Associations between 24-hour movement behaviours (physical activity, sedentary behaviour and sleep) and health among children in the Kingdom of Saudi Arabia

Yazeed Alkhalawi Alanazi

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Associations between 24-hour movement behaviours (physical activity, sedentary behaviour and sleep) and health among children in the Kingdom of Saudi Arabia

A thesis submitted in fulfilment of the requirements for the award of the degree

Doctor of Philosophy
from the University of Wollongong

by

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Bachelor of Physical Education
Master of Health and Kinesiology

Supervisors:
Professor Anthony D. Okely and Assoc. Prof. Anne-Maree Parrish

School of Health and Society
Faculty of the Arts, Social Sciences and Humanities
Early Start
University of Wollongong
July 2022
Abstract

Background

In Arabic countries, such as Saudi Arabia, no known studies have examined associations between 24-hour movement behaviours (sleep, sedentary behaviour (SB) and physical activity (PA)) and health among school-aged children. Most studies have assessed the relationship of each of these movement behaviours in isolation. Due to the high and increasing levels of obesity and physical inactivity among Saudi Arabian children, it is important to understand how movement behaviours are associated with health, and how to promote healthy levels of these movement behaviours, especially as the country moves on from the COVID-19 pandemic.

Aim

The original purpose of this doctoral research was to investigate the longitudinal associations between 24-hour movement behaviours and health and development among school-aged children in Saudi Arabia.

Methods

This doctoral thesis was designed to comprise a systematic review and a longitudinal study to be commenced in February 2020, with data collection at two time points (baseline and 12-month follow-up) targeting children enrolled in their second year of primary school.
(Grade 2; 7 years old), from urban (Riyadh city) and rural (Al Jubaylah town) schools in Saudi Arabia. Due to the COVID-19 pandemic in Saudi Arabia, baseline data collection for the longitudinal study was suspended in March, 2020 and schools remained closed until January, 2022. This suspension occurred two weeks after data collection commenced. As such, the following adjustments to this thesis were made:

1- Two online cross-sectional studies focusing on changes in movement behaviours due to COVID-19 was undertaken as an alternative to the longitudinal study.

2- Data that had been collected from baseline data collection were written up as a small cross-sectional study.

This doctoral thesis was revised to comprise a systematic review followed by three studies. The systematic review investigated the associations between 24-hour movement behaviours and health indicators in school-aged children in Arabic countries. Following this, a cross-sectional study was conducted to examine the impact of the COVID-19 outbreak on 24-hour movement behaviours among children in Saudi Arabia (Time 1) (October, 2020). A follow-up to this study assessed the impact of COVID-19 restrictions on movement behaviours of Saudi children (Time 2) (March, 2021) and compared the results to the initial study conducted at Time 1 (October, 2020). The final study used the baseline data collected from the first two weeks of the original longitudinal study to assess the associations between gross motor skills, adiposity and bone mineral density (BMD) among school-aged Saudi children.
Results:
The systematic review included 16 studies from nine Arabic countries. The results showed that low levels of PA, sleep and high SB were unfavourably associated with adiposity outcomes, behavioural problems, depression and low self-esteem among children.

The online survey (Time 1) included 1021 school-aged children, 6-12 years of age (60% girls), from across Saudi Arabia and found that only 3.4% of Saudi children met all components of 24-hour movement guidelines. Compared with before COVID-19, children’s PA levels declined, they slept more, and their use of electronic screen devices significantly increased.

The follow-up online survey (Time 2) included 1045 school-aged children, 6-12 years of age (51% girls), from across Saudi Arabia and found that only 1.8% of Saudi children met all components of the 24-hour movement guidelines, compared to 3.4% in Time 1. Boys slept more than girls, and girls spent more days per week participating in moderate- to vigorous-intensity physical activity (MVPA) ≥60 minutes than boys.

The cross-sectional study included 48 school-aged children (7.80±0.62 year, boys only) and found that non-overweight and overweight/obese boys did not significantly differ in their locomotor standard scores ($p=0.093$), object control standard scores ($p=0.876$) and BMD radius z-score ($p=0.343$). BMI was moderately and negatively correlated with locomotor
standard scores \( r = -0.32, p = 0.025 \), while BMD radius \( z \)-scores were not associated with BMI \( r = -0.245, p > 0.05 \).

**Conclusion**

The findings from this thesis provide new evidence to advance the understanding of the associations between 24-hour movement behaviours (sleep, sedentary behaviour and physical activity) and health among children in the Kingdom of Saudi Arabia, with particular reference to the period encompassing the COVID-19 pandemic. Further studies to address the dearth of literature from Arab-speaking countries on 24-hour movement behaviours and health across childhood are needed. Longitudinal studies with larger sample sizes are recommended to better understand how gross motor skills, adiposity and BMD may be associated with weight status among children. The COVID-19 pandemic unfavourably affected Saudi children’s movement behaviours. Policies that support the promotion of healthy levels of PA, SB and sleep by encouraging outdoor PA (where possible), minimizing children’s use of screen devices when sedentary, educating parents about the importance of meeting movement behaviour guidelines will help to ameliorate the long-term effects of the COVID-19 and better prepare for future pandemics to lessen their impact on children’s movement behaviours in Saudi Arabia. Finally, girls’ physical education classes were only introduced in 2018, as a part of the Kingdom’s vision (The Quality-of-Life Program). Therefore, more of a focus on promoting PA for girls is recommended as it is associated with better health outcomes.
Acknowledgments

I would like to begin by thanking my amazing and outstanding supervisors, Prof. Anthony D. Okely and Assoc. Prof. Anne-Maree Parrish, for their guidance, invaluable advice, continuous support, and patience throughout the entire journey. Your immense knowledge and plentiful experience have encouraged me in all the time of my academic research and enlightened my path and helped me overcome many obstacles I faced during my PhD. I am grateful to you!

My sincere thanks also go to Dr. Eduarda Sousa-Sá and Dr. Kar Hau Chong for their contributions to the systematic review work. Thank you also goes to the wonderful people at Early Start, Sarah Rayan, Penny Cross, Dr. Ellie Taylor, Dr. Byron Kemp, Dr. Dylan Cliff, Dr. Rebecca Stanley and the rest of my fellow PhD students at Early Start Research Institute.

Last but not the least, I would like to thank my family: my parents, my wife and my children, my brothers and sisters for supporting me throughout writing this thesis.
Certification

I, Yazeed Alkhalawi Alanazi, declare that this thesis submitted in fulfilment of the requirements for the conferral of the degree Doctor of Philosophy, from the University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. This document has not been submitted for qualifications at any other academic institution.

Yazeed Alkhalawi Alanazi

16th June 2022
List of names and abbreviations

BMI: Body Mass Index
CI: Confidence Interval
COVID-19: SARS-CoV-2
HREC: Human Research Ethics Committee
LPA: Light-Intensity Physical Activity
PA: Physical Activity
P: Probability
M: Mean
METs: Metabolic Equivalent of Task
MVPA: Moderate- to Vigorous-Intensity Physical Activity
N: Number (of participants, studies, etc.)
OR: Odds Ratio
PE: Physical Education
PRISMA: Preferred Reporting Items for Systematic reviews and Meta-Analyses
ROB: Risk of Bias
RST: Recreational Sedentary Screen Time
SAR: Saudi Riyal
SB: Sedentary Behaviour
SD: Standard Deviation
ST: Screen Time
SPSS: Statistical Package for the Social Sciences
TV: Television
UOW: University of Wollongong
US: United States
VG: Video Games
VPA: Vigorous Physical Activity
WHO: World Health Organization
Y: Years (of age)
24-h: 24-hour
Statement of thesis style

In agreement with my supervisors, Professor Anthony Okely and Assoc. Prof. Anne-Maree Parrish, this thesis has been prepared in journal publication compilation style. This style was appropriate for this thesis due to the rich and varied outcomes of the conducted studies providing important evidence to better understand the associations between 24-hour movement behaviours and health among children in the Kingdom of Saudi Arabia. Additionally, the study elucidated the potential interactive health effects, and how they, as combined movement behaviours, influence children’s health and development.

The program of research described in this PhD thesis has been reported in four individual manuscripts (Chapters 4,5,6,7) that have been published or accepted for publication in peer-reviewed journals. The articles include a systematic review (Chapter 4) and three cross-sectional studies (Chapter 5,6,7). They have been presented as published or accepted for publication, with minor changes in terms of formatting (figure and table numbering and the referencing style) based on the University of Wollongong’s referencing style “UOW Harvard”. This thesis also contains an introductory chapter, a literature review chapter, a methodology chapter and a general discussion and recommendations chapter as well as appendices.
Publications constituting this thesis

This thesis consists of four manuscripts that have been published or accepted for publication in peer-reviewed journals:

Chapter 4

Chapter 5

Chapter 6

Chapter 7
Authors’ contributions to publications

Article 1 (Chapter 4)
Yazeed Alanazi was involved in developing the research question, developing the PROSPERO protocol, development and testing of the search strategy, extraction of literature from databases, reviewing literature, conducting the risk of bias assessment, synthesizing results and drafting the manuscript. Dr. Eduarda Sousa-Sá and Dr. Kar Hau Chong were involved in reviewing literature and conducting the risk of bias assessment. Professor Anthony Okely and Dr. Anne-Maree Parrish were involved in developing the research question, developing the PROSPERO protocol, reviewing the search strategy and providing advice on the risk of bias assessment. All authors reviewed and approved the final manuscript.

Article 2 (Chapter 5)
Yazeed Alanazi was involved in developing the research question, gaining ethical approvals, data collection, data cleaning, development of the analytic strategy, analysis of data, interpretation of findings and drafting the manuscript. Professor Anthony Okely and Dr. Anne-Maree Parrish were involved in developing the research question, providing advice on data analysis and interpreting findings. All authors reviewed and approved the final manuscript.
**Article 3 (Chapter 6)**

Yazeed Alanazi was involved in developing the research question, gaining ethical approvals, data collection, data cleaning, development of the analytic strategy, analysis of data, interpretation of findings and drafting the manuscript. Professor Anthony Okely and Dr. Anne-Maree Parrish were involved in developing the research question, providing advice on data analysis and interpreting findings. All authors reviewed and approved the final manuscript.

**Article 4 (Chapter 7)**

Yazeed Alanazi was involved in developing the research question, gaining ethical approvals, data collection, cleaning, development of the analytic strategy, analysis of data, interpretation of findings and drafting the manuscript. Professor Anthony Okely and Dr. Anne-Maree Parrish were involved in developing the research question, providing advice on data analysis and interpreting findings. All authors reviewed and approved the final manuscript.
All authors hereby agree with the authors’ contributions statement:

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Chapter 1: Introduction and aims

1.1 Background

Physical inactivity and sedentary behaviours (SB) in children have received growing attention in the literature in recent years because of their high prevalence (Hidding et al., 2017) and related health risks (Katzmarzyk, 2010). Research also indicates that children’s physical activity (PA) patterns shaped during childhood may track into adolescence and adulthood (Thompson et al., 2003, Hirvensalo et al., 2011). A major limitation of these studies is that they only captured specific movement behaviours (e.g. moderate- to vigorous-intensity physical activity (MVPA), screen time) during waking hours, limiting our understanding of the child’s habitual body movements across a 24-hour period (from sleep (i.e. no/low movement) to vigorous-intensity physical activity (VPA) (i.e. high movement) (Chaput et al., 2014).

The early primary school period is important for children’s general health and wellbeing (Alexander and Ignjatovic., 2012). Despite evidence demonstrating the positive associations between PA (Poitras et al., 2016) and adequate sleep (Chaput et al., 2016) and the negative impact of screen-based SB (Carson et al., 2016) and health indicators in school-aged children, few studies to date have examined the associations between 24-hour movement behaviours and health among school-aged children. In fact, most published studies assess the relationship of each of these movement behaviours in isolation or partially adjusted for time spent in other behaviours (Tremblay et al., 2016). Due to the
high and increasing levels of obesity and physical inactivity among Saudi Arabian children (Al-Hussaini et al., 2019), it is important to understand how movement behaviours are associated with health, and how to promote healthy levels of these movement behaviours, especially as the country moves on from the COVID-19 pandemic.

More high-quality studies with robust research design, however, are needed to further extend the knowledge base regarding the health implications of 24-hour movement behaviours and support the 24-h movement behaviour approach in formulating future health-promoting strategies or guidelines. Moreover, almost all studies to date have come from English-speaking or European countries; more studies from other parts of the world are needed.

1.2 Purpose of the study

The main aim of this doctoral thesis was to examine the associations between 24-hour movement behaviours (sleep, SB and PA) and health among children in the Kingdom of Saudi Arabia. The specific aims of the thesis related to each of the included papers are summarised below.

Specific aim: to investigate the relationship between 24-hour movement behaviours and health indicators in school-aged children in Arabic countries.

Specific aim: to investigate the impact of COVID-19 on 24-hour movement behaviours among Saudi children aged 6-12 years, during the pandemic.

Specific aim: to investigate the changes in 24-h movement behaviours 12 months after the WHO declared COVID-19 a global pandemic.

Specific aim: to examine the associations between gross motor skills, adiposity and BMD-radius z-score among non-overweight and overweight/obese boys in Saudi Arabia.

1.3 Research Questions

**Research Question 1:**
What are the relationships between movement behaviours (physical activity, sedentary behaviour, and sleep) and health indicators in school-aged children in Arab-Speaking countries?
Research Question 2:
What is the impact of the COVID-19 outbreak on 24-h movement behaviours among Saudi children aged 6-12 years seven months after the WHO declared COVID-19 outbreak as a pandemic?

Research Question 3:
What is the impact of the COVID-19 outbreak on 24-h movement behaviours among Saudi children aged 6-12 years 12 months after the WHO declared COVID-19 outbreak as a pandemic?

Research Question 4:
What is the relationship between adiposity, gross motor skills and bone mineral density-radius z-score among non-overweight and overweight/obese boys in Saudi Arabia?

1.4 Significance of the study

This study examined the associations between 24-hour movement behaviours (physical activity, sedentary behaviour, and sleep) and health among school-aged children in the Kingdom of Saudi Arabia. Emerging evidence of the benefits of PA (e.g., moderate- to vigorous- intensity physical activity (MVPA) to overall health suggests that broader and integrated approaches incorporating 24-h movement behaviours are needed (Poitras et al., 2016) to understand the role of 24-hour movement behaviours and their influence on important health outcomes (obesity, motor development and bone health) across the years of primary school. Moreover, no known studies have examined associations between 24-
hour movement behaviours and health among school-aged children. Most studies have assessed the relationship of each of these movement behaviours in isolation. Despite more than 120 million children living in the 22 Arabic countries of relevance (Mirkin, 2010), as well as the high and increasing levels of childhood obesity and SB (Sharara et al., 2018; Farrag et al., 2017), the inadequate research evidence from the Arabic countries confirms that research is needed to address this inequality in the literature.

1.5 Overview of this thesis

This thesis by compilation consists of four manuscripts (a systematic literature review (Chapter 4) and the other three are original research studies (Chapters 5 to 7)) that have been published or accepted for publication in peer-reviewed journals. Each manuscript is presented as a separate chapter.
Chapter 2: Theoretical framework and literature review

Chapter 1 provided the background and rationale for this thesis and explained the concepts and issues under investigation. A broad overview of the thesis was provided, including the aims and research questions. This chapter describes the theoretical framework and includes a review of literature related to the thesis including definitions of 24-h movement behaviours, prevalence of 24-h movement behaviours, associations between 24-h movement behaviours and health among children, associations between adiposity, motor skills, and bone health in children and the impact of COVID-19 on movement behaviours. Research gaps are also identified.

2.1 Theoretical Framework

Sallas et al.’s (2000) Behavioural Epidemiology Framework provides an evidence-based public health approach to understating and promoting 24-h movement behaviours by proposing a general sequence of studies on health-related behaviours. In the context of 24-hour movement behaviours, the framework contains five phases:

1- Establish links between PA, SB, sleep and health.
2- Develop methods for measuring PA, SB, and sleep.
3- Identify factors that influence PA, SB, and sleep.
4- Evaluate interventions to promote healthy levels of PA, SB, and sleep.
5- Translate research into practice.

In this doctoral research, phases 1 and 3 were applied.
The WHO and several countries have developed guidelines for PA and SB for children and youth to support their healthy development (WHO, 2020, Parrish et al., 2020). Improving children's movement behaviours will reduce the risk of developing obesity and the associated noncommunicable diseases (NCDs) in later life (WHO, 2019). More than 140 million children live in the 22 Arabic countries (International Labour Organization, n.r), where there are high and increasing levels of childhood obesity and SB and decreasing in PA levels (Sharara et al., 2018; Farrag et al., 2017). The lack of evidence from these countries confirms that research is needed to address this gap in the literature (Sharara et al., 2018; Farrag et al., 2017). In response, Chapter 4, investigated the relationship between 24-hour movement behaviours and health indicators in school-aged children in Arabic countries. Children’s lifestyles have changed as a result of COVID-19 outbreak; their PA levels declined, they slept more, and their use of electronic screen devices increased (Kovacs et al., 2022; Moore et al., 2021). However, no known studies from Arabic countries have investigated the impact of COVID-19 on children’s movement behaviours. Chapters 5 and 6 investigated the impact of the COVID-19 outbreak on 24-h movement behaviours among Saudi children aged 6-12 years.

2.2 Literature Review

Noncommunicable diseases (NCDs) are the leading causes of death globally (WHO, 2018). Forty-one million people (71% of global deaths) die annually from NCDs (WHO, 2018). Most premature deaths are linked to physical inactivity, tobacco use, unhealthy diet, and harmful use of alcohol, which are called metabolic risk factors (WHO, 2018). Globally, levels of physical inactivity have not decreased since 2001 (29% in 2001; 28% in 2016) and
at present the world is not on track to meet the worldwide WHO 2025 target for decreased physical inactivity (WHO, 2016).

High levels of physical inactivity and childhood obesity are public health challenges and associated with a scope of unfavourable health outcomes (Poitras et al., 2016). To better understand and address this public health concern, emerging evidence of the benefits of PA (e.g., moderate- to vigorous-intensity physical activity (MVPA)) to overall health suggest that a broader approach is needed (Poitras et al., 2016). That is, meeting PA, SB and sleep guidelines is better than meeting any two, and meeting any combination of two guidelines is better than meeting just one (Okely et al., 2022). The WHO launched a global action plan to promote PA at all ages (WHO, 2018). In addition, the WHO and other countries have developed guidelines for PA, SB and sleep for children and youth to support their healthy development (WHO., 2020, Parrish et al., 2020).

2.3 Definitions of 24-Hour Movement Behaviours

2.3.1 24-Hour Movement Behaviours
Twenty-four-hour movement behaviours is a relatively new concept referring to the integration of PA, SB and sleep over the 24-h period (Okely et al., 2019, Tremblay et al., 2016). This terminology is considered to be a shift in thinking from focusing on movement behaviours in isolation to incorporating all movement behaviours across the 24-h period as they collectively impact health outcomes and represents an evolution of public health guidelines (Poitras et al., 2016). The 24-h movement behaviours can be classified by
movement (light-intensity physical activity (LPA), moderate-intensity physical activity (MPA), vigorous Physical Activity (VPA)) and non-movement (sleep and SB) behaviours (Rao et al., 2016), as well as by energy expenditure (< 1.5 METs for SB, and > 1.5 METs for PA) (Pedišić et al., 2017). These movement behaviours interact with one another to influence health outcomes (Chaput et al. 2017; Kuzik and Carson 2016).

