive electronic game use has been shown to be related to tendonitis.⁴⁶ However, cross-
8 sectional evidence suggests that young children who play greater amounts of interactive video games
9 have improved object control motor skills.¹⁰³

10

11 *Psychosocial*- Numerous studies have examined the relationship between other screens, particularly
12 computers and video games, with both positive and negative psychosocial outcomes. The majority have
13 been cross-sectional which again limits the ability to support causal relationships. A meta-analysis found
14 that violent video game play was related to increased aggressive behaviour, aggressive cognition, and
15 aggressive affect and decreased empathy and prosocial behaviour.¹⁰⁴ Time playing video games has
16 been cross-sectionally related to negative outcomes such as depression, lower academic achievement,
17 conduct problems¹⁰⁵ and poorer working memory,¹⁰⁶ whereas high amounts of computer use have
18 been associated with weaker performance in tests measuring flexibility of attention.¹⁰⁶

19

20 While many of the studies have found detrimental associations, there is also evidence for
21 benefits of other types of screen use. A cross-sectional study of adolescents found that self-reported
22 video usage was positively correlated with improvements in brain structures that correlate with
23 improved executive function.¹⁰⁷ In educational research, technology use (laptops and tablets) has been
24 shown to improve educational outcomes, but often the study designs were weak with small samples and
no comparison groups.¹⁰⁸ Technology may be especially beneficial for those with learning disabilities.

1 ^{109,110} Despite concerns over children becoming technology dependent and losing social interaction skills,
2 adolescents who had more smartphone use also had more face-to-face interactions. ¹¹¹

3
4 *Other* - Computer use has been cross-sectionally associated with poorer vision in 6 to 18 year old
5 children. ⁹⁶ Other media use, compared to TV, was more strongly correlated to health and wellbeing
6 among 8 to 13 year olds, though this was not adjusted for physical activity. ¹¹²

7

8 **Non-screen sedentary behaviours**

9 Non-screen sedentary behaviours have also been related to various health and development outcomes,
10 but the heterogeneity of behaviours and outcomes precludes a comprehensive review in this paper.
11 Further, much of the research has not separated non-screen sedentary behavior from other sedentary
12 behaviours. A few examples are, nevertheless, provided to illustrate how non-screen sedentary
13 behaviours may influence health. Puzzle play in early childhood has been associated with improved
14 spatial abilities. ¹¹³ Unsurprisingly, increased time spent reading during school was related to higher
15 reading achievement, although time spent reading at home was not. ¹¹⁴ Sedentary practices such as
16 meditation are associated with improved cognitive process ¹¹⁵ and self-esteem in school children. ¹¹⁶

17

18 ***Total sedentary time***

19 *Cardiometabolic*- Total sedentary time, in activities with a low energy expenditure, has been associated
20 with several cardiometabolic outcomes in a recent review, ⁶ although, after adjusting for MVPA, the
21 evidence was inconsistent. ¹⁵ The strength of association depends on the specific variables examined.
22 For example, in a cross-sectional study of multiple cardiometabolic outcomes among 5 to 10 year-old
23 children, only HDL cholesterol was negatively associated with sedentary time measured by
24 accelerometry, independent of physical activity. ¹⁶

1 Body mass index has been the most common cardiometabolic outcome measured, yet even the
2 evidence for this relationship has been inconsistent. In adults, a positive relationship between sedentary
3 time and BMI has been found, independent of physical activity.¹¹⁷ However, a recent review of
4 longitudinal studies among children has concluded that the evidence to support a relationship between
5 sedentary behaviour and adiposity is inconclusive.¹¹⁸ Reasons for the inconclusive findings may be the
6 predominance of cross-sectional studies, varying measures of sedentary time and inconsistent
7 adjustment for physical activity.³⁰ One problem with measuring sedentary time with accelerometers
8 may be the misclassification of standing time as sedentary.¹¹⁹

9 Similar to BMI and adiposity, the relationship between sedentary time and cardiorespiratory
10 fitness has been inconsistent. In adults, a large cross-sectional study using NHANES data, found an
11 inverse association between total sedentary time and cardiorespiratory fitness, even when adjusted for
12 exercise.¹² Comparatively in children, a cross-sectional study of over 2,000 10 to 18 year olds did not
13 find an independent relationship between cardiorespiratory fitness and total sedentary time when also
14 adjusted for physical activity.¹⁷ Additional evidence suggests that the relationship may differ between
15 genders.¹²⁰

16 Of particular interest to cardiometabolic outcomes may be sedentary time accumulated in long,
17 uninterrupted bouts. Literature in adults suggests that these long, uninterrupted bouts may be
18 particularly detrimental,^{13 121} though the evidence in children has been less conclusive and
19 predominantly cross-sectional,^{75,122 16} In one randomised crossover study, breaking up long bouts of
20 sedentary behaviour in 10 to 14 year olds did not result in changes to cardiometabolic markers.³⁹

21

22 *Neuromusculoskeletal-* Few studies have examined the relationship between total sedentary time and
23 neuromusculoskeletal outcomes including motor skills, bone structure, and musculoskeletal
24 discomfort or pain. One cross-sectional study found that increased sedentary time was negatively

1 associated with motor proficiency among 9 to 10 year-olds, independent of physical activity.¹²³ Another
2 cross-sectional study examined bone structure and found no association with total sedentary time when
3 adjusted for physical activity.⁴² Finally, there has been inconsistent evidence for sedentary time to be
4 related to musculoskeletal pain in children.¹²⁴⁻¹²⁶

5
6 *Psychosocial*-Of the multiple psychosocial outcomes that may be potentially affected by sedentary time,
7 very few studies have studied relationships with sedentary time. Two cross-sectional studies have found
8 no associations with self-esteem,¹²⁷ and negative associations with sustained attention but no other
9 tests in a cognitive battery.¹⁰⁶

10
11 *Other*- Total sedentary time may also be associated with other health related outcomes. In adults, there
12 is an increased risk of all-cause mortality with daily sitting time greater than eight hours per day
13 independent of physical activity.¹²⁸

14
15 In summary, there is considerable evidence showing sedentary behaviours have implications for child
16 health and development. However the strength of current evidence varies by types of sedentary
17 behaviour and health outcomes as well as the methodological approaches used to examine these
18 relationships.

19
20 **Further research needed to inform strategies to improve the grade**

21 To better understand which sedentary behaviours are occurring and answer Question 1, national
22 surveillance systems are required to provide robust estimates of children's sedentary behaviour
23 exposure. Data are required from infancy, across childhood to adulthood and need to examine the

1 different types of sedentary behaviours, the different devices used while sedentary, the content or tasks
2 performed and the context of behaviour. Data should also be tracked longitudinally.

3 To better understand the mechanisms for these impacts and answer Question 2, mechanistic
4 studies are required to test causal pathways and inform critical components for interventions. To better
5 understand the impact of these behaviours and answer Question 3, longitudinal and experimental
6 design studies are required to provide stronger causal evidence of the impacts of the various sedentary
7 behaviours on the full range of important child health and developmental outcomes. Analyses need to
8 consider dose-response relationships while also evaluating mediating and moderating influences such as
9 physical activity, built environment, family socio-economic status and parenting style. More
10 sophisticated statistical approaches are needed, for example compositional analysis may be useful when
11 considering the limited 24-hour nature of each day which can be divided into exhaustive and mutually
12 exclusive components.¹²⁹ A life-course approach can be used to evaluate critical windows and pathways
13 of causality.

14 Further research is needed to improve the measurement of both the amount and nature of
15 children's sedentary behaviours and which strategies are effective to improve sedentary behaviours.
16 Sedentary behaviour measurement needs to be improved to encompass a whole-of-day approach,
17 including sleep and wake time and the full spectrum of wake time 'activity'. Measurement needs to
18 capture not just the total amount of exposure, but also the pattern of exposure and the potential
19 overlap of behaviours with multi-tasking. Methods to accurately capture the context and
20 content/task/device details of behaviours also need to be developed. Standardised and practical
21 methods for classifying and quantifying sedentary behaviours need to be developed to enable valid
22 comparisons between countries. These methods need to match understandings of mechanisms and thus
23 key aspects of behaviour to capture. For example, [using inclinometers to measure total sedentary time or](#)
24 [validated technology monitoring apps to measure content, accumulation and pattern of screen time](#). Re-

1 evaluation and refinement of partitioning of 'activity' into different intensity-based categories also
2 needs to be conducted, to understand the postural or energy expenditure aspects which relate to
3 outcomes. Comparisons should also be undertaken of countries with healthier sedentary exposure for
4 their children to determine whether some aspects of that society can be promoted in countries with
5 poorer sedentary behavior grades.

6 Finally, while not reviewed in this paper, continued intervention research is needed to evaluate
7 the efficacy (do the interventions produce a desired effect) and cost efficiency (are the interventions
8 economical) of various strategies to improve sedentary behaviour exposure in children.¹³⁰ Reviews of
9 studies evaluating various strategies would provide useful guidance on policies and interventions to be
10 promoted. The importance of tailoring interventions to specific groups of children (age group, gender,
11 socio-economic status, leisure interests etc.) and targeting specific behaviour change (video games,
12 book reading, passive transport etc.) also needs to be evaluated.

14 **Conclusion**

15 The available evidence, whilst incomplete,⁶² is sufficiently convincing that sedentary behaviours are
16 critical to child health and development. Nations therefore need to have strategies to promote
17 appropriate exposure to these common behaviours. It appears likely that both the total exposure and
18 pattern of exposure are important for cardiometabolic and neuro-musculoskeletal outcomes and so
19 there is a need to reduce overall sedentary time and prolonged bouts of sedentary time for many
20 children. Aspects of sedentary tasks, such as content, device and context, also appear important to a
21 range of outcomes including psychosocial outcomes and thus need to be addressed.

22 Failure to adequately address this issue is likely to result in nations facing unsustainable health and
23 economic burdens for poor child and adult health and developmental outcomes. A range of intervention
24 options are available in all nations, targeting the child directly or indirectly via parents, teachers/schools,

1 peers, technology and societal infrastructure. Nations can therefore look forward to improving their
2 grade based on the sedentary behaviour of their children, if they invest sufficiently in understanding this
3 key behaviour and in strategies to promote appropriate behaviour.

4

5

6 **Acknowledgements**

7 Leon Straker is supported by a National Health and Medical Research Council of Australia Senior
8 Research Fellowship (1019980). Dylan Cliff is funded by an Australian Research Council Discovery Early
9 Career Researcher Award (DE140101588). Sjaan Gomersall is supported by a National Health and
10 Medical Research Council Program Grant (569940). The Australian Report Card on Physical Activity for
11 Children and Young People Research Working Group also included: Billie Giles-Corti, Louise Hardy, Kylie
12 Hesketh, Andrew Hills, David Lubans, Cuane Macdonald, Rona Macniven, Philip Morgan, Tony Okley,
13 Anne-Maree Parish, Ron Plotnikoff, Trevor Shilton, Anna Timperio, Stewart Trost and Stewart Vella.
14 LS, DC, MD, LE, SG, JZ, TO, NS, GT were members of the Research Working Group for the Australian
15 Physical Activity Report Card and reviewed the available evidence. GT and TO were lead investigators
16 and NS was the research project manager. LS and EH drafted the manuscript and all authors reviewed a
17 number of drafts prior to approving the final version.

18

19

References

- 20 1. Department of Health. *Australia's Physical Activity and Sedentary Behaviour Guidelines*. Canberra:
21 Commonwealth of Australia.
- 22 2. Schranz N, Olds T, Cliff D, et al. Results from Australia's 2014 report card on physical activity for
23 children and youth. *J Phys Act Health*. 2014;11(4 Suppl 1):S21-25.