The Canadian 24-Hour Movement Guidelines for Children and Youth reviewed the literature that investigated the combined effects of these behaviours among health outcomes on children (Tremblay et al., 2016, Poitras et al., 2016, Chaput et al., 2016, Carson et al., 2016). The literature was updated in 2018 as part of the development of Australian 24-Hour Movement Guidelines for Children and Young People (Okely et al., 2019). These Guidelines were launched as evidence-based guidelines to address the whole day movement behaviours instead of focusing on these behaviours in isolation, since studies previously were conducted to capture only specific movement behaviours (e.g. MVPA, screen time) during waking hours, which only accounts for a small part of children’s activity across the day (<5%) of the 24- h period), while sleep (~40%), SB (~40%) and LPA (~15%) account for 95% of the day (Chaput et al., 2014).
1. Physical Activity

Caspersen et al. (1985) defined PA as “any bodily movement produced by skeletal muscles that results in energy expenditure above the resting metabolic rate”. Physical inactivity refers to the condition of not meeting the recommended levels of PA (i.e. less than 60 min of MVPA) per day for children and adolescents) (Chaput et al., 2014). PA can be categorized into daily-living domains such as leisure time, household work, sports, transportation and other activities. The components of PA are duration (units of time); frequency (number of sessions, bouts or days); intensity (expressed as metabolic equivalent multiples of resting metabolic rate or METS (light = ≥1.5–2.9, moderate = 4.0–5.9, vigorous ≥6.0); mode (the type of PA behaviour, e.g., bicycling, walking, football); and domain (the context or reason for the PA) (Dollman et al., 2009). However, PA in children is different to that of adults as 1 MET for adults, which is used to measure the energy costs of physical activities as multiples of resting metabolic rate, represent oxygen uptake of 3.5
mL·kg$^{-1}$·min$^{-1}$ or 1 kcal·kg$^{-1}$·h$^{-1}$, however, these values are not applicable to children as they have higher basal metabolic rates per unit body mass and have disproportionally higher energy expenditure for physical activities (Butte et al., 2018); therefore, the intensity of PA can be classified as LPA (1.5 to < 4 METs), MPA (4 to < 6 METs), and VPA (> 6 METs) (Trost et al., 2011). Children’s PA can be measured using devices on direct observation (e.g., accelerometers, pedometers, heart rate monitors, and direct observation), or subjectively (e.g., self-report activity diaries/logs, and self- or proxy-report questionnaires (Sylvia et al., 2014). The methods used to assess children’s movement behaviours depend on five factors, the:

i. Quality of physical activity measured (e.g. activity type, intensity, frequency, and duration).
ii. Objectivity of the data.
iii. Subject burden (e.g. time and/or effort required to complete).
iv. Cost/burden to administer.
v. Study population (i.e. age, sex, body weight, and comorbid conditions). (Sylvia et al., 2014).

2. Sedentary Behaviour

SB is defined by Tremblay et al., (2017) as “any waking behaviour characterized by an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture”. SB is not ‘insufficient PA’ or ‘not meeting recommended levels’ of MVPA (Hamilton et al 2008; Yates et al 2011).
SB can be described as either screen-based (e.g., TV, smartphones, and computers), and non-screen-based (sitting doing homework) (Tremblay et al., 2017). However, screen-based is the most common form of SB among children (Cliff et al., 2016). As shown in Figure 1.3, SB can be measured objectively (observation, motion devices such as accelerometer and inclinometer, screen monitors, time use devices) or subjectively (self/proxy-report, log/diary) (Hardy et al., 2013).
3. Sleep

Chaput et al., (2014) defined sleep as “a naturally recurring state of body and mind characterized by altered consciousness, relatively inhibited sensory activity, inhibition of nearly all voluntary muscles and reduced interactions with surroundings”. Methods used to measure sleep include device-based (e.g. polysomnography, actigraphy/accelerometry) and subjective (e.g. self-report, proxy-report) measures. Optimal sleep requires sleep quantity,
quality (i.e. efficiency of staying asleep), timing (i.e. bedtime/wake up time), architecture (i.e. sleep stages), consistency (i.e. day-to-day variability) and continuity (i.e. variability in sleep duration within the same night) (Chaput et al., 2014). When measuring sleep in children, researchers usually examine the duration, although it has been recognised that sleep quality is important.

### 2.4 Prevalence of 24-Hour Movement Behaviours

Studies have shown age-associated declines in PA (Pate et al., 2019, Huang et al., 2018, Farooq et al., 2017, Ainsworth et al 2017) and sleep duration (Cao et al., 2019, Chaput et al., 2018, Matricciani et al., 2017, Hale et al., 2015,) and increase in SB (Cantarero et al., 2017, Wu et al., 2017, Corder et al., 2015, Tanaka et al., 2014) among school-aged children. Despite the evidence of health benefits, children are not meeting 24-h movement guidelines (Okely et al., 2019, Tremblay et a., 2016) for these three movement behaviours. To illustrate, in Canada, 1 in 5 children (17%) aged 6-17 years met the Canadian 24-h movement behaviours for MVPA (at least 60 min PA per day), SB (2 h or less recreational screen time per day), and sleep (9-11 hours) (Carson et al., 2016). Moreover, Roman-Viñas et al., (2016) conducted a cross-sectional multinational study designed on 6128 children aged 9–11 years from 12 countries to evaluate adherence to the Canadian 24-h movement guidelines and the results showed that 7% of children met all three behaviours, while 19% met none of the recommendations.
2.5 Associations Between 24-Hour Movement Behaviours and Health Among Children

2.5.1 Physical Activity and Health

In 2016, Poitras and colleagues conducted a systematic review to examine the relationships between device-based measured PA and relevant health indicators in children and youth aged 5–17 years. The results showed that total PA was favourably associated with adiposity, cardiometabolic biomarkers, physical fitness and bone health, with some support for favourable relationships between total PA and quality of life/well-being, motor skill development and psychological distress. Relationships were more consistent and robust for higher (e.g., MVPA) versus lower (e.g., LPA) intensity. In addition, the authors found that all patterns of activity (sporadic, bouts, continuous) provided health benefits. A systematic review to update the Australian 24-h movement guidelines showed a positive relationship between total PA, MVPA, MPA and cardiometabolic biomarkers, body composition, fitness, behavioural conduct/pro-social behaviour and cognition/academic achievement (Okely et al., 2022).

The results from the WHO PA guideline for children and adolescents showed that PA is positively associated with cardiometabolic health outcomes, including improved blood pressure, lipid profile, glucose control and insulin resistance; favourably associated with adiposity; cognitive function and healthy weight status in children and adolescents (WHO., 2020).
2.5.2 Sedentary Behaviour and Health

Carson et al., (2016) conducted a systematic review examining the relationships between device-based or self/parent proxy-reports measured SB and health indicators in children and youth aged 5–17 years. The results showed that higher durations/frequencies of screen time (ST) and television (TV) viewing were associated with unfavourable body composition, higher clustered cardiometabolic risk scores, unfavourable behavioral conduct/pro-social behaviour and associated with lower fitness. Also, higher durations of screen time and computer use were associated with lower self-esteem.

A systematic review to update the Australian 24-h movement guidelines showed that long bouts of sitting (>10 min) and the number of sit-to-stand transitions were associated with body composition (Okely et al., 2019). Moreover, higher durations or frequencies of accelerometer-derived sedentary time, ST, TV viewing and weekend internet use (internet use in last 30 days, school day internet use, % of internet activities for leisure) were significantly associated with poorer body composition (Okely et al., 2019).

The results from the WHO SB guideline for children and adolescents showed that SB was associated with unfavourable measures of adiposity; negative association between SB and well-being and quality of life; and unfavourable relationship between depression and leisure screen time in children and adolescents (WHO., 2020).
2.5.3 Sleep and Health
Chaput et al., (2016) conducted a systematic review to examine the relationships between objectively and subjectively measured sleep duration and various health indicators in children and youth aged 5–17 years. The results showed that longer sleep duration was associated with lower adiposity, better emotional regulation, academic achievement and quality of life/well-being and lower adiposity.

A systematic review conducted by Okely et al., (2019) showed significant associations between short sleep duration and adiposity gain. Significant associations were reported between longer sleep duration and reduced risk of adiposity. Longer sleep was related to better emotional regulation, while shorter sleep was associated with poorer emotional regulation. Longer sleep duration was associated with higher levels of systolic and diastolic blood pressure. There was a significant association between sleep duration and cardiometabolic biomarkers in children and youth.

2.5.4 Integration of Movement Behaviours and Health
A systematic review was conducted by Saunders et al., (2016) to investigate how combinations of sleep, SB and PA were associated with important health indicators (adiposity, cardiometabolic risk factors, cardiorespiratory or musculoskeletal fitness) in children and youth. The results showed that the combination of high PA/high sleep/low SB was associated with more favourable measures of adiposity and cardiometabolic health compared to low PA/low sleep/high SB.
Okely et al., (2022) conducted a systematic review that investigated combinations of PA, SB and sleep and their association with health indicators (5 to 17 years). The results showed that reallocation of time from sleep, SB or LPA to MVPA was associated with lower adiposity. No associations were reported for reallocations from SB to LPA. However, better cardiometabolic health was reported for the reallocation of time to VPA from LPA. Furthermore, better health-related quality of life was reported among children meeting all three guidelines compared with children meeting none, one or two of these guidelines; and for children meeting both the sleep and screen guidelines, compared to those not meeting these two guidelines.

Rollo et al., (2020) conducted a systematic review to synthesize evidence on the relationships between the composition of 24-h movement behaviours and health indicators across the lifespan. The results showed that children who meet all of the 24-h movement guideline recommendations generally had more favorable measures of adiposity; cardiometabolic health; fitness; perceived health, cognitive development, mental, social, and emotional health, and had healthier dietary patterns than those who did not meet the recommendations.

2.6 Associations Between Adiposity, Motor skills, and Bone Health in Children

The association between childhood obesity and gross motor skills in some populations is still unclear; does obesity lead to poor gross motor skills or does poor motor skills lead to unhealthy weight gain. Cheng et al (2016) conducted a study on 668 children (5 to 10
years) to clarify whether fine motor skills differ by children’s weight status. The results showed that higher weight status contributed to declines in motor skills and not the reverse and that overweight children had poorer gross motor skills than normal-weight children. Barnett et al. 2021 conducted a systematic review to compile mediation, longitudinal and experimental evidence in support of the role of motor competence in children’s PA and weight status. The results showed that childhood obesity negatively affects children's motor competence and it will be an obstacle to the development of motor competence especially for obese children at early years. The authors reported that the reverse (the effect of motor competence on childhood obesity) is harder to prove. A systematic review conducted by Barros and colleagues (2022) to assess the influence of overweight and/or obesity on motor performance and gross motor coordination in children and adolescents showed that children with higher BMI had declines in motor skills coordination. Another study conducted by Ružbarská et al., (2020) to investigate gross motor coordination comparing overweight and obese children to normal weight children showed that normal weight children had higher gross motor coordination than overweight and obese children.

The relationship between weight status and BMD remains unclear as some studies reported that overweight and obese children have a higher BMD compared with healthy-weight children (Leeuwen et al., 2017, Ferrer et al., 2021, Thamyongkit et al., 2020), while other studies showed that BMD decreased in obese children (Suárez et al., 2017, Goulding et al., 2000). Dolan and colleagues (2017) conducted a systematic review and meta-analysis to quantify correlations between absolute and relative adipose tissue mass and BMD in overweight and obese populations, the results showed that children’s and adolescent’s
adiposity is negatively correlated with BMD compared to those aged 25 years and over. However, none of these studies assessed the relationships between childhood obesity and gross motor skills or bone health were from Arabic countries. It is important to conduct studies on children from Arabic countries to address this gap in the literature as studies have shown that childhood obesity is chronic progressive disease (Ferrer et al., 2021) and it is associated with an increased risk of bone fractures (Lane et al., 2020). On top of that, childhood obesity may negatively impact children’s health and continue into adolescence (Ferrer et al., 2021) and adulthood (Simmonds et al., 2016).

Additionally, studies have shown that children's PA is one of the most effective strategies against osteoporosis (Gunter et al., 2012, Carter and Hinton., 2014) due to its important role in maximizing peak bone mass, which leads to make bones remain strong even after losing density later in life (Pitukcheewanont et al., 2010). In Arabic countries, including Saudi Arabia, osteoporosis is a neglected health priority (Sweileh et al., 2014). Therefore, conducting more studies on Arabic children is important to address this gap in the literature to better understand the relationship between childhood obesity and bone health.

2.7 Impact of COVID-19 on Movement Behaviours

Due to SARS-CoV-2 (COVID-19), many countries enforced restrictions that resulted in school-aged children not attending school. Studies have found that children’s PA levels declined, and leisure screen time and social media use, as well as sleeping time increased during the COVID-19 pandemic (Kovacs et al., 2021; Moore et al., 2020; Xiang et al.,
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Stockwell et al., (2021) conducted a systematic review that included six studies from Australia, Croatia, China, Canada, Latin America (Brazil, Chile, Colombia) and Europe (Italy and Spain) which investigated changes in PA and SB from before to during the COVID-19 lockdown. These studies reported a decrease in children’s PA levels, and five studies reported increases in SB. Two studies (Moore et al., 2021; Kovacs et al., 2022) examined changes in movement behaviours at two time points during COVID-19 and both reported decreases in PA levels and increases in SB at Time 2 compared to Time 1. However, none of these studies were from Arabic countries, indicating a noticeable gap in the literature.

2.8 Research gaps

Few studies have explored the associations between 24-hour movement behaviours (sleep, SB and PA) and health among school-aged children from Arabic countries. In particular, there are no known studies that have examined how changes in sleep, SB and PA may be associated with child’s health and development in Saudi Arabia. More studies to understand the role of 24-h movement behaviours and their influence on important health outcomes (obesity, motor development and bone health) are needed, particularly across the early years of primary school where there is little data on 24-h movement behaviours. This is especially true in Saudi Arabia where there has been a marked increase in childhood obesity and sedentary lifestyle (Aljassim and Jradi., 2021). In addition, it is likely there may be cultural differences in Arabic countries such as customs and traditions compared to Western countries, necessitate conducting more studies (Ourfali., 2015). Furthermore, global guidelines for PA and SB are based on evidence from high income countries.
(Pogrmilovic et al., 2018). More evidence from low- and middle-income countries, particularly from Arab-speaking countries are needed to address this inequality in the literature as more than 120 million children are living in these countries.
Chapter 3: Methodology

Chapter 2 provided an overview of the theoretical framework of this thesis and also identified gaps in the literature that formed the justification for this PhD research. To the researcher’s best knowledge, there has not been any study that examined the association between 24-hours movement behaviours and health among children in Saudi Arabia. Thus, conducting an in-depth investigation to address these gaps was of paramount importance.

The first component of this doctoral research was the systematic review. The purpose of this systematic review was to investigate the relationship between 24-hour movement behaviours and health indicators in school-aged children in Arabic countries. This systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO; Registration no. CRD42020143101). It was conducted and reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement for reporting systematic reviews and meta-analyses. Eligible participants included apparently healthy children aged 5 to 12 years old. Overweight and/or obese children were also included. To be included, studies had to be peer-reviewed, published, written in Arabic, English or French and reported parent proxy-reported or device-based measurement of PA or SB or sleep or their combination. Grey literature, student dissertations or conference abstracts were excluded. The main outcomes were adiposity, cardiometabolic biomarkers, fitness, behavioural conduct/pro-social behaviour, emotional regulation/psychological distress, cognition (academic achievement), quality of life and injuries. Secondary outcomes included bone density, motor skill development and
self-esteem. The review was limited to full manuscripts. There was no minimum sample size. All study designs were included.

In addition to the systematic review, it was planned to conducted a longitudinal study in February 2020, with data collection at two time points (baseline and 12-month follow-up) targeting children enrolled in their second year of primary school (grade 2; age 7 years old), from two urban (Riyadh city) and two rural schools (Al Jubaylah town) in Saudi Arabia. However, due to the Coronavirus (COVID-19) pandemic, all schools in Saudi Arabia were suspended in March 2020. As such, data collection procedures could not be completed. Therefore, the longitudinal study was changed to a cross-sectional study (Time 1 and Time 2) and the data were collected through a parent proxy-reported method (online questionnaire) as follows:

1- A cross-sectional survey: the aim of this study (Time 1) was to recruit a broadly nationally representative sample from all 13 regions of Saudi Arabia to investigate the impact of the COVID-19 outbreak on 24-h movement behaviours among Saudi children aged 6-12 years. The survey was promoted to parents through the Saudi Ministry of Education and on social media. Eligible parents who resided in Saudi Arabia with a child aged between 6-12 years were invited to complete the survey from October-November 2020. The study was approved by the University of Wollongong’s Human Research Ethics Committee (HE288/2021) and the Ministry of Education in Saudi Arabia (42640/2020) and
conducted according to the Helsinki Declaration for Human Studies. A total of 1,021 parents completed the survey.

2- A repeat cross-sectional study: the purpose of this study was to assess the impact of the COVID-19 social restrictions on movement behaviours of Saudi children at Time 2 (March, 2021) and to compare the results to our initial results from Time 1 (October, 2020). The methods of this study were identical to the previous study (Time 1). Approval was obtained from the Ministry of Education in Saudi Arabia (2639/2021) and the Human Research Ethics Committee at the University of Wollongong, Australia (HE288/2021).

3- A cross-sectional study: partial data that was obtained from baseline data collection of the longitudinal study were written up as a cross-sectional study. The aim of this study was to examine the associations between gross motor skills, adiposity and bone mineral density (BMD)- radius z- score among boys in Saudi Arabia. The data collection team started with boys’ schools first, and planned to collect the data from girls’ schools after this. However, due to schools’ suspension in Saudi Arabia, data collection could not be completed, hence only data from the boys’ schools were collected and analyzed in this study. Parents (or caregiver/legal guardian) with children enrolled in Grade 2 were approached and given consent forms to allow their children to participate in the study. Two hundred and eight students were invited to participate (n= 126 from the urban schools and n= 82 from the rural schools), and of these, forty-eight students provided parental approval (23%). Students were eligible to participate in the study if they were free from any form of physical or psychosocial illness/disability that could affect the results. Approvals were obtained from
the Ministry of Education in Saudi Arabia (Planning and Development Department, approval number 42640/2020) and the Human Research Ethics Committee at the University of Wollongong, Australia (HE 2019/288).

A full description of the methods, procedures and measures used in all studies included in this doctoral thesis are reported in detail in each of the papers.
Chapter 4: Systematic Review of the Relationships between 24-Hour Movement Behaviours and Health Indicators in School-Aged Children from Arab-Speaking Countries

Chapter 3 provided an overview of the methodological approach used in this thesis including the theoretical framework underpinning the thesis, as well as the studies design and methods. This chapter sought to address the following research question:

What are the relationships between movement behaviours (physical activity, sedentary behaviour, and sleep) and health indicators in school-aged children in Arab-Speaking countries?