- 1 3. Australian Bureau of Statistics. *Australian Health Survey: Physical Activity, 2011–12. Catalogue No.*
2 4364.0. Canberra: Australian Bureau of Statistics;2013.
- 3 4. Okely AD, Salmon J, Vella SA, et al. *A Systematic Review to inform the Australian Sedentary*
4 *Behaviour Guidelines for Children and Young People.* Report prepared for the Australian
5 Government Department of Health;2012.
- 6 5. Tremblay MS, LeBlanc AG, Kho ME, et al. Systematic review of sedentary behaviour and health
7 indicators in school-aged children and youth. *Int J Behav Nutr Phys Act.* 2011;8:98.
- 8 6. Saunders TJ, Chaput JP, Tremblay MS. Sedentary behaviour as an emerging risk factor for
9 cardiometabolic diseases in children and youth. *Can J Diabetes.* 2014;38(1):53-61.
- 10 7. Thyfault JP, Du M, Kraus WE, Levine JA, Booth FW. Physiology of sedentary behavior and its
11 relationship to health outcomes. *Med Sci Sports Exerc.* 2014. doi: 10.1249/mss.0000000000000518
- 12 8. Sedentary Behaviour Research Network. Standardized use of the terms "sedentary" and "sedentary
13 behaviours". *Appl Physiol Nutr Metab.* 2012;37:540-542.
- 14 9. Cain KL, Sallis JF, Conway TL, Van Dyck D, Calhoun L. Using accelerometers in youth physical activity
15 studies: a review of methods. *J Phys Act Health.* 013;10(3):437-450.
- 16 10. Reilly JJ, Janssen X, Cliff DP, Okely AD. Appropriateness of the definition of 'sedentary' in young
17 children: whole-room calorimetry study. *J Sci Med Sport.* 2014. doi: 10.1016/j.jsams.2014.07.013
- 18 11. Lubans DR, Hesketh K, Cliff DP, et al. A systematic review of the validity and reliability of sedentary
19 behaviour measures used with children and adolescents. *Obes Rev.* 2011;12(10):781-799.
- 20 12. Pate RR, Mitchell JA, Byun W, Dowda M. Sedentary behaviour in youth. *Br J Sports Med.*
21 2011;45(11):906-913.
- 22 13. Kulinski JP, Khera A, Ayers CR, et al. Association between cardiorespiratory fitness and
23 accelerometer-derived physical activity and sedentary time in the general population. *Mayo Clin*
24 *Proc.* 2014;89(8):1063-1071.

- 1 14. Latouche C, Jowett JB, Carey AL, et al. Effects of breaking up prolonged sitting on skeletal muscle
2 gene expression. *J Appl Physiol (1985)*. 2013;114(4):453-460.
- 3 15. Dunstan DW, Thorp AA, Healy GN. Prolonged sitting: is it a distinct coronary heart disease risk
4 factor? *Curr Opin Cardiol*. 2011;26(5):412-419.
- 5 16. Ekelund U, Luan J, Sherar LB, Esliger DW, Griew P, Cooper A. Moderate to vigorous physical activity
6 and sedentary time and cardiometabolic risk factors in children and adolescents. *JAMA*.
7 2012;307(7):704-712.
- 8 17. Cliff DP, Jones RA, Burrows TL, et al. Volumes and bouts of sedentary behavior and physical activity:
9 associations with cardiometabolic health in obese children. *Obesity (Silver Spring)*. 2014;22(5):E112-
10 118.
- 11 18. Marques A, Santos R, Ekelund U, Sardinha LB. Association between physical activity, sedentary time
12 and healthy fitness in youth. *Med Sci Sports Exerc*. 2014. doi: 10.1249/mss.0000000000000426
- 13 19. Mitchell JA, Pate RR, Beets MW, Nader PR. Time spent in sedentary behavior and changes in
14 childhood BMI: a longitudinal study from ages 9 to 15 years. *Int J Obes (Lond)*. 2013;37(1):54-60.
- 15 20. Abbott RA, Straker LM, Mathiassen SE. Patterning of children's sedentary time at and away from
16 school. *Obesity (Silver Spring)*. 2013;21(1):E131-133.
- 17 21. Hnatiuk J, Ridgers ND, Salmon J, Campbell K, McCallum Z, Hesketh K. Physical activity levels and
18 patterns of 19-month-old children. *Med Sci Sports Exerc*. 2012;44(9):1715-1720.
- 19 22. Hinkley T, Salmon J, Okely AD, Crawford D, Hesketh K. Preschoolers' physical activity, screen time,
20 and compliance with recommendations. *Med Sci Sports Exerc*. 2012;44(3):458-465.
- 21 23. Straker L, Smith A, Hands B, Olds T, Abbott R. Screen-based media use clusters are related to other
22 activity behaviours and health indicators in adolescents. *BMC Public Health*. 2013;13:1174.
- 23 24. Carson V, Cliff DP, Janssen X, Okely AD. Longitudinal levels and bouts of sedentary time among
24 adolescent girls. *BMC Pediatr*. 2013;13:173.

- 1 25. Currie C. *Social determinants of health and well-being among young people*. World Health
2 Organization Regional Office for Europe Copenhagen; 2012.
- 3 26. Department of Health and Ageing *Australian National Children's Nutrition and Physical Activity*
4 *Survey : main findings. Report prepared by Commonwealth Scientific and Industrial Research*
5 *Organisation (CSIRO) and the University of South Australia*. Canberra, ACT: Department of Health
6 and Ageing.
- 7 27. Australian Bureau of Statistics. *Childhood Education and Care, Australia*. 2011.
- 8 28. Vanderloo LM. Screen-viewing among preschoolers in childcare: a systematic review. *BMC Pediatr*.
9 2014;14:205.
- 10 29. Christakis DA. Interactive media use at younger than the age of 2 years: time to rethink the
11 American Academy of Pediatrics guideline? *JAMA Pediatr*. 2014;168(5):399-400.
- 12 30. Voss MW, Carr LJ, Clark R, Weng T. Revenge of the "sit" II: Does lifestyle impact neuronal and
13 cognitive health through distinct mechanisms associated with sedentary behavior and physical
14 activity? *Mental Health and Physical Activity*. 2014;7(1):9-24.
- 15 31. Foley LS, Maddison R, Jiang Y, Olds T, Ridley K. It's not just the television: survey analysis of
16 sedentary behaviour in New Zealand young people. *Int J Behav Nutr Phys Act*. 2011;8:132.
- 17 32. Straker L, Abbott R. Effect of screen based media on energy expenditure and heart rate in 9-12 year
18 old children. *Pediatric Exercise Science*. 2007;19:459-471.
- 19 33. Janssen I, LeBlanc AG. Systematic review of the health benefits of physical activity and fitness in
20 school-aged children and youth. *Int J Behav Nutr Phys Act*. 2010;7(40):1-16.
- 21 34. Marsh S, Ni Mhurchu C, Jiang Y, Maddison R. Comparative effects of TV watching, recreational
22 computer use, and sedentary video game play on spontaneous energy intake in male children. A
23 randomised crossover trial. *Appetite*. 2014;77:13-18.

- 1 35. Boyland EJ, Halford JC. Television advertising and branding: effects on eating behaviour and food
2 preferences in children. *Appetite*. 2013;62:236-241.
- 3 36. Boyland EJ, Harrold JA, Kirkham TC, et al. Food commercials increase preference for energy-dense
4 foods, particularly in children who watch more television. *Pediatrics*. 2011;128(1):e93-100.
- 5 37. Dunstan DW, Kingwell BA, Larsen R, et al. Breaking up prolonged sitting reduces postprandial
6 glucose and insulin responses. *Diabetes Care*. 2012;35(5):976-983.
- 7 38. Peddie MC, Bone JL, Rehrer NJ, Skeaff CM, Gray AR, Perry TL. Breaking prolonged sitting reduces
8 postprandial glycemia in healthy, normal-weight adults: a randomized crossover trial. *Am J Clin*
9 *Nutr*. 013;98(2):358-366.
- 10 39. Saunders TJ, Chaput JP, Goldfield GS, et al. Prolonged sitting and markers of cardiometabolic
11 disease risk in children and youth: a randomized crossover study. *Metabolism*. 2013;62(10):1423-
12 1428.
- 13 40. Golley RK, Maher CA, Matricciani L, Olds TS. Sleep duration or bedtime? Exploring the association
14 between sleep timing behaviour, diet and BMI in children and adolescents. *Int J Obes (Lond)*.
15 2013;37(4):546-551.
- 16 41. Straker LM, Campbell AC, Jensen LM, et al. Rationale, design and methods for a randomised and
17 controlled trial of the impact of virtual reality games on motor competence, physical activity, and
18 mental health in children with developmental coordination disorder. *BMC Public Health*.
19 2011;11:654.
- 20 42. Gabel L, McKay HA, Nettlefold L, Race D, Macdonald HM. Bone architecture and strength in the
21 growing skeleton: the role of sedentary time. *Med Sci Sports Exerc*. 2014. doi:
22 10.1249/mss.0000000000000418
- 23 43. McKay H, Liu D, Egeli D, Boyd S, Burrows M. Physical activity positively predicts bone architecture
24 and bone strength in adolescent males and females. *Acta Paediatr*. 2011;100(1):97-101.

- 1 44. Straker L, Mathiassen SE. Increased physical work loads in modern work--a necessity for better
2 health and performance? *Ergonomics*. 2009;52(10):1215-1225.
- 3 45. Okely AD, Salmon J, Vella SA, et al. *A Systematic Review to update the Australian Physical Activity*
4 *Guidelines for Children and Young People*. Report prepared for the Australian Government
5 Department of Health;2012.
- 6 46. Abood DA, Black DR, Coster DC. Evaluation of a school-based teen obesity prevention minimal
7 intervention. *J Nutr Educ Behav*. 2008;40(3):168-174.
- 8 47. Straker L, Abbott R, Collins R, Campbell A. Evidence-based guidelines for wise use of electronic
9 games by children. *Ergonomics*. 2014;57(4):471-489.
- 10 48. Ranelli S, Straker L, Smith A. Playing-related musculoskeletal problems in children learning
11 instrumental music: the association between problem location and gender, age, and music
12 exposure factors. *Medical Problems of Performing Artists*. 2011;26(3):123-139.
- 13 49. Costa-Giomi E. Does Music Instruction Improve Fine Motor Abilities? *An N Y Acad Sci*.
14 2005;1060(1):262-264.
- 15 50. Straker LM, Coleman J, Skoss R, Maslen BA, Burgess-Limerick R, Pollock CM. A comparison of
16 posture and muscle activity during tablet computer, desktop computer and paper use by young
17 children. *Ergonomics*. 2008;51(4):540-555.
- 18 51. Sigman A. Time for a view on screen time. *Arch Dis Child*. 2012;97(11):935-942.
- 19 52. Modecki KL, Minchin J, Harbaugh AG, Guerra NG, Runions KC. Bullying prevalence across contexts: a
20 meta-analysis measuring cyber and traditional bullying. *J Adolesc Health*. 2014;55(5):602-611.
- 21 53. Przybylski AK, Weinstein N. Can you connect with me now? How the presence of mobile
22 communication technology influences face-to-face conversation quality. *J Soc Pers Relat*.
23 2013;30(3):237-246.