This chapter has been published as:

4.1 Background

For years, movement guidelines for children and adolescents have concentrated on moderate- to vigorous-intensity physical activity (MVPA) (Tremblay et al., 2010). However, focusing on PA per se and omitting other movement behaviours, such as SB and sleep, has reduced our perception of how these daily movement behaviours interact to affect children’s health (Chaput et al., 2014). Hence, an approach that integrated all components of movement behaviours was required to review their combined influence on health and development (Chaput et al., 2014).

In 2016, the Canadian Society for Exercise Physiology released the world’s first integrated 24-hour movement guidelines for children and youth (5–17 years) (Tremblay et al., 2010) — a new concept describing the integration of PA, SB and sleep over the 24-hour period. This terminology is regarded as a shift in daily movement behaviour research and illustrates an evolution in PA guidelines (Tremblay et al., 2010). These guidelines were launched based on the results of four systematic reviews, investigating associations between PA, SB, sleep, and movement combinations, each one with health indicators (Tremblay et al., 2010). The authors found that children’s total PA was favourably associated with physical, psychological/social, and cognitive health indicators (Poitras et al., 2016). Higher levels of TV and screen time viewing were associated with unfavourable body composition, cardio-metabolic disease risk scores, hostile behavioural conduct/pro-social behaviour indicators, lower fitness and self-esteem in children (Carson et al., 2016). Shorter sleep duration was associated with poorer health outcomes (Chaput et al., 2016). Children who had higher levels of PA and sleep and less SB had more desirable measures of adiposity and
cardiometabolic health when compared with those with a combination of low PA and low sleep and high SB. Similarly, those with high PA and high sleep or high PA and low SB profiles demonstrated favourable health indicators compared with low PA and low sleep, or low PA and high SB profiles (Saunders et al., 2016).

In 2018, the literature on 24-hour movement guidelines was updated as part of the development of Australian 24-Hour Movement Guidelines for Children and Young People (Okely et al., 2019). These guidelines were launched as evidence-based guidelines to address movement behaviours observed over the whole day instead of focusing on these behaviours in isolation. Previous studies only captured specific movement behaviours (e.g., MVPA) during waking hours—which accounts for a small portion of children’s daily activity (<5%) in the 24-hour period; while sleep (~40%), SB (~40%) and LPA (~15%) make up nearly 95% of the day (Chaput et al., 2016). Furthermore, these guidelines were launched based on the results of systematic reviews that synthesized studies in English and French or other languages if able to be translated with Google translate, and found very few studies published in English or French from Arabic countries that examined the relationship between objectively measured SB, sleep and PA and health indicators in children aged 5–12 years. The search criteria did not elicit any studies published in Arabic from Arab countries.

Even though more than 140 million children live in the 22 Arabic countries (International Labour Organization., n.r), where there are high and increasing levels of childhood obesity
and sedentary behaviour (Sharara et al., 2018; Farrag et al., 2017), the lack of evidence from these countries confirms that research is needed to address this gap in the literature, to understand the role of 24-hour movement behaviours and its influence on important health outcomes (obesity, executive functions, motor development and bone health) across the years of primary school. Moreover, it is likely there may be cultural differences in 24-hour movement behaviours in Arabic countries compared to Western countries, necessitating a separate review. Therefore, the purpose of this systematic review was to investigate the relationship between 24-hour movement behaviours and health indicators in school-aged children in Arabic countries.

4.2 Methods

This systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO; Registration no. CRD42020143101). It was conducted and reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement for reporting systematic reviews and meta-analyses (Liberati et al., 2009). The protocol of this study was adopted partly from the systematic review performed by Saunders et al (Saunders et al., 2016).

4.2.1 Eligibility Criteria

Eligible participants included apparently healthy children aged 5 to 12 years old. Overweight and/or obese children were also included. Studies where the sample were aged above 12 years or below 5 years were included if the mean age was between 5–12 years. To
be included, studies had to be peer-reviewed, published, written in Arabic, English or French and reported self- or proxy-report or device-based measurement of PA or SB or sleep or their combination. Grey literature, student dissertations or conference abstracts were excluded. The main outcomes were adiposity, cardiometabolic biomarkers, fitness, behavioural conduct/pro-social behaviour, emotional regulation/psychological distress, cognition (academic achievement), quality of life and injuries. Secondary outcomes included bone density, motor skill development and self-esteem. The review was limited to full manuscripts. There was no minimum sample size. All study designs were included.

Twenty-four-hour movement behaviours incorporate sleep, SB and PA, which are independently defined as: Sleep: “a naturally recurring state of body and mind characterized by altered consciousness, relatively inhibited sensory activity, inhibition of nearly all voluntary muscles and reduced interactions with surroundings” (Chaput et al., 2017). SB: “any waking behaviour characterized by an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture” (Tremblay et al., 2017). PA: “any bodily movement produced by skeletal muscles that results in energy expenditure above the resting metabolic rate” (Caspersen et al., 1985).

4.2.2 Search Strategy

Six electronic databases were searched from January, 1990 to January, 2021 to identify relevant articles that were written in English or French: MEDLINE, EMBASE, SPORTdiscus, CINAHL, PsycINFO and Scopus. Eight electronic databases were searched
for Arabic studies: Saudi Digital Library, ArabBase, Human Index, KSUP, Pan-Arab Academic Journal, e-Marefa, Al Manhal eLibrary and Google Scholar. Search terms can be seen in the Appendix A.

4.2.3 Data Extraction

Studies were imported into Endnote X9 software (Thomson Reuters, San Francisco, CA, USA). After de-duplication, three authors (YA, ESS and KHC) screened titles and abstracts for relevant studies. Full-text copies of the eligible studies were assessed for final inclusion. Any disagreement between the three authors was resolved through a discussion and, when necessary, included a fourth author. The reference lists of all included studies were screened for additional studies not listed in the database search. Data were extracted for each study using an Excel spreadsheet; each study included article, author, study design, publication year, location, sample size, age, mean age, gender, outcomes and measures, study instrument and results (Table 4.1).

4.2.4 Quality Assessment

Three authors (YA, ESS and KHC) independently assessed the risk of bias (ROB) using the GRADE framework (Grading of Recommendations Assessment, Development, and Evaluation), which was also used to assess the quality of evidence for each health indicator. GRADE does not have an official tool for assessing ROB in observational studies but recommends the types of study characteristics to be evaluated (Guyatt et al 2011). The quality of evidence was assessed for each included study design based on selection bias,
attrition bias, detection bias, performance bias, and selective reporting bias. Quality of evidence scores were considered “low” for experimental and observational studies. Scores above 6/8 were considered as having low risk of bias.
<table>
<thead>
<tr>
<th>Literature Reference and Country</th>
<th>Study Design</th>
<th>Sample Size (% Female), Mean Age or Age Range (Years)</th>
<th>Type of Behaviour</th>
<th>Exposure and Assessment Instrument</th>
<th>Outcomes</th>
<th>Statistical Analysis &amp; Confounders (If Reported)</th>
<th>Main Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>AlHazzaa et al., (2019) Saudi Arabia [17]</td>
<td>Cross-sectional</td>
<td>1033 (51.1% female); mean age = 9.2 ± 1.7</td>
<td>Sleep</td>
<td>Sleep: Parent-proxy reported average sleep duration per night (&lt;9 h vs. ≥9 h).</td>
<td>Adiposity: body weight (kg) and BMI.</td>
<td>Logistic regression analysis. Confounders: body weight, age and gender.</td>
<td>No significant association between sleep duration and overweight or obesity status (aOR = 1.00; 95% CI 0.71 to 1.64; p = 0.717).</td>
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<tr>
<td>Al-Hazzaa, (2007) Saudi Arabia [18]</td>
<td>Cross-sectional</td>
<td>296 (100% male); mean age = 10.3 ± 1.3</td>
<td>PA</td>
<td>PA: Pedometer measured steps taken/day.</td>
<td>Adiposity: BMI, skinfold measurements (triceps and subcapular, body fat %, FMI and FFMI.</td>
<td>Pearson’s correlation. Confounders: age, gender, daily pedometer counts and total energy expenditure.</td>
<td>Significant negative associations between step counts/day and body fat % (r = −0.207; p = 0.006), BMI (r = −0.198; p = 0.007), FMI (r = −0.214; p = 0.004), but not with FFMI (r = −0.089; p = 0.231).</td>
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<tr>
<td>Hassan and Al-Kharusy, (2000) Oman [19]</td>
<td>Pilot study</td>
<td>109 (100% male); mean age = 9.68 ± 0.92</td>
<td>PA and SB</td>
<td>PA: Leisure time sport activities personal activity score (hours/week) assessed with 1.6-km run/walk. SB: Parent-proxy reported duration of TV watching and/or playing video or computer games.</td>
<td>Fitness: cardiorespiratory endurance. Adiposity: Log sum of 5 skinfold measurements (triceps, subcapular, suprailliac, abdominal and thigh).</td>
<td>Pearson correlation coefficients.</td>
<td>Personal activity score has a strong negative correlation with the time to complete the 1.6 km run/walk and the sum of skinfolds (r = −0.40, −0.42; p = 0.001). No significant associations between TV watching hours and fitness or fatness (p = n.r.).</td>
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<tr>
<td>Hadhood et al., (2016) Egypt [20]</td>
<td>Cross-sectional</td>
<td>711 (54.5% female); mean age = 10.36 ± 1.9</td>
<td>PA</td>
<td>PA: Parent-proxy reported weekly practice of physical exercise.</td>
<td>Adiposity: BMI and body weight.</td>
<td>Chi square test.</td>
<td>No significant association between physical exercise and overweight and/or obesity (p = 0.19).</td>
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<tr>
<td>Literature Reference and Country</td>
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<td>Statistical Analysis &amp; Confounders (If Reported)</td>
<td>Main Results</td>
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<td>Badawi et al., (2013) Egypt [21]</td>
<td>Cross-sectional</td>
<td>852 (50.2% female); mean age = 9.5 ± 1.8</td>
<td>PA and SB</td>
<td>PA: Parent-proxy reported practice of sports, and transportation to school. SB: Parent-proxy reported time spent watching TV.</td>
<td>Adiposity: BMI and body weight.</td>
<td>t-test, ANOVA test.</td>
<td>Significant association between low PA and BMI ($p = 0.001$). Significant association between SB and BMI ($p = &lt;0.001$).</td>
</tr>
<tr>
<td>Al-Lahham et al., (2019) Palestine [22]</td>
<td>Cross-sectional</td>
<td>1320 (48% female); mean age = 9.5 ± 1.5</td>
<td>PA and SB</td>
<td>PA: Parent-proxy reported daily PA (min), mode of transport to school. SB: Parent-proxy reported screen time (min).</td>
<td>Adiposity: BMI and body weight.</td>
<td>Chi square test. Confounders: transporting means to school, total screen time, total PA time and age.</td>
<td>Significant association between levels of PA (transportation means only) and BMI ($p = 0.031$). Screen time had no significant effect on BMI, however, it had a borderline effect ($p = 0.069$).</td>
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<tr>
<td>Jemaa et al., (2018) Tunisia [23]</td>
<td>Cross-sectional</td>
<td>40 (47.5% female); mean age = 9.34 ± 0.94</td>
<td>PA and SB</td>
<td>PA and SB: Accelerometer measures (LPA, MPA, VPA, MVPA); Subjective measures (mean PA Questionnaire for Older Children (PAQ-C) score and intensity classification).</td>
<td>Adiposity: % fat mass.</td>
<td>Pearson Correlation coefficient.</td>
<td>The average MVPA showed a negative significant correlation with body fat % ($r = -0.343$, $p = 0.030$). The score of PA determined by PAQ-C was not significantly correlated with the body fat % ($r = -0.227$, $p = 0.158$).</td>
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<td>Lafta and Kadhim, (2005) Iraq [24]</td>
<td>Case control</td>
<td>2084 (male and female); 7–13 (age range)</td>
<td>SB</td>
<td>SB: Parent proxy reported watching TV (&gt;3 h/day) via questionnaire.</td>
<td>Adiposity: BMI-defined overweight/obese.</td>
<td>Chi-square test. Confounders: age, birth rank, type of feeding during infancy, dietary pattern, pattern of PA and working after school time.</td>
<td>Watching TV (&gt;3 h/d) was a significant factor for overweight in 7–9 year males ($x^2 = 19.69$, 95% CI 1.79 to 4.97; $p &lt; 0.001$).</td>
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<td>Alam (2008) Saudi Arabia [25]</td>
<td>Cross-sectional</td>
<td>1072 (100% female); 8–12 (age range)</td>
<td>SB</td>
<td>SB: Parent proxy reported duration of</td>
<td>Adiposity: BMI and body weight.</td>
<td>Chi square test.</td>
<td>Watching TV (&gt;2 h/d) was significantly higher</td>
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<tr>
<td>Literature Reference and Country</td>
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<td>TV watching via questionnaire.</td>
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<td>Arora et al., (2018) Qatar [26]</td>
<td>Cross-sectional</td>
<td>264 (62.1% female); mean age = 9.0 ± 1.2</td>
<td>Sleep and SB</td>
<td>Sleep: weekday sleep duration. SB: SB time assessed with wrist Actigraphy/Technology Use Questionnaire.</td>
<td>Adiposity: BMI z-score, waist circumference, neck circumference, body fat % and fat mass.</td>
<td>Multiple linear regression. Confounders: objective estimate of sedentariness, dietary habits, age, sex, ethnicity and total technology use.</td>
<td>Significant associations between sleep duration and sleep insufficiency (&lt;8 h) and all indicators of obesity ($p &lt; 0.001$) except for neck circumference. Waist circumference (cm) yielded the largest effect: $\beta = -4.99$, $p &lt; 0.001$ (average sleep duration) and $\beta = 6.49$, $p &lt; 0.001$ (&lt;8 h). Sleep duration variation (night-to-night sleep duration variability) was not significantly associated with any outcome. Poor sleep efficiency was positively associated with body fat percentage ($\beta = 2.20$, $p = 0.028$).</td>
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<tr>
<td>Al-Kutbe et al., (2017) Saudi Arabia [27]</td>
<td>Cross-sectional</td>
<td>266 (100% female); 8–11 (age range)</td>
<td>PA and SB</td>
<td>PA and SB: Number of steps taken/day with accelerometer (WGT3X-weight (kg).)</td>
<td>Adiposity: body energy intake, daily total energy expenditure, body weight, age and family income.</td>
<td>Multiple linear regression. Confounders: daily energy intake, daily total energy expenditure, body weight, age and family income.</td>
<td>No association between the number of steps or the time spent in MVPA and body weight (Beta = 0.034; $p = 0.575$, 0.368).</td>
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<td>Al-Hazzaa and Alrasheedi, (2007) Saudi Arabia [28]</td>
<td>Cross-sectional</td>
<td>224 (51.3% female); mean age = 5.19 ± 0.85</td>
<td>PA and SB</td>
<td>PA: Pedometer measured steps taken/day, SB: Parent</td>
<td>Adiposity: BMI, skinfold measurements</td>
<td>One-way ANOVA and post hoc test (Scheffe). Confounders: body size obese and non-obese</td>
<td>No significant differences between</td>
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<tr>
<td>Literature Reference and Country</td>
<td>Study Design</td>
<td>Sample Size (% Female), Mean Age or Age Range (Years)</td>
<td>Type of Behaviour</td>
<td>Exposure and Assessment Instrument</td>
<td>Outcomes</td>
<td>Statistical Analysis &amp; Confounders (If Reported)</td>
<td>Main Results</td>
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<tr>
<td>Alqaderi et al., (2016) Kuwait [29]</td>
<td>Longitudinal study</td>
<td>8317 in 1st phase and 6316 in 2nd phase (61.4% female); 8–11 at visit 1, 10–12 at follow up (age range)</td>
<td>Sleep: Lifestyle habits interview reported daily sleep hours, TV and video game use.</td>
<td>proxy reported duration of TV watching/day via questionnaire.</td>
<td>(triceps, subscapular (sum and ratio), FM %, FFM %, FMI and FFMI)</td>
<td>for FMI and FFMI only.</td>
<td>children in steps counts/day ($p = 0.109$). No significant difference between active and inactive preschool children in any of the measured anthropometric and body composition variables (body weight ($p = 0.644$), BMI ($p = 0.961$), triceps skinfold ($p = 0.975$), subscapular skinfold ($p = 0.738$), sum of 2 skinfolds ($p = 0.854$), subscapular/triceps ratio ($p = 0.219$), fat % ($p = 0.985$), fat mass ($p = 0.664$), fat free mass ($p = 0.744$), FMI ($p = 0.850$), FFMI ($p = 0.896$). Obese children spent significantly more time watching TV ($197.5 \pm 89.3$ min/day) than their non-obese peers ($150.0\pm 60.9$ min/day) ($p = 0.001$).</td>
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<tr>
<td>Al-Ghamdi, (2013) Saudi Arabia [30]</td>
<td>Case control</td>
<td>397 (49.3% female); mean age = 11.4 (SD: n.r.)</td>
<td>PA and SB</td>
<td>Adiposity: BMI.</td>
<td>Chi-square test. Confounders: TV, VG</td>
<td>Watching TV (&gt;3 h/d), especially over the</td>
<td></td>
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</table>

*PA: Physical Activity; SB: Screen-Based Activity; TV: Television; VG: Video Games*
<table>
<thead>
<tr>
<th>Literature Reference and Country</th>
<th>Study Design</th>
<th>Sample Size (% Female), Mean Age or Age Range (Years)</th>
<th>Type of Behaviour</th>
<th>Exposure and Assessment Instrument</th>
<th>Outcomes</th>
<th>Statistical Analysis &amp; Confounders (If Reported)</th>
<th>Main Results</th>
</tr>
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<tbody>
<tr>
<td>Yousef et al., (2013) UAE [31]</td>
<td>Cross-sectional</td>
<td>197 (34% female); mean age = 8.7 ± 2.1</td>
<td>SB</td>
<td>Parent proxy reported watching TV (&gt;2 h/d).</td>
<td>Behavioral problems.</td>
<td>Chi square test, logistic regression. Confounders: birth order and number of siblings</td>
<td>Watching TV/video game &gt; 2 h/day was associated with withdrawn behavior (OR = 0.275; 95% CI 0.106 to 0.712; p = 0.008), attention problem (OR = 0.480; 95% CI 0.241 to 0.956; p = 0.037), externalizing problems (OR = 0.393; 95% CI 0.201 to 0.771; p = 0.007) and Child Behavior Checklist total score (OR = 0.441; 95% CI 0.229 to 0.848; p = 0.014).</td>
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<tr>
<td>Zayed and Kilani, (2014) Oman [32]</td>
<td>Cross-sectional</td>
<td>165 (100% female); 10–13 (age range)</td>
<td>PA</td>
<td>Number of occurrences and the duration of the practice of PA per week assessed with PA interview questionnaire.</td>
<td>Depression and low self-esteem.</td>
<td>One-way ANOVA and post hoc test (Scheffe).</td>
<td>Regular PA was significantly associated with improved self-esteem; differences were seen between those who never exercised and those who exercised regularly (mean square =</td>
</tr>
<tr>
<td>Literature Reference and Country</td>
<td>Study Design</td>
<td>Sample Size (% Female), Mean Age or Age Range (Years)</td>
<td>Type of Behaviour Exposure and Assessment Instrument</td>
<td>Outcomes</td>
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<td>358.257; F = 4.787; p = 0.10.</td>
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</table>

Abbreviations: SD = standard deviation; BMI = body mass index; FMI = fat mass index; FM = fat mass; FFM = fat-free mass; WC = waist circumference; PA = physical activity; MVPA = moderate-to-vigorous physical activity; SB = sedentary behavior; n.r. = not reported; OR = odds ratio; CI = confidence interval
4.3 Results

A total of 612 studies were eligible for inclusion. After title and abstract screening, 102 studies were assessed for full-text review. Of those, 86 were excluded for the following reasons: did not contain measures of PA or SB or sleep as an independent variable (n = 21); did not contain a measure of a health indicator and its association with PA or SB or sleep (n = 13); out of range for age (n = 37); dissertation (n = 7); studies conducted in non-Arab countries (n = 4); unavailability of the full article (n = 3); and lack of statistical data (n = 1). After all exclusions, 16 studies met the inclusion criteria (Figure 1). These studies provided results from 15,346 participants from 9 Arabic countries: Saudi Arabia, n = 6, United Arab Emirates, n = 1, Egypt, n = 2, Oman, n = 2, Kuwait, n = 1, Iraq, n = 1, Tunisia, n = 1, Qatar, n = 1 and Palestine, n = 1 (Table 4.1). Of all included studies, 12 were cross-sectional, two were case-control, one was longitudinal and one was a pilot study. These studies were conducted between 2000 and 2019 and included children between 3.4 and 14 years of age (mean age 5.19–11.4 y). Sample sizes ranged from 40 to 8317 participants. Out of the 16 included studies, 14 reported data on adiposity (Al-Hazzaa et al., 2019; Al-Hazzaa and Alrasheedi, 2007; Hassan and Al-Kharusy, 2000; Hadhood et al., 2016; Badawi et al., 2013; Al-Lahham et al., 2019; Jemaa et al., 2018; Lafta and Kadhim., 2005; Alam, 2008; Arora et al., 2018; Al-Kutbe et al., 2017; Al-Hazzaa, 2007; Al-Qaderi et al., 2016; Al-Ghamdi, 2013), one on behavioural problems (Yousef et al. 2013), one on depression and low self-esteem (Zayed and kilani, 2014), and one on fitness (Hassan and Al-Kharusy, 2000). Out of the sixteen studies included in this review, eight studies (50%) were classified as having a low ROB and eight as having a high ROB (50%). All studies had a reliable and/or valid tool to assess movement behaviours and health outcomes. The criteria
used to assess ROB can be seen in Table 2. It was not possible to conduct meta-analyses due to heterogeneity of the data, therefore, narrative syntheses were conducted.

Figure 4.1 PRISMA Flow Diagram.

Flow diagram for the identification, screening, eligibility, and inclusion of studies.


Table 4.2 Risk of bias for included studies

<table>
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</thead>
<tbody>
<tr>
<td>Clear criteria for those included and/or excluded?</td>
<td>Was the sample randomly selected?</td>
<td>Did an adequate proportion (at least 70%) of those consenting to participate in the study have complete data? (Incomplete follow-up; high loss to follow-up; missing data)</td>
<td>Did the study report the sources and details of the tool used in the study to assess the outcomes?</td>
<td>Was the tool used in the study to assess the outcomes reliable and/or valid?</td>
<td>Did the study report the sources and details of the measurement tool used in the study for movement behaviours?</td>
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0= No or unclear; 1= Yes. * Scores above 6/8 were considered as having low risk of bias.
### 4.3.1 Measurement of Movement Behaviours

Sleep was device-based measured by wrist actigraphy in one study (Arora et al., 2018) and subjectively measured using questionnaires in two studies (Al-Hazzaa et al., 2019; Al-Qaderi et al., 2016). SB was measured using screen time in eight studies (Al-Hazzaa and Alrasheedi., 2007; Yousef et al., 2013; Lafta and Kadhim, 2005; Alam, 2008; Hassan and Al-Kharusy, 2000; Al-Lahham et al., 2019; Al-Ghamdi, 2013; Badawi et al., 2013) and device-based measured using accelerometers in two studies (Jemaa et al., 2018; Al-Kutbe et al., 2017), and by both methods (wrist actigraphy and a questionnaire) in one study (Arora et al., 2018). PA was measured using an accelerometer in one study (Al-Kutbe et al., 2017) and by pedometer in two studies (Al-Hazzaa, 2007; Al-Hazzaa and Alrasheedi., 2007); whereas five studies measured it subjectively using parent proxy-reports (Zayed and kilani, 2014; Hadhood et al., 2016; Badawi et al., 2013; Al-Lahham et al., 2019, and Al-Ghamdi, 2013). Two studies combined both report and device-based methods: accelerometers plus questionnaire (Jemaa et al., 2018) and cardiorespiratory endurance (1.6 km run/walk) plus questionnaire (Hassan and Al-Kharusy, 2000).

### 4.3.2 Health Indicators

#### 4.3.2.1 Adiposity

As shown in Table 4.3, adiposity was assessed through the following indicators: BMI, body weight, % fat mass, BMI z-score, and waist circumference. It was reported in 14
studies, of which 10 were cross-sectional (Al-Hazzaa et al., 2019; Al-Hazzaa and Alrasheedi., 2007; Hadhood et al., 2016; Badawi et al., 2013; Al-Lahham et al., 2019; Jemaa et al., 2018; Alam, 2008; Arora et al., 2018; Al-Kutbe et al., 2017; and Al-Hazzaa, 2007), one was longitudinal (Al-Qaderi et al., 2016), two were case control (Al-Ghamdi., 2013 and Lafta and Kadhim., 2005) and one was a pilot study (Hassan and Al-Kharusy., 2000). Three studies investigated the relationship between sleep and adiposity outcomes. Of the three studies, two reported significant positive associations (Arora et al., 2018, Alqaderi et al., 2016), while one found no significant relationship (Al-Hazzaa et al., 2019). Nine studies examined the relationship between SB and adiposity outcomes. SB was positively associated with adiposity outcomes in six of the nine studies (Badawi et al., 2013, Arora et al., 2018, Alam, 2008, Al-Hazzaa and Alrasheedi., 2007, Lafta and Kadhim., 2005, Al-Ghamdi., 2013). The remaining three studies found no associations with adiposity outcomes (Al-Kutbe et al., 2017, Jemaa et al 2018, Al-Lahham et al., 2019). Nine studies examined adiposity relationship with PA. Of the nine studies, five found significant associations between adiposity outcomes and PA (Jemaa et al., 2018, Badawi et al., 2013, Al-Lahham et al., 2019, Al-Hazzaa., 2007, Hassan and Al-Kharusy., 2000) while four studies reported null associations (Al-Kutbe et al., 2017, Hadhoodet al., 2016, Al-Hazzaa and Alrasheedi., 2007, Al-Ghamdi., 2013).
4.3.2.2 Behavioural Problems

Behavioural problems were reported in only one cross-sectional study (Yousef et al., 2013) involving 197 subjects (mean age 8.7 ± 2.1), which studied the relationship between SB and behavioural problems in school-aged children. The results showed that watching TV/playing video games for more than two hours were positively associated with withdrawn behaviour, attention and externalizing problems.

4.3.2.3 Depression and Low Self-Esteem

One study examined the association between PA and depression and low self-esteem (Zayed and kilani, 2014); it involved 165 female subjects with age range of 10–13 years. The results indicated that regular PA (number of occurrences and the duration of the practice of PA per week) was significantly associated with improved self-esteem.

4.3.2.4 Fitness

One study assessed the relationship between SB and fitness and reported null associations (Hassan and Al-Kharusy., 2000). The results showed that the personal activity score had a strong negative correlation with the time to complete the 1.6 km run/walk and the sum of skinfolds. There were no significant associations between TV watching hours and fitness or fatness.
There were no studies investigating the associations with the rest of the primary outcomes, namely cardio metabolic biomarkers, psychological distress, cognition (academic achievement), quality of life, injuries, nor on secondary outcomes including bone density and motor skill development.
Table 4.3 Results of studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Outcomes</th>
<th>Exposure: Favorable Associations</th>
<th>Exposure: Null Associations</th>
<th>Summary</th>
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</table>
4.4 Discussion

This study systematically reviewed the relationships between the movement behaviours of physical activity, sedentary behaviours and sleep and health indicators among school-aged children in Arab-speaking countries. Most of the included studies in this review were cross-sectional (75%). The sample sizes ranged from 40 to 8317 participants. These studies reported mostly favourable and some null associations between PA, SB, and sleep and adiposity, behavioural problems, depression and low self-esteem and fitness outcomes. Low levels of PA and sleep and high SB were associated with higher levels of adiposity, behavioural problems, depression and low self-esteem.

Reasons for the small number of studies investigating these movement behaviours in school-aged children in Arab-speaking countries are that this field of research is still in its early stages of development in these countries, with most child health research focusing on more pressing issues such as infectious diseases. In addition, the unstable political environment in some of the Arab countries, has made conducting such research challenging (United Nations., 2020). The availability of funds is another reason that limited the number of these types of studies. For instance, in 2013, the gross domestic expenditure on research and development (GERD) in North America was $427 billion (28.9%) of the worldwide GERD ($1477.7 billion), while Arab countries collectively only spent $15.4 billion (1%) (UNESCO Science Report., 2016). Finally, although the Arabic databases were searched for relevant studies in this systematic review, there might be some studies that could not be identified due to the small number of Arabic databases available.
Existing Arabic studies assessed movement behaviours in isolation from each other. Of these studies, most used self- or proxy-report methods to assess PA, sleep and SB. On the other hand, the Canadian (Tremblay et al., 2016; Poitras et al., 2016; Chaput et al., 2016; Saunders et al., 2016) and the Australian 24-Hour Movement Guidelines (Okely et al., 2019) indicated that focusing on movement behaviours across the entire day is more important than focusing on movement behaviours in isolation. For example, a Canadian study investigating the health outcomes associated with meeting the 24-hour movement behaviour guidelines for children and youth showed that meeting none, one and two recommendations were associated with higher BMI z-score, waist circumference, behavioural strengths and difficulties scores and lower aerobic fitness in a gradient pattern (ptrend < 0.05), while meeting all the guidelines during a 24-hour period was associated with better health (Carson et al., 2017).

Furthermore, due to the prior emphasis on MVPA (Tremblay et al., 2010) and the common use of subjective assessments of PA (Poitras et al., 2016), no study in the present review examined different PA intensities such as light-intensity physical activity (LPA), although emerging evidence suggests that LPA may provide some important health benefits for children and adolescents (Chaput et al., 2014; Tremblay et al., 2016; Poitras et al., 2016). Moreover, children cannot participate in MVPA during all waking hours. Therefore, engaging in LPA (e.g., walking) is considered achievable and an easier way to reduce SB, that also provides health benefits (Chaput et al., 2014).
Few studies in this systematic review assessed the relationship between sleep and adiposity outcomes. A possible explanation of this gap is that sleep and SB are new areas of research in this region when compared to the PA field as the SB included studies were published between 2005–2019, while sleep studies were published in the last five years. Therefore, the Arab countries are urgently in need to conduct more studies that focus on sleep and SB to better understand their impact on school-aged children’s health.

Despite the importance of the weather and its impact on movement behaviours (Turrisi et al., 2021), no study in the present review assessed the relationship between 24-hour movement behaviours and climatic factors, although most of the Arab countries have a hot and dry climate (Elasha et al., 2010). Previous research in other countries indicates that children’s PA levels are affected by seasonal periods across the year and this varies between countries, with PA levels decreasing in specific climatic conditions such as winter, summer, sandstorms areas, humidity and rain (Al-Mohannadi and Moahhed., 2015; Tucker and Gilliland., 2007). Moreover, extreme weather conditions (high or low temperatures) increase SB (Edwards et al., 2015) and decrease sleep efficiency (Quante et al., 2019), therefore, conducting more studies investigating the association between the weather and movement behaviours and potential interventions may help children in these regions to meet movement behaviours recommendations.
4.4.1 Areas for Future Research

The lack of evidence from the Arab countries confirms that research is needed to address the inequality in the literature, especially with the high and still increasing levels of childhood obesity and SB in the 22 countries. Moreover, it is important to use different types of study designs (longitudinal and experimental) with larger sample sizes to better understand the role of 24-hour movement behaviours, to improve health outcomes. Studies included in this review focused on obesity, however, the field of PA is broader than this health outcome, therefore, it is recommended to conduct more studies reflecting on all movement behaviours across the 24-hour period.

4.4.2 Strengths and Limitations

To our knowledge, the present review is the first study investigating current research assessing the association between movement behaviours and health indicators in school-aged children in the Arab-speaking countries. A lack of Arabic databases is also a potential limitation. Meta-analyses were not possible to conduct due to heterogeneity of the data, therefore, narrative syntheses were conducted.

4.5 Conclusions

Most of the included studies reported favourable associations between movement behaviours and health outcomes. Low levels of PA and sleep and high SB were unfavourably associated with adiposity outcomes, behavioural problems, depression and low self-esteem. Further studies to address the inequality in the literature in the Arab-
speaking countries to understand the role of 24-hour movement behaviours and its positive influence on health outcomes across the early years of primary school are urgently needed. Based on the differences between societies and their needs, as well as environmental differences, it might be beneficial to also understand associations between weather conditions and children’s movement behaviours. Conducting more studies on different types/intensities of PA, SB and sleep for both boys and girls, and using different types of study designs (longitudinal and experimental) with larger sample sizes will improve the quality of future studies.

**Author Contributions:** Conceptualization, Y.A.A., E.S.-S., K.H.C., A.-M.P. and A.D.O.; methodology, Y.A.A., E.S.-S., K.H.C., A.-M.P. and A.D.O.; writing—original draft preparation, Y.A.A.; writing—review and editing, all authors. All authors have read and agreed to the published version of the manuscript.

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**Conflicts of Interest:** The authors declare that they have no competing interests.
Appendix A. Supplementary Information

“Physical activit*” OR “Movement behavi*” OR “physical inactivity” OR exercise OR “physical fitness” OR “energy expenditure” OR “sedentary*” OR sit* OR sitting OR lifestyle OR “television view*” OR “tv view*” OR “screen time” OR “electronic media” OR Sleep* OR Bedtime OR “Bed time” OR Nap* OR “Time on bed” OR “Night rest” Child* Arab* OR “Saudi Arabia” OR “United Arab Emirates” OR Bahrain OR Kuwait OR Oman OR Qatar OR Egypt OR Sudan OR Palestine OR Jordan OR Iraq OR Lebanon OR Syria OR Yemen OR Libya OR Morocco OR Tunisia OR Algeria OR Comoros OR Djibouti OR Mauritania OR Somalia.

Chapter 4 systematically reviewed the relationship between 24-h movement behaviours and health indicators in school-aged children in Arabic countries. The following chapter investigated the relationship between the impact of COVID-19 and school-aged Saudi children’s movement behaviours and how they were affected seven months after the WHO declared COVID-19 outbreak as a pandemic.

This chapter sought to address the following research question:

What is the impact of the COVID-19 outbreak on 24-h movement behaviours among Saudi children aged 6-12 years seven months after the WHO declared COVID-19 outbreak as a pandemic?

This chapter has been published as:

Abstract

Background: In March 2020, the World Health Organization (WHO) declared the coronavirus (COVID-19) outbreak as a pandemic. This led many governments to place restrictions on population movement to aid in pandemic control. These restrictions were expected to produce some type of impact on the daily lives of children and their families. The purpose of this study was to investigate the impact of COVID-19 on 24-hour movement behaviours among Saudi children aged 6-12 years, during the pandemic.

Methods: An online survey of Saudi parents (n=1021) was conducted between October 1 to November 11, 2020, to gather information about the impact of the COVID-19 outbreak on children’s 24-hour movement behaviours, parent and child factors that may be associated with movement behaviours, and perceived changes in children’s movement behaviours.

Results: Only 3.4% of Saudi children met all components of 24-hour movement guidelines. Compared with before COVID-19, children’s PA levels declined, they slept more, and their use of electronic screen devices significantly increased. The perceived changes in PA and SB were more unfavourable among girls than boys. Children of older parents, mothers, and those with lower education levels and lower monthly incomes were more likely to meet 24-hour movement guidelines.

Conclusion: The COVID-19 virus outbreak unfavourably affected Saudi children’s movement behaviours, more specifically, girls, which should be taken into account in future research. The results provide an insight into what has changed because of the COVID-19 restrictions and could be considered as part of the response strategies in Saudi Arabia.
Keywords: sleep, sedentary screen time, physical activity, child, covid-19.

5.1 Introduction

In March 2020, the World Health Organization (WHO) declared the coronavirus (COVID-19) outbreak as a pandemic (World Health Organization, 2020). Many governments placed restrictions on population movement to aid in pandemic control (Han et al., 2020). These restrictions likely impacted children’s physical activity (PA), sedentary behaviour (SB), and sleep. Children spent less time outdoors, which is associated with PA levels (Mitra et al., 2020). School closures, which affected more than 1.5 billion children globally (Bates et al., 2020), also reduced opportunities for PA (Guan et al., 2020).

COVID-19 restrictions affected children’s opportunities to meet 24-h movement guidelines (Guerrero et al., 2020). Studies have found that during COVID-19, most children did not meet PA or screen time (ST) guidelines, and there was an increase in ST, social media use and in sleep duration, compared with before COVID-19 (Moore et al., 2020, Kovacs et al., 2021, Xiang, Zhang, & Kuwahara, 2020, Al Hourani, Alkhatib, & Abdullah, 2021).

More than 140 million children live in the 22 Arabic countries, including Saudi Arabia (International Labour organization, n.d.). Across these countries, childhood obesity and sedentary behaviour levels are high and increasing (Sharara et al., 2018; Farrag et al., 2017). Further, there is a lack of evidence from these countries on the impact of COVID-19 on 24-hour movement behaviours and on important health outcomes (obesity, executive function, motor development and bone health) across the years of primary school.
Assessing the impact of COVID-19 during the elementary school years is important to monitor prevalence and changes in adequate motor development (Simons et al., 2008; Valentini, 2012).

To our knowledge, no studies have examined the impact of COVID-19 on movement behaviours among school-aged children in an Arabian country. By January 2022, the number of COVID-19 cases has exceeded 575,293 in Saudi Arabia with more than 8,892 deaths (Johns Hopkins University, 2021). These are the highest of any Arabian country and have prompted long-term government restrictions such as school closures and home quarantines. Schooling was conducted remotely for a long period of time (from March to November, 2020) and this, along with the other restrictions imposed, likely resulted in changes in the time spent in movement behaviours. Given the high and increasing rates of child obesity in Saudi Arabia, these changes due to COVID-19 could have significant impact on children’s health and development. Therefore, the purpose of this study was to investigate the impact of the COVID-19 outbreak on 24-h movement behaviours among Saudi children aged 6-12 years.

5.2 Methods

This online cross-sectional survey aimed to recruit children from all 13 regions of Saudi Arabia. The survey was promoted to parents through the Saudi Ministry of Education and on social media.
5.2.1 Data Collection

Eligible parents who resided in Saudi Arabia with a child aged between 6-12 years completed the survey between October 1 to November 11, 2020. The survey comprised: a) parental and child demographics, b) child’s movement behaviours, and c) changes in the child’s movement behaviours due to COVID-19. Questions used in the current analyses are shown in Table 1. An online parent information sheet and consent form were completed before commencing the survey. Parents with more than one child were asked to complete a separate questionnaire for each child.