- 1 54. McHale SM, Crouter AC, Tucker CJ. Free-time activities in middle childhood: links with adjustment
 2 in early adolescence. *Child Dev.* 2001;72(6):1764-1778.
- 3 55. Ryan RM, Rigby CS, Przybylski A. The motivational pull of video games: a self-determination theory
 4 approach. *Motiv Emot.* 2006;30(4):344-360.
- 5 56. Corno L, Mandinach EB. The role of cognitive engagement in classroom learning and motivation.
 6 *Educ Psychol.* 1983;18(2):88-108.
- 7 57. Lillard AS, Peterson J. The immediate impact of different types of television on young children's
 8 executive function. *Pediatrics.* 2011;128(4):644-649.
- 9 58. Biddle SJ, Asare M. Physical activity and mental health in children and adolescents: a review of
 10 reviews. *Br J Sports Med.* 2011;45(11):886-895.
- 11 59. Haapala EA, Poikkeus AM, Kukkonen-Harjula K, et al. Associations of physical activity and sedentary
 12 behavior with academic skills - a follow-up study among primary school children. *PLoS One.*
 13 2014;9(9):e107031.
- 14 60. Straker L, Pollock C, Maslen B. Principles for the wise use of computers by children. *Ergonomics.*
 15 2009;52(11):1386-1401.
- 16 61. Biddle SJ, Pearson N, Ross GM, Braithwaite R. Tracking of sedentary behaviours of young people: a
 17 systematic review. *Prev Med.* 2010;51(5):345-351.
- 18 62. Jones RA, Hinkley T, Okely AD, Salmon J. Tracking physical activity and sedentary behavior in
 19 childhood: a systematic review. *Am J Prev Med.* 2013;44(6):651-658.
- 20 63. Gebremariam MK, Totland TH, Andersen LF, et al. Stability and change in screen-based sedentary
 21 behaviours and associated factors among Norwegian children in the transition between childhood
 22 and adolescence. *BMC Public Health.* 2012;12:104.
- 23 64. Francis SL, Stancel MJ, Sernulka-George FD, Broffitt B, Levy SM, Janz KF. Tracking of TV and video
 24 gaming during childhood: Iowa Bone Development Study. *Int J Behav Nutr Phys Act.* 2011;8:100.

- 1 65. Smith L, Gardner B, Hamer M. Childhood correlates of adult TV viewing time: a 32-year follow-up of
2 the 1970 British Cohort Study. *J Epidemiol Community Health*. 2014. doi: 10.1136/jech-2014-204365
- 3 66. de Rezende LF, Rodrigues Lopes M, Rey-Lopez JP, Matsudo VK, Luiz Odo C. Sedentary behavior and
4 health outcomes: an overview of systematic reviews. *PLoS One*. 2014;9(8):e105620.
- 5 67. Grontved A, Ried-Larsen M, Moller NC, et al. Youth screen-time behaviour is associated with
6 cardiovascular risk in young adulthood: the European Youth Heart Study. *Eur J Prev Cardiol*.
7 2014;21(1):49-56.
- 8 68. Maher C, Olds TS, Eisenmann JC, Dollman J. Screen time is more strongly associated than physical
9 activity with overweight and obesity in 9- to 16-year-old Australians. *Acta Paediatr*.
10 2012;101(11):1170-1174.
- 11 69. Mitchell JA, Pate RR, Blair SN. Screen-based sedentary behavior and cardiorespiratory fitness from
12 age 11 to 13. *Med Sci Sports Exerc*. 2012;44(7):1302-1309.
- 13 70. Sandercock GR, Ogunleye AA. Screen time and passive school travel as independent predictors of
14 cardiorespiratory fitness in youth. *Prev Med*. 2012;54(5):319-322.
- 15 71. Kremer P, Elshaug C, Leslie E, Toumbourou JW, Patton GC, Williams J. Physical activity, leisure-time
16 screen use and depression among children and young adolescents. *J Sci Med Sport*.
17 2014;17(2):183-187.
- 18 72. Page AS, Cooper AR, Griew P, Jago R. Children's screen viewing is related to psychological
19 difficulties irrespective of physical activity. *Pediatrics*. 2010;126(5):e1011-1017.
- 20 73. Browne KD, Hamilton-Giachritsis C. The influence of violent media on children and adolescents:a
21 public-health approach. *Lancet*. 005;365(9460):702-710.
- 22 74. Vallance JK, Buman MP, Stevinson C, Lynch BM. Associations of overall sedentary time and screen
23 time with sleep outcomes. *Am J Health Behav*. 2015;39(1):62-67.

- 1 75. Hale L, Guan S. Screen time and sleep among school-aged children and adolescents: a systematic
 2 literature review. *Sleep Med Rev.* 2014. doi: 10.1016/j.smr.2014.07.007
- 3 76. Shantakumari N, Eldeeb R, Sreedharan J, Gopal K. Computer use and vision-related problems
 4 among university students in ajman, United arab emirate. *Ann Med Health Sci Res.* 2014;4(2):258-
 5 263.
- 6 77. Stamatakis E, Coombs N, Jago R, et al. Type-specific screen time associations with cardiovascular
 7 risk markers in children. *Am J Prev Med.* 2013;44(5):481-488.
- 8 78. Vaisto J, Eloranta AM, Viitasalo A, et al. Physical activity and sedentary behaviour in relation to
 9 cardiometabolic risk in children: cross-sectional findings from the Physical Activity and Nutrition in
 10 Children (PANIC) Study. *Int J Behav Nutr Phys Act.* 2014;11:55.
- 11 79. Saunders TJ, Tremblay MS, Mathieu ME, et al. Associations of sedentary behavior, sedentary bouts
 12 and breaks in sedentary time with cardiometabolic risk in children with a family history of obesity.
 13 *PLoS One.* 2013;8(11):e79143.
- 14 80. Staiano AE, Abraham AA, Calvert SL. Adolescent exergame play for weight loss and psychosocial
 15 improvement: a controlled physical activity intervention. *Obesity (Silver Spring).* 2013;21(3):598-
 16 601.
- 17 81. Braithwaite I, Stewart AW, Hancox RJ, Beasley R, Murphy R, Mitchell EA. The worldwide association
 18 between television viewing and obesity in children and adolescents: cross sectional study. *PLoS*
 19 *One.* 2013;8(9):e74263.
- 20 82. Mota J, Ribeiro JC, Carvalho J, Santos MP, Martins J. Television viewing and changes in body mass
 21 index and cardiorespiratory fitness over a two-year period in schoolchildren. *Pediatr Exerc Sci.*
 22 2010;22(2):245-253.