5.2.2 Survey

The survey was based on a parental survey of young children’s movement behaviours during COVID-19 (Okely et al., 2021) and the Children and Youth Movement and Play Behaviours Survey (Moore et al., 2020). It was translated into Arabic and back-translated into English to ensure appropriateness of the questions. Approval was obtained from the Ministry of Education in Saudi Arabia (42640/2020) and the Human Research Ethics Committee at The University of Wollongong (HE288/2021).

Child and parent birth, sex, region of residence, parental education, and income were assessed using standard questions. PA duration was assessed through parents’ responses to questions related to their children’s time spent playing outside, doing activities to strengthen their muscles and bones, and being physically active for a total of ≥ 60 minutes per day in the past seven days. SB was assessed through questions related to child’s time
spent watching TV, using a smart phone, using social media, or playing video games (VG) for entertainment for < two hours while sitting or lying down, over the past 7 days. Sleep duration was assessed through questions related to children’s wake up and sleep times, while sleep quality was assessed based on a scale of 1 to 7. Parents reported the balance of their child’s overall healthy movement behaviours compared with before COVID-19 using a 5-point Likert scale ranging from “a lot worse” (score=1) to “a lot better” (score=5).
Table 5.1 Selected items used in the current analysis from the child survey during COVID-19 virus outbreak

<table>
<thead>
<tr>
<th>Survey Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MODULE OF CHILD AND CAREGIVER BACKGROUND</strong></td>
</tr>
<tr>
<td>Option</td>
</tr>
<tr>
<td>What is the date of birth of the child?</td>
</tr>
<tr>
<td>What is the (parent/caregivers) date of birth?</td>
</tr>
<tr>
<td>What is the sex of the child?</td>
</tr>
<tr>
<td>Parent/caregiver's relationship to the child participating in the study?</td>
</tr>
<tr>
<td>In which region in Saudi Arabia do you live?</td>
</tr>
<tr>
<td>What is the highest level of parental education?</td>
</tr>
<tr>
<td>What is your monthly income (SAR)?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CURRENT MOVEMENT BEHAVIOURS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over the past 7 days, on how many days was your child physically active for a total of at least 60 minutes per day?</td>
</tr>
<tr>
<td>During the past 7 days, on how many days did your child do activities to strengthen their muscles and bones?</td>
</tr>
<tr>
<td>Over the past 7 days, on how many days did your child watch TV/videos/Internet using a smart phone or tablet or play video or computer games for entertainment for less than two hours while sitting or lying down?</td>
</tr>
<tr>
<td>During the past 7 days, on average how much time per day did your child play outside?</td>
</tr>
<tr>
<td>How many hours of sleep does your child get in a typical 24-hours day (including naps)?</td>
</tr>
<tr>
<td>On a scale of 1 to 7, with the higher number indicating higher quality, how would you rate the quality of your child's sleep?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHANGE IN MOVEMENT BEHAVIOURS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compared to before the COVID-19 outbreak and related restrictions:</td>
</tr>
<tr>
<td>my child is doing physical activities or sport outside?</td>
</tr>
<tr>
<td>my child is doing physical activities or sport inside?</td>
</tr>
<tr>
<td>my child watches TV, movies, uses the computer for leisure or plays sedentary video games?</td>
</tr>
<tr>
<td>my child uses social media?</td>
</tr>
<tr>
<td>my child sleeps?</td>
</tr>
<tr>
<td>my child’s sleep quality is?</td>
</tr>
<tr>
<td>the balance of my child’s overall healthy movement behaviours (i.e., physical activity, sedentary behaviours, and sleep) are?</td>
</tr>
<tr>
<td>As a result of the COVID-19 outbreak and related restrictions:</td>
</tr>
<tr>
<td>is there an inside leisure activity or hobby that your child is doing a lot more now?</td>
</tr>
<tr>
<td>is there an outside leisure activity or hobby that your child is doing a lot more now?</td>
</tr>
<tr>
<td>has there been a decrease in your child’s health (e.g., existing condition worsened or new condition developed)?</td>
</tr>
<tr>
<td>- A lot better</td>
</tr>
</tbody>
</table>

| | |
| | |

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Children were classified as meeting 24-h movement guidelines (Bull et al., 2020; Okely et al., 2019; Tremblay et al., 2016) if they reported (per day): 1) ≥60 minutes of moderate- to vigorous-intensity physical activity (MVPA); 2) ≤ 2 hours of recreational ST; and 3) uninterrupted sleep for 9 to 11 hours per night (Bull et al., 2020; Okely et al., 2019; Tremblay et al., 2016).

5.2.2.1 Statistical analyses

Data were downloaded from Qualtrics and manually checked and cleaned in Excel. Statistical analyses were carried out using SPSS software (version 27, Chicago, IL, USA). Sample characteristics were summarized using the mean and standard deviation and percentage of children meeting 24-h movement guidelines. Pearson correlations were used to test associations between parent age and the time their child spent in PA, SB, using social media, and sleep. Differences between boys and girls in the time parents reported their child spent in PA, SB, using social media and sleep were assessed using independent samples t-tests. Spearman’s rank order correlations were used to assess associations between parent education level and income and time their child spent in PA, SB, using social media and sleep. A 95% confidence interval for the percentages were calculated by using the formula of proportion: 

\[ p \pm z_{1-\alpha} \sqrt{\frac{p(1-p)}{n}}. \]

A forest plot was used to present parent-reported changes in 24-h movement behaviours of the children. Statistical significance was set at \( p<0.05 \) for all analyses.
5.3 Results

5.3.1 Parent and child characteristics

A total of 1,021 parents completed the survey, of which 78.8% were Saudis. There were 2,799 parents who started, but did not complete, the questionnaire. Parents were required to complete all questions before they could submit the survey. Fifty-five percent of respondents were mothers with an average age of 41 (±9.2) years. The mean age of the children was 8.5 (±1.85) years. Sixty-percent of the study sample were girls. Parents’ average monthly income was $4,355. One-quarter of parents had a high school, 41% had a bachelor’s degree, and 14% had a master’s or PhD. Compared with the Saudi population, our sample of parents comprised more mothers and was slightly older. The monthly income and education levels were similar to the Saudi population (General Authority for Statistics, 2017, 2018, 2021) (Table 2).
Table 4.2 Characteristics of parents and children

<table>
<thead>
<tr>
<th>Parents demographic profile</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), M (SD)</td>
<td>40.5 (7.58)</td>
</tr>
<tr>
<td>Parent/caregiver's relationship to the child participating in the study, n (%)</td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td>565 (55.3)</td>
</tr>
<tr>
<td>Father</td>
<td>456 (44.7)</td>
</tr>
<tr>
<td>Nationality, n (%)</td>
<td></td>
</tr>
<tr>
<td>Saudi</td>
<td>804 (78.8)</td>
</tr>
<tr>
<td>Non-Saudi</td>
<td>217 (21.2)</td>
</tr>
<tr>
<td>Education level, n (%)</td>
<td></td>
</tr>
<tr>
<td>Primary school</td>
<td>81 (8)</td>
</tr>
<tr>
<td>High school</td>
<td>268 (26)</td>
</tr>
<tr>
<td>Diploma</td>
<td>117 (11.5)</td>
</tr>
<tr>
<td>Bachelor's degree</td>
<td>418 (41)</td>
</tr>
<tr>
<td>Master's degree</td>
<td>101 (9.9)</td>
</tr>
<tr>
<td>PhD</td>
<td>36 (3.6)</td>
</tr>
<tr>
<td>Living region, n (%)</td>
<td></td>
</tr>
<tr>
<td>Al-Riyadh</td>
<td>477 (46)</td>
</tr>
<tr>
<td>Al-Jouf</td>
<td>35 (3.5)</td>
</tr>
<tr>
<td>Al-Qassim</td>
<td>63 (6.2)</td>
</tr>
<tr>
<td>Al-Bahah</td>
<td>10 (1)</td>
</tr>
<tr>
<td>Asir</td>
<td>18 (1.8)</td>
</tr>
<tr>
<td>Eastern Province</td>
<td>131 (12.9)</td>
</tr>
<tr>
<td>Hail</td>
<td>28 (2.8)</td>
</tr>
<tr>
<td>Jazan</td>
<td>8 (0.8)</td>
</tr>
<tr>
<td>Mecca</td>
<td>79 (8)</td>
</tr>
<tr>
<td>Medina</td>
<td>112 (11)</td>
</tr>
<tr>
<td>Northern Borders</td>
<td>45 (4.5)</td>
</tr>
<tr>
<td>Najran</td>
<td>6 (0.6)</td>
</tr>
<tr>
<td>Tabuk</td>
<td>9 (0.9)</td>
</tr>
<tr>
<td>Monthly income (SAR), n (%)</td>
<td></td>
</tr>
<tr>
<td>0-3000</td>
<td>268 (26.3)</td>
</tr>
<tr>
<td>3000-7000</td>
<td>186 (18.3)</td>
</tr>
<tr>
<td>7000-10,000</td>
<td>112 (11)</td>
</tr>
<tr>
<td>10,000-15,000</td>
<td>237 (23.2)</td>
</tr>
<tr>
<td>15,000-20,000</td>
<td>155 (15)</td>
</tr>
<tr>
<td>20,000+</td>
<td>63 (6.2)</td>
</tr>
</tbody>
</table>

Child demographic profile

<table>
<thead>
<tr>
<th>Age (years), M (SD)</th>
<th>8.5 (1.85)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender, n (%)</td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>405 (39.7)</td>
</tr>
<tr>
<td>Girls</td>
<td>616 (0.3)</td>
</tr>
</tbody>
</table>
5.3.2 Children’s behaviours and changes in behaviours during COVID-19

Table 3 shows the movement behaviours in Saudi children during the COVID-19 outbreak compared with before COVID-19. Only 3.4% (95% CI 0.00, 9.5) of children met the PA, SB and sleep recommendations. Slightly more than half the children met the sleep recommendations (95% CI 52.9, 60.9), just over one third met the PA recommendations (95% CI 30.6, 40.8) and 15% met the SB recommendations (95% CI 9.5, 20.9). Boys’ SB was significantly higher than girls (5.6 (2.15) vs 5.3 (2.20) hours, \(p=0.013\)). For other behaviours, there were no significant differences between boys and girls. Sleep quality was reasonably high (average of 5.4 (2.26) points out of 7.0) and children played outside for 2.19 (1.34) h/day. Less boys than girls met the SB recommendations (13.1% (95% CI 4.0, 22.2) and 16.6% (95% CI 9.4, 23.8), respectively, \(p=0.002\)). During COVID-19, children spent less time in outdoor PA than before COVID-19 (average of 2.16 (1.22) points out of 5.0) (Figure 1). Watching TV or playing sedentary VG and using social media were higher than before COVID-19 (average of 3.28 (1.32) and 3.54 (1.48) points out of 5.0, respectively). Forty-percent of children had a screen device in their bedroom. Parents of girls perceived greater decreases in time spent in PA indoors (average of 2.85 points out of 5.0 (1.24)), \(p=0.037\), greater increases in watching TV or playing sedentary VG (average of 3.49 points out of 5.0 (1.26)), \(p<0.0001\) and greater increases in using social media (average of 4.08 points out of 5.0 (1.55)), \(p<0.0001\) than boys.
Table 5.3 Children’s movement behaviours during the COVID-19 virus outbreak and compared with before COVID-19

<table>
<thead>
<tr>
<th>Children’s movement behaviours, M (SD)</th>
<th>Total (n = 1021)</th>
<th>Girls (n = 616)</th>
<th>Boys (n = 405)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVPA ≥60 min (days/week)</td>
<td>4.52 (2.40)</td>
<td>4.51 (2.39)</td>
<td>4.54 (2.41)</td>
<td>0.865</td>
</tr>
<tr>
<td>Activities to strengthen muscles and bones (number of days)</td>
<td>2.59 (2.37)</td>
<td>2.52 (2.34)</td>
<td>2.70 (2.42)</td>
<td>0.258</td>
</tr>
<tr>
<td>Sleep duration (hours/day)</td>
<td>9.67 (2.26)</td>
<td>9.75 (2.42)</td>
<td>9.55 (1.99)</td>
<td>0.136</td>
</tr>
<tr>
<td>Sleep quality</td>
<td>5.40 (2.26)</td>
<td>5.38 (2.04)</td>
<td>5.42 (1.90)</td>
<td>0.697</td>
</tr>
<tr>
<td>Screen time ≤2h/day (number of days/week)</td>
<td>5.39 (2.19)</td>
<td>5.26 (2.20)</td>
<td>5.60 (2.15)</td>
<td>0.013</td>
</tr>
<tr>
<td>Playing outside (hours/day)</td>
<td>2.19 (1.34)</td>
<td>2.15 (1.32)</td>
<td>2.26 (1.35)</td>
<td>0.175</td>
</tr>
</tbody>
</table>

Proportion of children meeting the WHO/Australian/Canadian guidelines (%) and 95% CI

| MVPA                                                   | 35.7 (30.6, 40.8) | 32.6 (26.1, 39.1) | 35.1 (27.2, 43.0) | <0.0001 |
| Screen time                                            | 15.2 (9.5, 20.9)  | 16.6 (9.4, 23.8)  | 13.1 (4.0, 22.2)  | 0.002   |
| Sleep*                                                 | 56.9 (52.9, 60.9) | 55.6 (50.3, 60.9) | 58.8 (52.5, 65.1) | <0.0001 |
| 24h combined                                           | 3.4 (0.00, 9.5)   | 3.8 (0.00, 11.6)  | 2.7 (0.00, 12.3)  | <0.0001 |

Perceived change in child movement behaviours during COVID-19 outbreak, M (SD)

| Physical activity or sport outside                      | 2.16 (1.22)       | 2.19 (1.21)       | 2.11 (1.23)       | 0.293   |
| Physical activity or sport inside                       | 2.78 (1.24)       | 2.85 (1.24)       | 2.68 (1.23)       | 0.037   |
| Watching TV or playing sedentary video games            | 3.28 (1.32)       | 3.49 (1.26)       | 2.96 (1.35)       | <0.0001 |
| Using social media                                      | 3.54 (1.48)       | 4.08 (1.55)       | 2.72 (0.87)       | <0.0001 |
| Sleep duration                                          | 3.15 (.94)        | 3.17 (.96)        | 3.12 (.90)        | 0.411   |
| Sleep quality                                           | 3.06 (.94)        | 3.07 (.95)        | 3.04 (.92)        | 0.598   |
| Overall healthy movement behaviours                     | 2.78 (1.02)\(^1\) | 2.83 (1.01)       | 2.71 (1.04)       | 0.072   |

\(^1\) Parent-reported the balance of their children’s overall healthy movement behaviours (sleep, SST and PA) as compared to before the COVID-19 outbreak based on responses to a 5-point scale ranging from “a lot worse” to “a lot better”.

MVPA = moderate to vigorous physical activity; * = meeting sleep guideline (5–13 years). 95% CI = confidence interval.
Tables 4 and 5 show associations between parental demographic factors and children’s movement behaviours. Parent age showed a significant positive, but weak correlation with the time their child spent using social media ($r=0.08$, $p=0.007$) (Table 4). No other associations between parent age and children’s movement behaviours were significant.

The results of the Spearman correlations (Table 5) showed a significant, but weak negative correlation between parent education level and the time their child spent in outside PA/sport ($r=-0.06$, $p=0.04$), and significant, but weak negative correlations in the quality of
their child’s sleep ($r=-0.11, p<0.0001$) and in overall healthy movement behaviours ($r=-0.14, p<0.0001$). Further, parent education had a significant, but weak positive correlation with the time their child spent in indoor PA ($r=0.09, p=0.004$) and in watching TV or sedentary VG ($r=0.17, p<0.0001$).

Parent income level (Table 5) showed a significant negative correlation with the time their child spent in outside PA/sport ($r=-0.06, p=0.04$) and the quality of their child’s sleep ($r=-0.06, p=0.049$), and a significant, weak negative correlation in their child’s overall healthy movement behaviours ($r=-0.10, p<0.0001$). In addition, parent income level was positively correlated with the time their child spent in indoor PA ($r=0.09, p=0.005$) and in social media use ($r=0.08, p=0.009$), and a significant, weak positive correlation in watching TV or sedentary VG ($r=0.15, p<0.0001$). However, all of these correlations were weak.

**Table 5.4 Pearson correlation analysis between parent’s age and children’s movement behaviours**

<table>
<thead>
<tr>
<th>Parent's age</th>
<th>Outside PA/Sport</th>
<th>Inside PA/Sport</th>
<th>Watches TV/Sedentary VG</th>
<th>Social Media</th>
<th>Sleep Time</th>
<th>Sleep Quality</th>
<th>Overall Healthy Movement Behaviors</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.003</td>
<td>-0.01</td>
<td>-0.03</td>
<td>-0.03</td>
<td>0.08**</td>
<td>0.02</td>
<td>-0.02</td>
<td>-0.01</td>
</tr>
<tr>
<td>p=0.93</td>
<td>p=0.68</td>
<td>p=0.25</td>
<td>p=0.007</td>
<td>p=0.38</td>
<td>p=0.51</td>
<td>p=0.81</td>
<td></td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).
Table 5.5 Spearman correlation between parent education level and income and child’s movement behaviours

<table>
<thead>
<tr>
<th></th>
<th>Outside PA/Sport</th>
<th>Inside PA/Sport</th>
<th>Watches TV/Sedentary VG</th>
<th>Social Media</th>
<th>Sleep Time</th>
<th>Sleep Quality</th>
<th>Overall Healthy Movement Behaviours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent’s education</td>
<td>-0.06* p=0.04</td>
<td>0.09** p=0.004</td>
<td>0.17** p&lt;0.0001</td>
<td>0.05 p=0.09</td>
<td>-0.01 p=0.63</td>
<td>-0.11** p&lt;0.0001</td>
<td>-0.14** p&lt;0.0001</td>
</tr>
<tr>
<td>Parent’s income</td>
<td>-0.06* p=0.04</td>
<td>0.09** p=0.005</td>
<td>0.15** p&lt;0.0001</td>
<td>0.08** p=0.009</td>
<td>0.029 p=0.36</td>
<td>-0.06** p=0.049</td>
<td>-0.10** p&lt;0.0001</td>
</tr>
</tbody>
</table>

Parent’s education= Primary school, High school, Diploma, Bachelor’s degree, Master’s degree and PhD. Monthly income= 0-3000, 3000-7000, 7000-10,000, 10,000-15,000, 15,000-20,000, more than 20,000. * Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

5.3.3 New ways families are approaching movement behaviours

Almost half the parents (42%) indicated that their child was involved in more inside leisure activities during COVID-19 than before COVID-19. These included drawing (32.8%), playing VG (14.9%), playing soccer (13%), playing Intelligence Quotient games (11.1%), reading stories (6.1%) and yoga (4%). Few children were involved in sewing/crafts, house framing and dancing (3%). Only 17% of parents indicated their child was involved in more outside leisure activity during the COVID-19 outbreak. These included running (23.6%), hiking (17.2%), swimming (14.4%), visiting relatives (11.5%), martial arts (9.8%), photography (9.2%), biking (8.6%) and gymnastics (5.7%).