- 1 83. Tucker LA, Arens PJ, Lecheminant JD, Bailey BW. Television viewing time and measured
 2 cardiorespiratory fitness in adult women. *Am J Health Promot.* 2014. doi: 10.4278/ajhp.131107-
 3 QUAN-565
- 4 84. Olafsdottir S, Eiben G, Prell H, et al. Young children's screen habits are associated with consumption
 5 of sweetened beverages independently of parental norms. *Int J Public Health.* 2014;59(1):67-75.
- 6 85. Borghese MM, Tremblay MS, Leduc G, et al. Independent and combined associations of total
 7 sedentary time and television viewing time with food intake patterns of 9- to 11-year-old Canadian
 8 children. *Appl Physiol Nutr Metab.* 2014:1-7.
- 9 86. Sisson SB, Shay CM, Broyles ST, Leyva M. Television-viewing time and dietary quality among US
 10 children and adults. *Am J Prev Med.* 2012;43(2):196-200.
- 11 87. Balague F, Troussier B, Salminen JJ. Non-specific low back pain in children and adolescents: risk
 12 factors. *Eur Spine J.* 1999;8(6):429-438.
- 13 88. Gunzburg R, Balague F, Nordin M, et al. Low back pain in a population of school children. *Eur Spine*
 14 *Jy.* 1999;8(6):439-443.
- 15 89. Hakala P, Rimpela A, Saarni L, Salminen J. Frequency computer-related activities increase the risk of
 16 neck-shoulder and low back pain in adolescents. *Eur J Public Health.* 2006;16(5):536-541.
- 17 90. Yousef S, Eapen V, Zoubeidi T, Mabrouk A. Behavioral correlation with television watching and
 18 videogame playing among children in the United Arab Emirates. *Int J Psychiatry Clin Pract.* 2014.
 19 doi: 10.3109/13651501.2013.874442
- 20 91. Parkes A, Sweeting H, Wight D, Henderson M. Do television and electronic games predict children's
 21 psychosocial adjustment? Longitudinal research using the UK Millennium Cohort Study. *Arch Dis*
 22 *Child.* 2013;98(5):341-348.
- 23 92. Verlinden M, Tiemeier H, Hudziak JJ, et al. Television viewing and externalizing problems in
 24 preschool children: the Generation R Study. *Arch Pediatr Adolesc Med.* 2012;166(10):919-925.

- 1 93. Hamer M, Stamatakis E, Mishra G. Psychological distress, television viewing, and physical activity in
 2 children aged 4 to 12 years. *Pediatrics*. 2009;123(5):1263-1268.
- 3 94. Tin SP, Ho DS, Mak KH, Wan KL, Lam TH. Association between television viewing and self-esteem in
 4 children. *J Dev Behav Pediatr*. 2012;33(6):479-485.
- 5 95. Robertson LA, McAnally HM, Hancox RJ. Childhood and adolescent television viewing and antisocial
 6 behavior in early adulthood. *Pediatrics*. 2013;131(3):439-446.
- 7 96. Mitrofan O, Paul M, Spencer N. Is aggression in children with behavioural and emotional difficulties
 8 associated with television viewing and video game playing? A systematic review. *Child Care Health
 9 Dev*. 2009;35(1):5-15.
- 10 97. Nathanson AI, Sharp ML, Aladé F, Rasmussen EE, Christy K. The relation between television
 11 exposure and theory of mind among preschoolers. *J Communication*. 2013;63(6):1088-1108.
- 12 98. Duch H, Fisher EM, Ensari I, et al. Association of screen time use and language development in
 13 Hispanic toddlers: a cross-sectional and longitudinal study. *Clin Pediatr (Phila)*. 2013;52(9):857-865.
- 14 99. van Egmond-Frohlich AW, Weghuber D, de Zwaan M. Association of symptoms of attention-
 15 deficit/hyperactivity disorder with physical activity, media time, and food intake in children and
 16 adolescents. *PLoS One*. 2012;7(11):e49781.
- 17 100. Bener A, Al-Mahdi HS, Ali AI, Al-Nufal M, Vachhani PJ, Tewfik I. Obesity and low vision as a result of
 18 excessive Internet use and television viewing. *Int J Food Sci Nutr*. 2011;62(1):60-62.
- 19 101. Cespedes EM, Gillman MW, Kleinman K, Rifas-Shiman SL, Redline S, Taveras EM. Television viewing,
 20 bedroom television, and sleep duration from infancy to mid-childhood. *Pediatrics*. 2014. doi:
 21 10.1542/peds.2013-3998
- 22 102. Marinelli M, Sunyer J, Alvarez-Pedrerol M, et al. Hours of television viewing and sleep duration in
 23 children: a multicenter birth cohort study. *JAMA Pediatr*. 2014;168(5):458-464.