5.4 Discussion

This is the first known study from an Arabian country to provide data on school-aged children’s 24-h movement behaviour in relation to the COVID-19 pandemic. The results indicate that children spent less time being physically active or playing outdoor sports,
more time watching TV or playing sedentary VG and more time sleeping. Girls were less active, engaged in more social media and spent more time sleeping than boys.

Our findings are consistent with previous studies which have found that children’s PA levels declined, and leisure screen time and social media use, as well as sleeping time increased during the COVID-19 pandemic (Kovacs et al., 2021; Moore et al., 2020; Xiang et al., 2020). We found marked increases in time children spent in SB. It is likely these changes are a result of the government restrictions put in place due to COVID-19 which limited children’s opportunities to play outdoors (Kovacs et al., 2021). Moreover, as parents were working from home, they likely allowed their children to use electronic devices for longer periods of time to keep them busy as they worked (Okely et al., 2021). This finding may explain the significant increase in SB and the decrease in PA levels.

School closures may be another reason for the decrease in children’s PA levels. These may include not walking to school, which is associated with a decrease in PA levels (Faulkner, Stone, Buliung, Wong, & Mitra, 2013).

Most children in the study did not have consistent bedtimes or wake-up times during COVID-19. As our data showed, on average children had later bedtimes (after 11pm) than before COVID-19. This may be explained by their increased use of screen devices in the two hours before bedtime. However, the starting time for school was much later (15:30) during COVID when schooling was remotely delivered. This much later starting time likely explains the increase in sleep duration.
Moreover, 40% of children had a screen device in their bedroom and this practice has been shown to be associated with lower sleep duration and quality (Chaput et al., 2014). Further, parents may be inadvertently influencing the quality of their child’s sleep by using electronic devices during bedtime routines with their children (El Rafihi-Ferreira, Pires, & de Mattos Silvares, 2019; Fadzil, 2021). These sleep patterns are concerning as inconsistent wake-up and bedtimes and inadequate sleep time may affect children’s executive function (Warren, Riggs, & Pentz, 2016) academic performance (Sun, Ling, Zhu, Lee, & Li, 2019), and may have long-term health consequences including hypertension, dyslipidaemia, weight gain and metabolic syndrome (Medic, Wille, & Hemels, 2017). As children are influenced by the feelings and behaviours of their parents through observation and imitation (Bandura, 2008), modelling and encouraging these behaviours may help children meet the sleep and SB recommendations.

Internationally, a large proportion of children are not meeting the 24-h movement guidelines (Roman-Viñas et al., 2016). However, the percentage of Saudi children not meeting 24-h movement behaviour guidelines was much lower than international studies conducted before the COVID-19 pandemic. A multi-national survey of school-aged children to evaluate adherence to integrated movement behaviours in 12 countries showed that around 7% of children met the three recommendations (Roman-Viñas et al., 2016).

The current study found that girls were less active than boys during the COVID-19 pandemic. The decrease in PA levels can be partially explained by gender differences. For
example, it has been reported that boys are more active than girls and that the gender difference in total amounts of activity is mainly due to gender differences in the amounts of self-organized PA (Nielsen, Pfister, & Bo Andersen, 2011). However, it could also be due to lower levels of PE among girls in Saudi Arabia, as during COVID-19 PE classes (remotely) were only provided in boys’ schools.

Parents perceived a greater change in boys PA indoors compared to girls. This indicates that boys, in generally, were less active indoors than they were before COVID-19. On the other hand, screen based indoor activities were more unfavourable among girls than boys. This could be explained by the distribution of girls’ time during a 24-h period. For example, the time spent in one behaviour could have displaced the time spent in another behaviour. In this study, girls slept more, spent less time in both MVPA and playing outside compared to boys, therefore, they had more time for indoor activities. Moreover, the culture and tradition of the Saudi society may encourage girls to spend more time watching TV and using social media as they have fewer opportunities to participate in PA compared to boys.

Parental age was positively, albeit weakly, associated with the time their child spent using social media. This could be explained by the differences in contemporary parenting compared with previous generations. Parents today may find it more challenging to control their children’s use of social media. Moreover, as children are influenced by the feelings and behaviours of their parents (Bandura, 2008), the use of smartphones by parents could
encourage children to use screen devices more (Hoyos Cillero & Jago, 2011; Ozturk Eyimaya & Yalçin Irmak, 2021).

Parents’ education levels and income were weakly associated with children’s movement behaviours change perceived by parents. In this study, children’s sleep quality, the time spent in outdoor PA, and overall healthy movement behaviours decreased as parent education levels and income increased. Conversely, as parents’ education level increased, the time their child spent in indoor PA and in watching TV or VG increased. A possible explanation of these results is that educated and high-income parents could be more aware of the effects of COVID-19 outbreak on their children’s health. Therefore, they may have promoted their children’s indoor PA level to reduce the effects of COVID-19 outbreak.

As no Saudi 24-h movement guidelines currently exist, we recommend the development of such guidelines for children in Saudi Arabia (Parrish et al., 2020). Furthermore, we suggest three strategies that may help Saudi children meet the 24-h movement guidelines during the COVID-19 outbreak. First, we recommend the Ministry of Education consider providing high-quality online PE lessons. Kovacs and colleagues found that 57% of children who were active during online PE lessons also met the WHO PA recommendation (Kovacs et al., 2021). Also, when children revert to normal school days after the COVID-19 pandemic, PE lessons should include a focus on time spent in PA during class for boys and girls to recover the decrease level of PA during COVID-19 (Štveráková et al., 2021). This is especially important for girls, for who PE classes were only introduced in 2018, as a part of
the Kingdom’s vision (The Quality-of-Life Program). Second, parents should encourage their children to follow a structured daily schedule, which has been shown to be associated with higher odds of meeting ST and PA recommendations during the COVID-19 (Kovacs et al., 2021). Finally, parents should encourage their children to participate in outdoor play to improve their PA levels (Kovacs et al., 2021; Tu et al., 2017). Parents should be encouraged to be more active with their children as they are a role model for their children (Brouwer et al., 2018).

To our knowledge, this is the first study in Saudi Arabia that investigated the cross-sectional impact of COVID-19 on movement behaviours among Saudi children (aged 6-12 years). A limitation of the study is that movement behaviours were subjectively captured via an online parent questionnaire, however it was not possible to collect data using device-based measures on a large sample due to the COVID-19 pandemic. Using 24-h movement guidelines from other countries is another potential limitation, highlighting the need to develop country-specific guidelines for Saudi Arabia. Further, just over 70% of parents who started the questionnaire did not complete it and it is not known if these parents differed from those who did complete the questionnaire.

5.5 Conclusions

The results of the current study demonstrate the impact of the COVID-19 pandemic on Saudi children’s 24-h movement behaviours, prompting recommendations to parents, schools and education decision-makers, to reduce the effect of the COVID-19 outbreak and
future pandemics on children’s movement behaviours. Stakeholders are strongly encouraged to promote healthy levels of PA, SB and sleep, by encouraging outdoor PA (where possible), minimizing children’s use of screen devices when sedentary, educating parents about the importance of meeting movement guidelines by introducing national 24-h guidelines or promoting the WHO guidelines.

**Key Messages:**

- This research examined the impact of COVID-19 on 24-hour movement behaviours among Saudi children during the COVID-19 pandemic.
- Children’s PA levels declined, they slept more, and their use of electronic screen devices significantly increased.
- The perceived changes in PA and SB were more unfavourable among girls than boys.
- The Ministry of Education, parents and children need to work together to address the adverse impact of COVID-19 on Saudi children's movement behaviours.

**Data availability statement**

The data that support the findings of this study are available from the corresponding author upon reasonable request.
Chapter 6: 24-hour movement behaviours and COVID-19 among children in the Kingdom of Saudi Arabia: A repeat cross-sectional study

Chapter 5 investigated the relationship between the COVID-19 and school-aged Saudi children’s movement behaviours and how they had been affected seven months after the WHO declared COVID-19 outbreak as a pandemic. The following chapter reinvestigated the relationship between the COVID-19 and school-aged Saudi children’s movement behaviours 12 months after the WHO declared COVID-19 outbreak as a pandemic.

This chapter sought to address the following research question:

What is the impact of the COVID-19 outbreak on 24-h movement behaviours among Saudi children aged 6-12, 12 months after the WHO declared COVID-19 outbreak as a pandemic?

This chapter has been published as:

Abstract

This study investigated how children’s 24-hour (24-h) movement behaviours were affected by SARS-CoV-2 (COVID-19) in the Kingdom of Saudi Arabia. Previous research examined 24-h movement behaviours in Saudi Arabia 7 months after the World Health Organization (WHO) declared COVID-19 a global pandemic. This repeat cross-sectional study examined changes in 24-h movement behaviours 12 months after the WHO declaration. Time 2 survey repeated five months (1 March – 15 May 2021) after Time 1 survey (1 October – 11 November 2020). The survey was distributed to parents of children aged 6-12 years across Saudi Arabia via an online survey. Children were classified as meeting 24-h movement guidelines if they reported uninterrupted sleep for 9-11 hours per night, ≤2 hours of recreational sedentary screen time (RST) per day and ≥60 minutes of moderate-to vigorous-intensity physical activity (MVPA) per day. A total of 1,045 parents from all regions of Saudi Arabia responded (42.4%). Only 1.8% of children met all components of the guidelines, compared to 3.4% in Time 1. In the present study, girls spent more days per week in MVPA ≥60 minutes duration than boys (3.0 vs 2.6; p=0.025), while boys had spent more days per week engaged in activities that strengthened muscle and bone than girls (3.0 vs 2.8; p=0.019). Healthy levels of physical activity (PA), sedentary behaviour (SB) and sleep further declined in Saudi children five months after the Time 1 survey. These challenges require urgent intervention to ensure children’s movement behaviours improve as Saudi Arabia moves out of the COVID-19 pandemic.

Keywords: sleep; sedentary behaviour; physical activity; children; COVID-19.
6.1 Introduction

One of the health consequences of lockdowns associated with the SARS-CoV-2 (COVID-19) pandemic has been on the movement behaviours of school-aged children (López-Gil et al., 2021). In this paper, movement behaviours refer to physical activity (PA), sedentary behaviour (SB) – including screen time (ST) and sleep (Okely et al., 2022). Globally, many countries enforced restrictions that resulted in school-aged children not attending school, with classes delivered remotely (ECLAC-UNESCO., 2020). A systematic review (Stockwell et al., 2021) that included six studies from Australia, Croatia, China, Canada, Latin America (Brazil, Chile, Colombia) and Europe (Italy and Spain) investigated changes in PA and SB from before to during the COVID-19 lockdown. These studies reported a decrease in children’s PA levels, and five studies reported increases in SB. A subsequent study from Spain showed similar results (Medrano et al., 2021).

We conducted an initial study in the Kingdom of Saudi Arabia (Alanazi et al., 2022) which investigated the impact of COVID-19 on children’s 24-hour (24-h) movement behaviours early in the pandemic, using the World Health Organization (WHO), Australian and Canadian guidelines (as no Saudi 24-h movement guidelines currently exist) (Okely et al., 2022, Tremblay et al., 2016, Bull et al., 2020). We found that children’s PA levels declined, they slept more, and their use of electronic screen devices significantly increased. To date, only two studies have examined the changes in movement behaviours at two time points during COVID-19 and both reported decreases in PA levels and increases in SB at Time 2 compared to Time 1(Moore et al., 2021, Kovacs et al., 2022). Neither of these two studies were from the Eastern Mediterranean region, a region where there has been a noticeable gap in the literature. We hypothesize
that COVID-19 has a negative impact on Saudi children’s 24-h movement behaviours. The purpose of this study was to investigate the five-months changes in movement behaviours among children in Saudi Arabia, at a time when there were governmental restrictions.

**Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COVID-19</td>
<td>SARS-CoV-2</td>
</tr>
<tr>
<td>M</td>
<td>Mean</td>
</tr>
<tr>
<td>MVPA</td>
<td>Moderate-to Vigorous-Intensity Physical Activity</td>
</tr>
<tr>
<td>N</td>
<td>Number</td>
</tr>
<tr>
<td>P</td>
<td>Probability</td>
</tr>
<tr>
<td>PA</td>
<td>Physical Activity</td>
</tr>
<tr>
<td>RST</td>
<td>Recreational Sedentary Screen Time</td>
</tr>
<tr>
<td>SAR</td>
<td>Saudi Riyal</td>
</tr>
<tr>
<td>SB</td>
<td>Sedentary Behaviour</td>
</tr>
<tr>
<td>SD</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>SPSS</td>
<td>Statistical Package for the Social Sciences</td>
</tr>
<tr>
<td>ST</td>
<td>Screen Time</td>
</tr>
<tr>
<td>TV</td>
<td>Television</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
<tr>
<td>VG</td>
<td>Video Games</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>PE</td>
<td>Physical Education</td>
</tr>
<tr>
<td>24-h</td>
<td>24-hour</td>
</tr>
</tbody>
</table>
6.2 Methods

The methods of this study were identical to those reported in the previous (Time 1) study (Alanazi et al., 2022). This repeat cross-sectional study (Time 2) collected data between March and May, 2021. The survey was promoted across all 13 regions of Saudi Arabia through the Education Policy Research Centre at the Saudi Ministry of Education in Riyadh to all elementary schools as well as on social media (Twitter and WhatsApp). Approval was obtained from the Ministry of Education in Saudi Arabia (2639/2021) and the Human Research Ethics Committee at the University of Wollongong, Australia (HE288/2021).

For the survey to be submitted parents were required to complete all of the survey questions. The Time 1 survey (Alanazi et al., 2022) was conducted between October and November 2020 in autumn (temperatures ranged between 24°C (75°F) and +40°C (104°F) in September, and between 14°C (57°F) and +27°C (81°F) in November), and during school days (remotely delivered classes online), with governmental restrictions due to COVID-19, which resulted in schools suspended. The Time 2 survey was conducted during spring (temperature ranged from +14.5°C (58°F) to +28°C (83°F) in March, and from +24°C (75°F) to +39°C (102°F) in May) and during school days (remotely delivered classes) with similar governmental restrictions. During Time 2, there was a 20-day school holiday period. During remotely delivered classes period in Time 1 and Time 2, there were no active physical education (PE) classes online. Schooling started at 3:30 pm (remotely) and ending at 7pm.
6.2.1 Data collection

Parents of healthy children aged between 6 and 12 years and were living in Saudi Arabia were invited to participate in the study. A link to an online survey in Arabic, using the Qualtrics platform, was provided to parents. The survey was designed to take approximately 10 minutes to complete and consisted of three parts: parental and child demographics, child’s current movement behaviours, and changes in child’s movement behaviours as a result of COVID-19. Before answering the survey, parents were provided with an online parent information sheet and consent form as the first page of the survey. Parents were asked to complete a separate survey if they had more than one child (aged 6-12 years).

6.2.2 Survey

The survey was based on two previous surveys: parental survey of young children’s movement during COVID-19 (Okely et al., 2021) and the Children and Youth Movement and Play Behaviours Survey (Moore et al., 2020). It was translated into Arabic and back translated into English to ensure appropriateness of the questions.

Child and parent data including birth, sex, region of residence, parental education, and income were assessed using standard questions (Okely et al., 2021). Children’s sleep duration, PA duration and SB were proxy-reported by parents. Using a 5-point Likert scale ranging from “a lot worse” (score=1) to “a lot better” (score=5), parents reported the balance of their children’s overall healthy movement behaviours compared to before the COVID-19 outbreak.
Sleep quality was measured on a scale of 1 to 7, with 1 indicating “very difficult to settle to sleep” and 7 indicating “settles and drifts off to sleep within a few minutes”. Children were classified as meeting the recommendation of the WHO, Australian and Canadian guidelines, if they reported uninterrupted sleep for 9 to 11 hours per night, meeting the SB recommendation if they reported no more than 2 hours of recreational sedentary screen time (RST) per day and meeting the PA recommendation if they reported ≥60 minutes of moderate-to vigorous-intensity physical activity (MVPA) per day (Okely et al., 2022, Tremblay et al., 2016, Bull et al., 2020). Selected items that were used in the current study are listed in Appendix A (the full survey is available in Appendix B).

6.2.3 Statistical analyses

Statistical analyses were carried out in Statistical Package for the Social Sciences (SPSS) (version 28, Chicago, IL, USA). Sample characteristics were summarized using means and standard deviations (SD) for all variables and percentage of children meeting the 24-h movement guidelines (Okely et al., 2022, Tremblay et al., 2016, Bull et al., 2020). Gender differences in time spent in PA, SB, and sleep and in using social media were analysed using an independent samples t-test. A forest plot was used to present the parent-reported changes in 24-h movement behaviours of the children during the first (October to November, 2020) and second time (March to May, 2021) of the COVID-19 pandemic. Statistical significance was set at p<0.05 for all analyses.
6.3 Results

6.3.1 Parents and children characteristics
Table 1 shows the demographics of the parents who responded to the survey. Of those parents who expressed an interest (n=2464), 1,045 completed the survey (42.4%). Of these, 88.6% were Saudis and 11.4% were non-Saudis. The respondents included 587 mothers (56.2%) with an average age of 42.6 (±9.2) years. The mean age of the children was 8.7 (±1.9) years. Fifty-one per cent of the study sample were girls. Parents’ average monthly income was $4,355. Most parents had bachelor’s degree (47%). Just under half of the sample of children were boys (49.2%). Compared with the Saudi population, our sample comprised more females, was slightly older, and had a similar monthly income and education level (General Authority for Statistics, 2017, 2017, 2018).

6.3.2 Children’s current behaviours and changes in behaviours during COVID-19
Table 2 reports time spent in movement behaviours and the proportion of children meeting the guidelines during COVID-19 outbreak in Saudi Arabia. Girls spent significantly more days/week in MVPA ≥60 minutes than boys ($p=0.025$); however, boys spent more days in activities that strengthened their muscles and bones ($p=0.019$). For the remainder of the behaviours (sleep duration and quality; ST and playing outside), there were no significant differences between boys and girls.

Regarding the proportion of children meeting the 24-h movement guidelines (Okely et al., 2022, Tremblay et al., 2016, Bull et al., 2020), only 1.8% met all three of the 24-h movement behaviour recommendations. When examining the behaviours separately, 26.8% of children met the sleep guidelines, 18.2% met the PA recommendation and 12.8% met the SB recommendation. The proportion of girls who met the PA and RST
recommendations were significantly higher than boys ($p<0.0001, 0.001$, respectively). However, more boys met the sleep recommendation ($p=0.048$).

**Table 6.1 Parent and child characteristics at Time 2 ($n=1,045$).** ($M =$ Mean, $SD =$ Standard Deviation, SAR = Saudi Riyal, $n =$ number).