- 1 103. Mo-Suwan L, Nontarak J, Aekplakorn W, Satheannoppakao W. Computer game use and television
- 2 viewing increased risk for overweight among low activity girls: Fourth Thai National Health
- 3 Examination Survey 2008-2009. *Int J Pediatr.* 2014;2014:364702.
- 4
- 5

Accepted

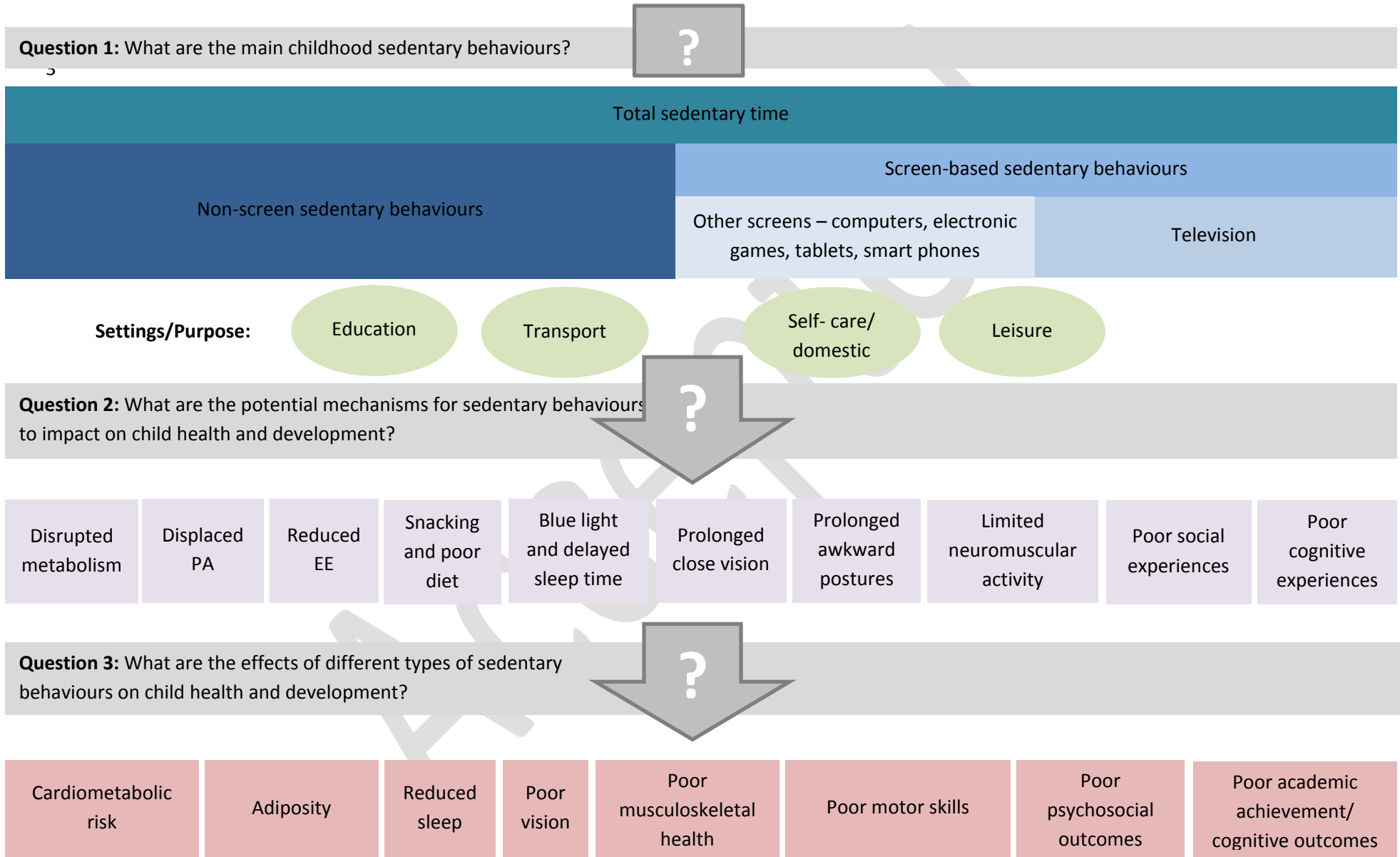
1 **Table 1: Summary of Sedentary Behaviour Grades in National Physical Activity Report Cards**

	Grade	Percentage (%) meeting screen time guidelines (≤2 hours/day unless otherwise noted)*
Ghana	B	79% of 13-17 year olds (global PA guidelines, <3 hours sitting) Average of 1.75 hours screen time on school
Kenya	B	day, 4.25 hours on weekend days for 9-11 year olds
New Zealand	C	60% of 5-9 year olds, 33% of 10-14 year olds
Ireland	C-	54% of 11-15 year olds (TV only)
Colombia	D	42% of 5-12 year olds
Finland	D	22% of 11-15 year olds (on weekdays)
Mexico	D	33% of 10-18 year olds
United States	D	59% of 6-8 year olds, 48% of 9-11 year olds (but ethnic disparities)
Australia	D-	29% of 5-17 year olds
Canada	F	69% of 5-11 year olds, 19% of 10-16 year olds
Nigeria	F	5-35% of 6-18 year olds (<3 hours per day)
Scotland	F	24% of 11-15 year olds (TV only)
South Africa	F	Average 3 hours TV per day for 10-17 year olds

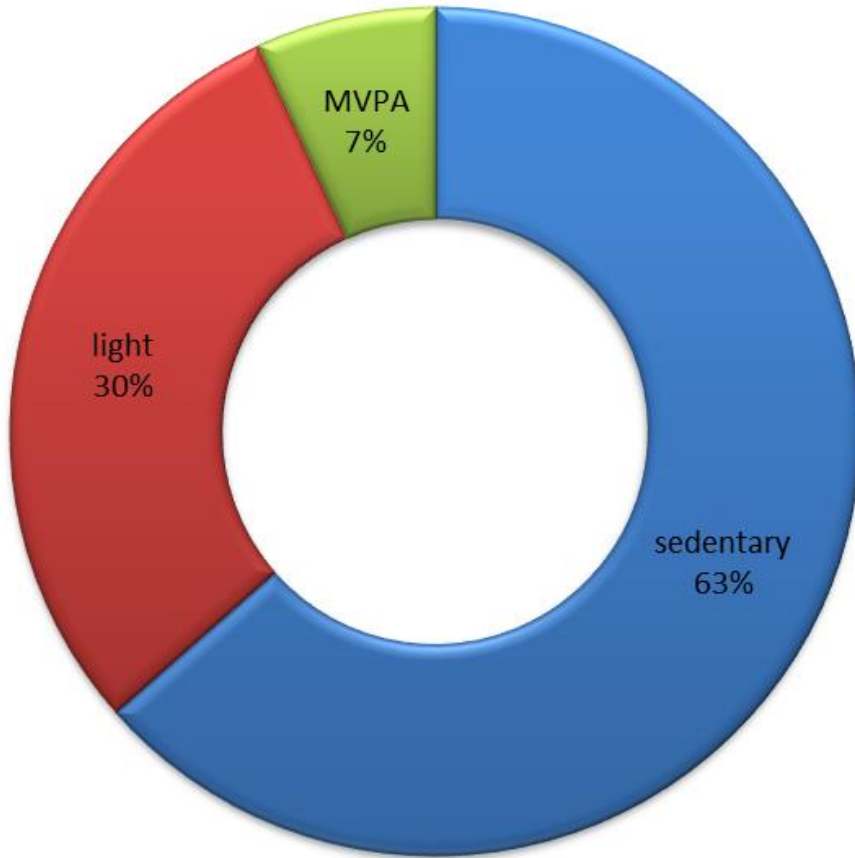
2 *Note: estimates are taken from respective country report cards, and the definitions of meeting
3 guidelines varied, as did the survey instruments used and age groups assessed

4

1 **Figure 1.** Sedentary behaviours, mechanisms and impact on child health and development

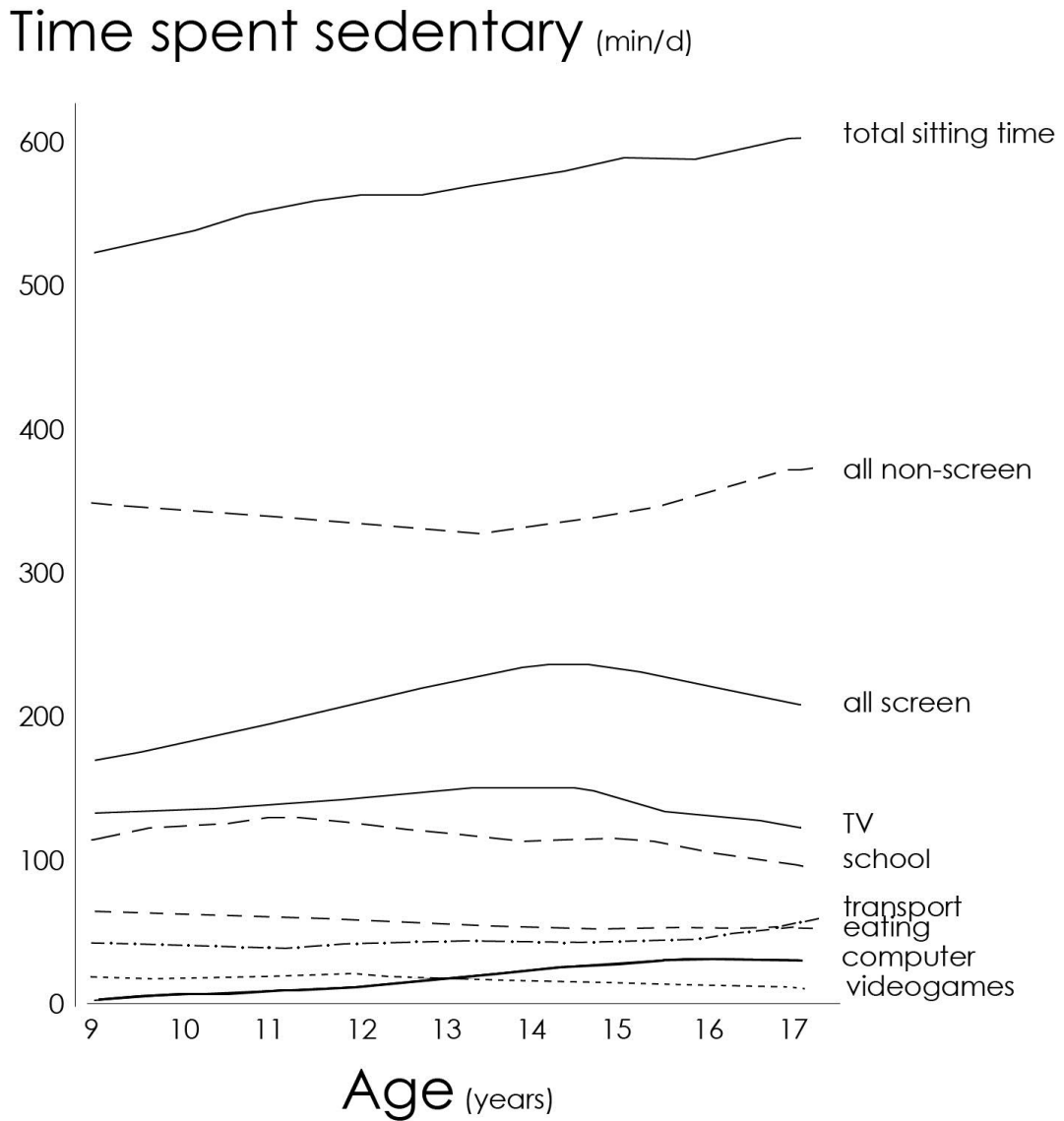


1 **Figure 2.** Average proportion of daily wake time spent in 'activity' of different intensity for
2 Australian children aged 10-12 years (data from ¹⁹)



3
4
5

1 **Figure 3.** Daily time Australian children spend being sedentary (data from the Australian
2 National Children's Nutrition and Physical Activity Survey ²⁵)



3
4
5