<table>
<thead>
<tr>
<th>Study sample</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), M (SD)</td>
<td>42.6 (9.2)</td>
</tr>
<tr>
<td>Parent/caregiver's relationship to the child participating in the study, n (%)</td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td>587 (56.2)</td>
</tr>
<tr>
<td>Father</td>
<td>458 (43.8)</td>
</tr>
<tr>
<td>Nationality, n (%)</td>
<td></td>
</tr>
<tr>
<td>Saudi</td>
<td>926 (88.6)</td>
</tr>
<tr>
<td>Non-Saudi</td>
<td>119 (11.4)</td>
</tr>
<tr>
<td>Education level, n (%)</td>
<td></td>
</tr>
<tr>
<td>Primary school</td>
<td>43 (4.1)</td>
</tr>
<tr>
<td>High school</td>
<td>220 (21)</td>
</tr>
<tr>
<td>Diploma</td>
<td>97 (9.4)</td>
</tr>
<tr>
<td>Bachelor's degree</td>
<td>491 (47)</td>
</tr>
<tr>
<td>Master's degree</td>
<td>133 (12.7)</td>
</tr>
<tr>
<td>PhD</td>
<td>61 (5.8)</td>
</tr>
<tr>
<td>Living region, n (%)</td>
<td></td>
</tr>
<tr>
<td>Al-Riyadh</td>
<td>334 (32)</td>
</tr>
<tr>
<td>Al-Jouf</td>
<td>39 (3.7)</td>
</tr>
<tr>
<td>Al-Qassim</td>
<td>36 (3.4)</td>
</tr>
<tr>
<td>Al-Bahah</td>
<td>16 (1.7)</td>
</tr>
<tr>
<td>Asir</td>
<td>44 (4.2)</td>
</tr>
<tr>
<td>Eastern Province</td>
<td>124 (11.8)</td>
</tr>
<tr>
<td>Hail</td>
<td>26 (2.4)</td>
</tr>
<tr>
<td>Jazan</td>
<td>14 (1.3)</td>
</tr>
<tr>
<td>Mecca</td>
<td>308 (29.6)</td>
</tr>
<tr>
<td>Medina</td>
<td>39 (3.7)</td>
</tr>
<tr>
<td>Northern Borders</td>
<td>21 (2)</td>
</tr>
<tr>
<td>Najran</td>
<td>13 (1.2)</td>
</tr>
<tr>
<td>Tabuk</td>
<td>31 (3)</td>
</tr>
<tr>
<td>Monthly income (SAR), n (%)</td>
<td></td>
</tr>
<tr>
<td>0-3000</td>
<td>137 (13.3)</td>
</tr>
<tr>
<td>3000-7000</td>
<td>107 (10.2)</td>
</tr>
<tr>
<td>7000-10,000</td>
<td>135 (12.9)</td>
</tr>
<tr>
<td>10,000-15,000</td>
<td>320 (30.6)</td>
</tr>
<tr>
<td>15,000-20,000</td>
<td>238 (22.7)</td>
</tr>
<tr>
<td>20,000+</td>
<td>108 (10.3)</td>
</tr>
</tbody>
</table>

**Child demographic profile**

| Age (years), M (SD) | 8.7 (1.9) |
| Gender, n (%) |  |
| Boys | 514 (49.2) |
| Girls | 531 (50.8) |
Table 2 also reported parent perceived changes in their child’s movement behaviours during the COVID-19 outbreak. Children’s perceived combined indoor PA and sport significantly decreased compared to before the COVID-19 outbreak (an average of 2.61 points (a 5-point Likert scale ranging from “a lot worse” (score=1) to “a lot better” (score=5)) out of 5.0), ($p=0.037$). Boys were perceived to have significantly more sleeping time than girls (average of 3.93 vs 3.79 points out of 5.0), ($p=0.041$). Notably, 70% of children had an electronic screen device in their bedroom.

6.3.3 New ways families are approaching movement behaviours
Parents were asked if there was an inside leisure activity or hobby that their child was doing a lot more during the COVID-19 outbreak, and 22.8% of parents answered yes. These included drawing (25%), playing soccer (18.2%), playing Intelligence Quotient games (21.3%), playing ping pong (11%), playing chess (9.2%), playing in the backyard (8.2%), doing handcrafts (2.9%), reading (2.1%), and learning new languages (2.1%). Only 11% of parents indicated their child was involved in a lot more outside leisure activity or hobbies during the COVID-19 outbreak. These included playing soccer (29%), hiking (26.7%), running or walking (24.2%), martial arts (6.1%), biking (4.9%), playing archery (4.6%), and swimming (4.5%).

6.3.4 Comparison between Time 1 and Time 2 during the COVID-19 outbreak
Table 2 compared the results from Time 1 to Time 2 in terms of how movement behaviours have been affected by COVID-19 among Saudi children. For the entire sample, there were significant differences between Time 1 and Time 2, for all considered variables ($p<0.0001$), except for sleep quality. These differences showed decreased in children’s MVPA and playing outside, and increased in activities to
strengthen muscles and bones, ST and sleep duration. The analysis of the results for girls and boys separately were in line with the total sample results, with the exception of activities to strengthen muscles and bones, where there was not a significant change for boys. The proportion of total sample (boys and girls) meeting the MVPA, RST, sleep and the 24-h combined guidelines significantly decreased ($p<0.0001$) in Time 2 compared to Time 1.

As seen in Figure 1, parents perceived changes in children’s movement behaviours from Time 1 to Time 2 significantly decreased ($p<0.0001$), including children’s outside and inside PA and sport and sleep quality, while sleep duration, watching television (TV) or playing sedentary video games, and the use of social media significantly increased ($p<0.0001$).

6.4 Discussion

The findings of this study confirmed our hypothesis that COVID-19 has a negative impact on Saudi children’s 24-h movement behaviours. This repeat cross-sectional study assessed the impact of COVID-19 restrictions on movement behaviours of Saudi children during the period March to May, 2021, compared with our initial results from October to November, 2020. The results showed that only 1.8% of children (1.6% of boys and 2.1% of girls) met all recommendations of the 24-h movement guidelines. Twenty-seven percent of children met the sleep recommendation, 18.2% met the PA recommendation and 12.8% met the SB recommendation compared to Time 1 where 57% met the sleep recommendation, 35.7% met the PA recommendation and 15.2% met the SB recommendation.
The results of the comparison between Time 1 and Time 2 showed that COVID-19 had a significant impact and affected children’s movement behaviours negatively within a short period of time. The percentage of children meeting the combined 24-h movement guidelines in Time 2 decreased significantly when compared to Time 1. Our findings are consistent with the results of a Canadian study (Moore et al., 2021) which reported a decreased in the proportion of children who met movement guidelines in Time 2 (4.5%) compared to Time 1 (4.8%) due to the impact of COVID-19. However, our results showed that the percentage of girls who met movement guidelines were higher than in boys (2.1% vs 1.6%). Our findings are also consistent with the results from nine European countries (Kovacs et al., 2022) which showed that 9.3% of children met the WHO PA recommendation in Time 2 compared to 19% in Time 1, while the proportion of children who did not meet RST recommendation was high in both phases (60.6% (weekdays) and 47.7% (weekend days) in Time 2 compared to 69.5% (weekdays) and 64% (weekend days) in Time 1).

These results were somewhat expected as tighter government restrictions were introduced over the course of the COVID-19 pandemic which further limited children’s opportunities to play outdoors, which has been shown to be positively associated with children’s PA levels (Lee et al., 2021).

School closures could be another reason for the decrease in children’s PA levels, as children, in general, were more physically active at school pre-COVID-19 (Moore et al., 2021). A study involving 785 Canadian children (10.57 ± 0.7 years) (Faulkner et al., 2013) and a systematic review of 68 studies (Larouche et al., 2014) showed that not walking to school was associated with a decrease in PA levels. Furthermore, as there
were no active PE classes online, this may have contributed to a further reduction in children’s PA levels. A European study showed that 57% of children who were active during online PE classes during the COVID-19 outbreak met the WHO PA recommendations (Kovacs et al., 2021).

The sleep patterns of children in the current study have been affected by policy changes as a result of the COVID-19 pandemic. To ensure working parents could assist children in their schooling, the Saudi Ministry of Education mandated that schooling started at 3:30 pm (online) and ended at 7pm. These changes to daily routines may also have affected the time that children went to sleep. In addition, the absence of a structured day time schedule could have further hindered opportunities to meet ST and PA recommendations, as shown in a study conducted on 8395 children from 10 European countries (Kovacs et al., 2021).

In the present study, school-aged children had a school holiday for 20 days during Time 2, which may have negatively impacted their movement behaviours (Weaver et al., 2020). A study investigated the changes in sleep and PA of 154 United States (US) school-aged children (5–9 years) showed that a 1-week holiday had a negative impact on sleep, while a 3-week holiday had more increase in children’s SB (33 min) and decrease in MVPA (12 min) per day (Weaver et al., 2019). The structured days hypothesis indicates that during the unstructured days (e.g. school holidays), children’s sleep, SB and PA are less regulated compared to structured days (e.g. school days) (Larouche et al., 2014), therefore, there might be less opportunities for children to meet the 24-h movement guidelines during school holidays. This could be another reason that may explain the decline in children’s movement behaviours.
### Table 6.2 Comparison of five-months changes in children’s movement behaviours during the COVID-19 outbreak

(n = number, \( p \) = probability, MVPA = Moderate-to-Vigorous-Intensity Physical Activity, ST = Screen Time, 24-h = 24-hour, WHO = World Health Organization, COVID-19 = SARS-CoV-2, M = Mean, SD = Standard Deviation, PA = Physical Activity, TV = Television, VG = Video games.)

<table>
<thead>
<tr>
<th>Children’s movement behaviors, M (SD)</th>
<th>Total sample</th>
<th></th>
<th>Girls</th>
<th></th>
<th>Boys</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oct 2020 (n=1021)</td>
<td>Mar 2021 (n=1045)</td>
<td>( p ) value</td>
<td>Oct 2020 (n=616)</td>
<td>Mar 2021 (n=531)</td>
<td>( p ) value</td>
</tr>
<tr>
<td>MVPA ≥60 min (days/week)</td>
<td>4.52 (2.40)</td>
<td>2.77 (2.67)</td>
<td>&lt;0.0001</td>
<td>4.51 (2.40)</td>
<td>2.95 (2.69)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Activities to strengthen muscles and bones (days/week)</td>
<td>2.59 (2.37)</td>
<td>2.89 (1.96)</td>
<td>&lt;0.0001</td>
<td>2.52 (2.34)</td>
<td>2.75 (2.05)</td>
<td>0.08</td>
</tr>
<tr>
<td>Sleep (hours/day)</td>
<td>9.68 (2.26)</td>
<td>11.28 (2.22)</td>
<td>&lt;0.0001</td>
<td>9.76 (2.42)</td>
<td>11.30 (2.15)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Sleep quality</td>
<td>5.40 (1.99)</td>
<td>5.39 (1.82)</td>
<td>0.93</td>
<td>5.38 (2.05)</td>
<td>5.46 (1.85)</td>
<td>0.51</td>
</tr>
<tr>
<td>ST ≤2h (days/week)</td>
<td>5.39 (2.19)</td>
<td>4.95 (1.89)</td>
<td>&lt;0.0001</td>
<td>5.26 (2.21)</td>
<td>4.84 (1.97)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Playing outside (hours/day)</td>
<td>2.19 (1.34)</td>
<td>1.57 (1.03)</td>
<td>&lt;0.0001</td>
<td>2.15 (1.33)</td>
<td>1.62 (1.11)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Proportion of children meeting the WHO/Australian/Canadian guidelines (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MVPA</td>
<td>35.7</td>
<td>18.2</td>
<td>&lt;0.0001</td>
<td>32.6</td>
<td>19.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>ST</td>
<td>15.2</td>
<td>12.8</td>
<td>&lt;0.0001</td>
<td>16.6</td>
<td>14.3</td>
<td>0.001</td>
</tr>
<tr>
<td>Sleep</td>
<td>56.9</td>
<td>26.8</td>
<td>&lt;0.0001</td>
<td>55.6</td>
<td>24.3</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>24-h combined</td>
<td>3.4</td>
<td>1.8</td>
<td>&lt;0.0001</td>
<td>3.57</td>
<td>2.1</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Five-months changes in children’s movement behaviours during COVID-19 outbreak, M (SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PA or sport outside</td>
<td>2.16 (1.27)</td>
<td>1.76 (1.16)</td>
<td>&lt;0.0001</td>
<td>2.19 (1.22)</td>
<td>1.75 (1.12)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>PA or sport inside</td>
<td>2.78 (1.26)</td>
<td>2.61 (1.06)</td>
<td>&lt;0.0001</td>
<td>2.85 (1.26)</td>
<td>2.54 (1.07)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Watches TV or sedentary VG</td>
<td>3.28 (1.23)</td>
<td>4.10 (1.26)</td>
<td>&lt;0.0001</td>
<td>3.49 (1.26)</td>
<td>4.03 (1.30)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Uses social media</td>
<td>3.54 (1.87)</td>
<td>3.76 (1.31)</td>
<td>&lt;0.0001</td>
<td>4.08 (1.85)</td>
<td>3.73 (1.34)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Sleep quantity</td>
<td>3.15 (0.94)</td>
<td>3.86 (1.10)</td>
<td>&lt;0.0001</td>
<td>3.17 (0.96)</td>
<td>3.79 (1.15)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Sleep quality</td>
<td>3.06 (0.95)</td>
<td>2.80 (0.93)</td>
<td>&lt;0.0001</td>
<td>3.07 (0.96)</td>
<td>2.84 (0.97)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Overall healthy movement behaviours</td>
<td>2.78 (1.03)</td>
<td>2.90 (0.83)</td>
<td>0.01</td>
<td>2.83 (1.02)</td>
<td>2.91 (0.89)</td>
<td>0.14</td>
</tr>
</tbody>
</table>
The number of children in this study who had an electronic screen device in their bedroom increased from Time 1 (40%) to Time 2 (70%). This may explain the decrease in the proportion of children meeting the ST recommendation, as having these electronic screen devices in children’s bedroom negatively affects their sleep quality and duration (Hale and Guan., 2015). Our numbers align with what was reported in a study from the US which indicated that 75% of US children, aged 6-17 years (mean age: 11.4), had an electronic screen device in their bedroom (Buxton et al., 2015). The authors reported that 90% of children had insufficient sleep time and that having household rules and regular sleep-wake routines may encourage children to have better sleep (Buxton et al., 2015).

As the data of this repeated cross-sectional study were from all the 13 regions of Saudi Arabia, there may be some differences and disparities between urban and rural areas in meeting the recommendations of movement behaviours due to the level of government restrictions and COVID-19 infections in each region. In addition, there are differences in the climate of the 13 regions in Saudi Arabia due to its large area. The climate is moderate in the west and the southwestern areas, hot in the interior areas, and hot and humid in the coastal areas (General Authority for Statistics., 2019). These differences in the weather may play an important role in meeting 24-h movement guidelines as reported in a study that examined the relationship between climate indicators and daily detected COVID-19 cases in Saudi Arabia which showed a positive association between the spread of COVID-19 and temperature among the top Saudi cities (Riyadh, Jeddah, Makkah, Madinah, and Dammam) affected by COVID-19 (Abdel-Aal et al., 2021).
6.4.1 Strengths and limitations

This study is the first known from an Arabian country to provide data on school-aged children’s 24-h movement behaviour at two points of time during the COVID-19 outbreak. Moreover, this study provided data across all the 13 regions of Saudi Arabia since there is no nationally representative data of 24-h movement behaviours during the COVID-19 pandemic.

Figure 6.1 Parent-reported changes in 24-h movement behaviours in Saudi children (6 to 12 years) during the first (October 2020) and second time (March 2021) of the COVID-19 pandemic. Scores are based on a 5-point scale ranging from “a lot less” (score 1) to “about the same” (score 3) to “a lot more” (score 5). Green arrows represent when October 2020 (Time 1) scores ranked less compared with March 2021 (Time 2) within the same variable. Red arrows represent when October 2020 (Time 1) scores ranked higher compared with March, 2021 (Time 2) within the same variable. PA= physical activity. VG= video games.
outbreak. A limitation of the study is that movement behaviours were assessed via a parent survey as collecting data using device-based measures on a large sample was not possible due to the COVID-19 restrictions. As the data were anonymous, the differences from Time 1 to Time 2 could be due to differences in the samples, in addition to COVID-19.

6.5 Conclusion

This repeat cross-sectional study provided evidence of the impact of the COVID-19 restrictions on Saudi children’s movement behaviours and investigated the changes in these behaviours over the two time periods during the COVID-19 restrictions. Due to the difference in the COVID-19 infections rate in the several regions of Saudi Arabia, it is recommended for future studies to be conducted by region. As no Saudi 24-h movement guidelines currently exist, we recommend the development of such guidelines for children in Saudi Arabia as they have significant public health benefits. The findings of this study contribute to support the efforts to mitigate the negative impact for this pandemic, as part of the response strategies, and for future pandemics.

Conflicts of Interest: The authors declare that they have no competing interests.

Submission statement: All authors have read and agree with manuscript content and while this manuscript is being reviewed for this journal, the manuscript will not be submitted elsewhere for review and publication.

Authors' contributions

original draft preparation, Y.A.A.; writing—review and editing, all authors. All authors have read and agreed to the published version of the manuscript.

**Ethical approval statement**

The study was conducted in accordance with the Declaration of Helsinki. Approval was obtained from the Ministry of Education in Saudi Arabia (2639/2021) and the Human Research Ethics Committee at the University of Wollongong, Australia (HE288/2021). This survey collected data between March and May, 2021. A link to an online survey in Arabic, using the Qualtrics platform, was provided to parents. Before answering the survey, parents were provided with an online parent information sheet and consent form as the first page of the survey.

**Acknowledgements**

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Chapter 7: Associations between gross motor skills, adiposity and bone mineral density among boys in the Kingdom of Saudi Arabia: a cross sectional study

*Chapter 6* investigated how children’s 24-hour movement behaviours were affected by COVID-19 in the Kingdom of Saudi Arabia 12 months after the WHO declared COVID-19 outbreak as a pandemic. The following chapter examined the associations between gross motor skills, adiposity and BMD- radius $z$-scores among non-overweight and overweight/obese boys in Saudi Arabia.

This chapter sought to address the following research question:

What is the relationship between adiposity, gross motor skills and bone mineral density-radius $z$-score among non-overweight and overweight/obese boys in Saudi Arabia?

This chapter has been accepted for publication in the *Journal of Sport Sciences and Physical Education*:

Abstract

**Background:** Development of gross motor skills is important for a child’s health and cognition. Early evaluation of gross motor skills during elementary school years is important to monitor and respond to the developmental needs of the child. The association between childhood obesity and gross motor skills in some populations, such as Saudi Arabia is still unclear. Therefore, this study aimed to examine the associations between gross motor skills, adiposity and BMD- radius z-scores among non-overweight and overweight/obese boys in Saudi Arabia.

**Methods:** A cross-sectional study \((n= 48)\) was conducted in Riyadh city in February 2020 to collect data on children’s gross motor skills, BMD- radius z-scores and anthropometric measurements.

**Results:** Non-overweight and overweight/obese boys did not significantly differ in their locomotor standard scores \((p=0.093)\), object control standard score \((p=0.876)\), gross motor quotient \((p=0.297)\), or BMD radius z-score \((p=0.343)\). BMI was moderately and negatively correlated with locomotor standard scores \(rs(46) = -0.323, p = 0.025\).

**Conclusion:** Longitudinal studies with larger sample sizes, including both boys and girls are needed to better understand the associations between gross motor skills, adiposity and BMD among obese/overweight and non-overweight Saudi children.

**Keywords:** gross motor skills, adiposity, bone mineral density, child.
7.1 Introduction

Childhood obesity is a major public health concern (Lobstein et al., 2004; WHO, 2020). Globally, the number of obese children and young adults aged 5 to 19 years old with obesity is predicted to increase from 158 million in 2020 to 254 million in 2030 (World Obesity Federation, 2021). Childhood obesity can adversely affect children’s physical health (Sahoo et al., 2015) and motor skills (Wang et al., 2016), and is likely to track into adulthood increasing the risk of non-communicable diseases (Wang et al., 2016). The development of gross motor skills is also critical for children to improve their developmental function and cognitive abilities (Piek et al., 2008; Veldman et al., 2016). Early evaluation of these skills during elementary school years is important to monitor and respond to the developmental needs of the child (Simons et al., 2008; Valentini, 2012). The association between childhood obesity and gross motor skills in some populations is still unclear; does obesity lead to poor gross motor skills or does poor motor skills lead to unhealthy weight gain (Weisstaub et al., 2017).

Childhood obesity is also negatively associated with children’s bone health (Heaney et al., 2000). A UK longitudinal study (Ireland et al., 2016) of 2327 participants found that reduced bone strength at age 17 was related to a lower motor competence in early life (18 months). Studies have shown that schools are an ideal setting for promoting children’s physical activity (PA) levels (Reimers & Knapp, 2017; Sumiya & Nonaka, 2021) and decreasing sedentary behaviour (SB) (Hamer et al., 2017) as well as developing their motor skills (True et al., 2017). In Saudi Arabia, 60% of schools do not have playgrounds or activity-supporting environments (Algarni & Male, 2014; Samargandi, 2018). In addition,
time spent in physical education (PE) classes per week is limited (45 min) (Samargandi, 2018). Providing evidence on the association between motor skills, adiposity and bone health can support efforts to promote quality physical education and health promoting environments in schools in Saudi Arabia. To the best of our knowledge, no studies in Saudi Arabia have examined the associations between adiposity, gross motor skills and bone mineral density (BMD) in school-aged Saudi children. Therefore, the purpose of this study was to assess the associations between gross motor skills, adiposity and BMD radius \( z \)-score among non-overweight and overweight/obese boys in Saudi Arabia.

### 7.2 Method

This study was initially designed as a longitudinal study commencing in February 2020, with data collection at two time points (baseline and 12-month follow-up). Parents of children enrolled in their second year of primary school (Grade 2; aged 7 years old), from two urban (Riyadh city) and two rural schools (Al Jubaylah town) (two boys’ schools and two girls’ schools noting that elementary schools in SA are all single sex) in Saudi Arabia were approached to participate in the study. These schools were selected based on the recommendation of the Planning and Development Department at the Saudi Ministry of Education. Unfortunately, due to the COVID-19 pandemic, all schools in Saudi Arabia were suspended in March 2020 just as data collection in the second school commenced. As such, data collection procedures in the other schools were suspended. The study was revised to be a cross-sectional study. In the two boys’ schools, all parents (or caregiver/legal guardian) with children enrolled in Grade 2 were approached and provided consent for their children to participate in the study. Trained faculty members with a
physical education background, from the College of Sport Sciences and Physical Activity at King Saud University collected the data after attending a one-day training workshop. The workshop for data collectors was facilitated by faculty members from the Departments of Physical Education and Exercise Physiology at King Saud University. It included an overview of the Test of Gross Motor Development (TGMD-2) (definition and importance), general testing information, test scores and their interpretation and completing the examiner record form. All 12 skills in the TGMD were viewed and explained via YouTube clips. The workshop also included information on conducting the anthropometric measurements following the World Health Organization (WHO) procedures and how to use these measurements to calculate body mass index (BMI). The last part of this workshop included an overview of the BMD- radius z-scores and how to assess it using the quantitative transaxial ultrasound method (Sunlight MiniOmni device).

7.2.1 Ethical Considerations

Approval was obtained from the Ministry of Education in Saudi Arabia (Planning and Development Department, approval number 42640/2020) to conduct the study in each of the schools, followed by the permission from the principals and Grade 2 teachers. The Human Research Ethics Committee at The University of Wollongong, Australia, reviewed and approved this study (approval number HE 2019/288).

Data collection included teacher and parent questionnaires, child assessments, gross motor competence, anthropometric measurements, and bone mineral density.
7.2.2 Teacher questionnaire

The child’s classroom teachers were asked to complete the Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997) for each consenting child. This questionnaire gathered information on positive and negative psychological attributes of each student across five scales, each comprising five items: emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems and prosocial behaviors.

7.2.3 Parent questionnaire

The parent questionnaire was distributed to all children during class to take it home to be completed by their parent. The parent questionnaire reported on their child’s use of electronic media, bed and wake-up times, sleep quality, restrained sedentary time and sociodemographic information (child and parent birth, sex, region of residence, parental education, and income). The questionnaire comprised six parts: child and parents’ (or caregiver/legal guardian) demographics; time their child spent using electronic media for entertainment, time spent sleeping and sleep quality; food sources; dietary diversity; eating behaviors at home and food insecurity. The questionnaire was adapted from the Sunrise Parent Questionnaire (Okely et al., 2021).
7.2.4 Child assessments

Children’s body weight and height were measured prior to the children’s gross motor skills, and BMD being assessed. The order of testing was determined by the school principal and based on children’s timetable.

7.2.5 Gross Motor Competence

The TGMD-2 was used to assess children’s performance of 12 fundamental movement skills (Ulrich & Sanford, 1985). The 12 skills took approximately 15-20 minutes to assess for each child. Following the TGMD-2 protocols, one data collector demonstrated each gross motor skill to the children. Children were scored while performing the tasks by a second data collector. It was not possible to video the children when they undertook the measures as using a video camera to record the children was prohibited by the Ministry of Education in Saudi Arabia (Planning and Development Department). Children’s performance criterion was scored as “0” for an unsuccessful trial or “1” for a successful trial. Raw scores were converted to standard scores for each subtest and the standard score was used for locomotor and object control skills. The standard scores were then combined and a gross motor quotient calculated to provide an overall score of gross motor competence.

7.2.6 Anthropometric measurements

Body mass and height were measured following WHO procedures (WHO) with the participants in light clothing and without shoes. These measurements were used to calculate
BMI. Height was measured using a Seca 213 mobile stadiometer (Seca, Germany). The data collector recorded the height measurement to the nearest 0.1 centimeter. Weight was measured using a Seca 803 electronic flat scale (Seca, Germany), recorded to the nearest 0.1 kilogram. WHO Child Growth Standards was used to obtain percentile and category (non-overweight, obese, overweight) (WHO, 2009). Height and weight measures were recorded twice and the average of the two measures reported. If the two measures differed by more than 0.5 cm for height and 0.5 kg for weight, a third measure was recorded and the median score was used.

7.2.7 Bone mineral density

BMD was assessed using the quantitative trans axial ultrasound method (Sunlight MiniOmni device) (Zamir, 2020). The phantom and the probe were at the same room temperature (between 15 and 30 degrees Centigrade) when conducting System Quality Verification. The MiniOmni measures bone speed of sound (SoS; meters per second [m/sec]). Bone SoS was measured at the radius of the student’s non-dominant arm while the student was seated. Higher SoS values represent greater bone density. System Quality Verification (SQV) was performed before beginning the first SoS measurements. Z-scores were reported as the outcome included standard deviations related to age and gender.

7.2.8 Data analysis

The Statistical Package for Social Sciences (SPSS) version 28 was used for data entry and analysis. The data were initially presented as means and standard deviations. Differences in
means were determined using an independent samples t-test between non-overweight and overweight/obese children. Comparison between locomotor and object control standard scores and BMD radius z-score was performed by weight category (obese/overweight and non-overweight). Independent samples t-tests were used to test for differences between non-overweight and overweight/obese children in their locomotor standard scores, object control standard scores, BMD radius z-scores, and gross motor quotient (GMQ). A Spearman's rank-order correlation was conducted to examine associations between gross motor skills, adiposity and BMD. A multiple linear regression was conducted to ascertain the association of locomotor standard scores and BMD- radius z-scores on children's BMI while controlling for age. Due to the small number of participants, obese and overweight children were combined as one group.

7.3 Results

Data collection commenced at the boys’ schools first, and planned to collect the data from girls’ schools after this. Due to the suspension of schooling in Saudi Arabia, however, face-to-face data collection could not be completed. As such only data from the boys’ schools were collected and analyzed in this study. In addition, teacher and parent questionnaires were distributed, however, these were not received back due to COVID-19.

Forty-eight students (n= 34 from the urban school and n= 14 from the rural schools) provided parental consent in this study. Their age ranged between 6.4 and 9.1 years with a mean age of 7.8 (SD = 0.62). Their average height was 124.3cm (SD = 7.71) and average
weight was 26.8kg (SD = 8.12). Thirty-four students were identified as non-overweight (71%), 4 students as overweight (8.2%) and 10 students as obese (20.8%) (Table 7.1).

Table 7.1: Sample description

<table>
<thead>
<tr>
<th></th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>7.80±0.62</td>
</tr>
<tr>
<td>Height</td>
<td>124.29±7.69</td>
</tr>
<tr>
<td>Weight</td>
<td>26.77±8.7</td>
</tr>
<tr>
<td>BMI</td>
<td>17.05±3.60</td>
</tr>
<tr>
<td>Locomotor Standard Scores</td>
<td>8.21±3.01</td>
</tr>
<tr>
<td>Object Control Standard Scores</td>
<td>6.60±2.93</td>
</tr>
<tr>
<td>Gross Motor Quotient</td>
<td>84.44±15.70</td>
</tr>
<tr>
<td>BMD Radius z-scores</td>
<td>0.68±0.87</td>
</tr>
</tbody>
</table>

SD=standard deviation

Table 7.2 shows the difference between non-overweight and overweight/obese boys in their locomotor standard scores, object control standard scores, gross motor quotient, and BMD radius z-scores. Non-overweight and overweight/obese boys did not significantly differ in their locomotor standard scores (p=0.093), object control standard score (p=0.876), gross motor quotient (p=0.297), or BMD radius z-scores (p=0.343).
Table 7.2 Difference between non-overweight and overweight/obese boys for locomotor standard score, object control standard score, gross motor quotient, and BMD radius z-score

<table>
<thead>
<tr>
<th></th>
<th>Mean±SD</th>
<th>t value</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Locomotor standard score</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Overweight</td>
<td>8.68±2.637</td>
<td>1.713</td>
<td>0.093</td>
</tr>
<tr>
<td>Overweight/ Obese</td>
<td>7.07±3.626</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Object control standard score</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Overweight</td>
<td>6.65±2.729</td>
<td>0.156</td>
<td>0.876</td>
</tr>
<tr>
<td>Overweight/ Obese</td>
<td>6.50±3.481</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gross motor Quotient</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Overweight</td>
<td>85.97±13.512</td>
<td>1.056</td>
<td>0.297</td>
</tr>
<tr>
<td>Overweight/ Obese</td>
<td>80.71±20.166</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BMD radius z-score</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Overweight</td>
<td>0.79±0.946</td>
<td>0.957</td>
<td>0.343</td>
</tr>
<tr>
<td>Overweight/ Obese</td>
<td>0.50±1.019</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As seen in Table 7.3, BMI was moderately and negatively correlated with locomotor standard scores ($r = -0.322$), $p = 0.026$. BMI was not associated with object control standard scores ($r = -0.165$) or gross motor quotients ($r = -0.279$), $p > 0.05$. BMD- radius z-scores were not significantly correlated with locomotor standards scores ($r = 0.277$), object control standards scores ($r = 0.135$) and gross motor quotients ($r = 0.254$), $p > 0.05$. 
Table 7.3 Correlation of BMI and BMD- radius z-score

<table>
<thead>
<tr>
<th></th>
<th>BMI</th>
<th>BMD radius z-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locomotor standards score</td>
<td>-.322*</td>
<td>0.277</td>
</tr>
<tr>
<td>Object control standards scores</td>
<td>-0.165</td>
<td>0.135</td>
</tr>
<tr>
<td>Gross motor quotient</td>
<td>-0.279</td>
<td>0.254</td>
</tr>
<tr>
<td>BMD- radius z-score</td>
<td>-0.245</td>
<td></td>
</tr>
</tbody>
</table>

*. Correlation is significant at the 0.05 level (2-tailed).

A multiple linear regression was conducted to evaluate associations between locomotor standards scores, object control standards scores, BMD- radius z-scores and BMI while controlling for children’s age. The full model accounted for 12.5% of the variability in BMI, with age independently accounting for 3% of this variability. This proportion of the variability in BMI was not statistically significant, $F(4, 43) = 2.288, p = 0.075$.

Table 5.4 Results from multiple regression examining associations between BMI, gross motor skills and BMD.

<table>
<thead>
<tr>
<th></th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>95.0% Confidence Interval for B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
</tr>
<tr>
<td>(Constant)</td>
<td>14.428</td>
<td>6.962</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.792</td>
<td>0.835</td>
<td>0.136</td>
</tr>
<tr>
<td>Locomotor Standards Score</td>
<td>-0.384</td>
<td>0.210</td>
<td>-0.321</td>
</tr>
<tr>
<td>Object Control Standards Scores</td>
<td>-0.031</td>
<td>0.205</td>
<td>-0.025</td>
</tr>
<tr>
<td>BMD- radius z-score</td>
<td>-0.303</td>
<td>0.605</td>
<td>-0.073</td>
</tr>
</tbody>
</table>

a. Dependent Variable: BMI
7.4 Discussion

This study found that obese/overweight boys did not differ in their gross motor skills or bone health compared with non-overweight/obese boys. Children’s BMI was moderately and negatively correlated with locomotor standard scores. The combination of gross motor skill and bone mineral density was not associated with BMI.

It is not possible to compare the findings with local studies since this study is the first of its type in Saudi Arabia. However, when looking at studies undertaken in other countries, our results are consistent with previous findings which found that obese/overweight children tend to have lower gross motor scores comparing with their peers (Cheng et al., 2016; Gentier et al., 2013; Marmeleira et al., 2017; Morano et al., 2011; Okely et al., 2004; Southall et al., 2004).

We found that children’s BMI was moderately and negatively correlated with locomotor skills. This indicates that when children’s BMI increases, locomotor skills decrease. This could be explained by their PA levels. Data showed that PA promotes gross motor skills (Dapp et al., 2021), therefore, obese/overweight children with low levels of PA may find it difficult to participate in such activities due to the larger body mass and moving against gravity (Riddiford-Harland et al., 2006), which in turn may affect their locomotor skills performance. Moreover, the decline in obese/overweight children’s locomotor standard scores could be explained by the lack of playgrounds as 60% of schools in Saudi Arabia do not have playgrounds, in addition to the limited time of PE class. Playgrounds provide a
great opportunity for children to promote their PA levels, which in turn promotes their gross motor skills (Dapp et al., 2021). Another factor may affect children’s gross motor skills performance could be the foot structure of overweight children. For example, Mickle et al reported that overweight/obese children had a significantly lower plantar arch height (0.9 +/- 0.3 cm) than their non-overweight counterparts (1.1 +/- 0.2 cm; $p = 0.04$) due to lowering of the longitudinal arch as their feet continually bearing excess mass (Mickle et al., 2006).

The findings showed that there was no relationship between BMI and object control skills. A possible explanation for this is that object skills tend to be more static and do not require children to move their body compared with locomotor skills. Gross motor skills are more impacted by excessive body weight than object control skills, therefore, they appear to be relatively independent of the effect of excessive body weight (Marmeleira et al., 2017). Moreover, as children are still developing their motor skills in this age, and that locomotor skills develop before the object control skills (Stodden et al., 2014), the differences in object control skills may become more obvious as children aged and these skills become more complex and diversified (Castetbon et al., 2012).

There was not a significant association between BMD and motor skills. This could be due to having a small sample size since it can result in decreased statistical power (Knudson, 2017; Mullineaux et al., 2001). In addition, correlation coefficient showed that the r values
were positive and they indicate a low to moderate associations. Therefore, having a larger sample size may result in having a significant association between BMD and motor skills.

The present study found no significant differences between non-overweight and overweight/obese children in their gross motor skills. This could be partly explained by their age. A study conducted by Cheng et al (Cheng et al., 2016) on 668 children (5 to 10 years) showed that the differences between normal weight, overweight and obese children in their total and gross motor skills increased as they aged. This is also consistent with the findings of D’Hondt et al study which conducted on 954 Belgian children (5 to 12 years) (D'Hondt et al., 2011) and 100 Belgian children (6 to 10 years) (D'Hondt et al., 2013) which reported that BMI-related differences in gross motor coordination become more pronounced at older ages. Therefore, this may explain the level of convergence between the two groups in this study and that they could be more noticeable with age.

Non-overweight and overweight/obese children did not differ in their BMD. The relationship between weight status and BMD remains unclear as some studies reported that overweight and obese children have a higher BMD compared with healthy-weight children (Ferrer et al., 2021; Thamyongkit et al., 2020; van Leeuwen et al., 2017), while other studies showed that BMD decreased in obese children (Gállego Suárez et al., 2017; Goulding et al., 2000). Since the greatest bone mass is gained during adolescence (Mosca et al., 2013), this may help explain these conflicting results. However, Dolan and colleagues conducted a systematic review and meta-analysis to quantify correlations between absolute and relative adipose tissue mass and BMD in overweight and obese populations (after
adjusting for age). The results showed that children and adolescent’s adiposity is negatively correlated with BMD compared to those aged 25 years and over (Dolan et al., 2017), as bone metabolism is in a state of flux during this stage of growth in children, and that strongest evidence in the youngest age category (R = −0.28; 95%CI, −0.45 to −0.08) support this negative correlation (Dolan et al., 2017).

Studies have shown that small samples can result in decreased statistical power (Knudson, 2017; Mullineaux et al., 2001). Moreover, the proportion of non-overweight children in the present study was 71%, while the obese and overweight children made up 29% of the sample. Having unequal sample sizes between the two groups may have more impact on the lack of significance (Mullineaux et al., 2001).

Regarding the association with BMI, age was added as a covariate (6-10 years) as this period is important for children as they move towards young adolescence. During this period, children have many physiological and hormonal changes in their growth and development (Murdoch Children Research Institute, 2015) that may partly explain the lack of an association with BMI. Studies have shown that children (6-12 years old) increase in height more than gaining weight during this period and that they start to gain weight (boys gain more muscle tissue, while girls gain more fat tissue) when they mature (Paediatrics & Child Health, 2004; Nemours KidsHealth, 2019).
Longitudinal studies with a larger sample size with both boys and girls are needed to better understand the associations between gross motor skills, adiposity and BMD of obese/overweight and non-overweight children.

7.4.1 Limitations

To our knowledge, this is the first study in Saudi Arabia that investigated the associations between gross motor skills, adiposity and BMD among school-aged children. A limitation of the study is that the data collection could not be completed as planned due to COVID-19. Moreover, having a small and unequal sample size may have more impact on the lack of significance. Using BMI as a measure of overweight and obesity is another limitation as it is not entirely accurate and does not discriminate between fat and lean body mass. As a cross-sectional study, the data were collected at one point in time. Therefore, it is difficult to establish causal relationships from cross-sectional analysis compared to longitudinal and cohort studies.

7.5 Conclusion

The findings of this study demonstrate the associations between gross motor skills, adiposity and BMD- radius z-scores of obese/overweight and non-overweight boys in Saudi Arabia. Longitudinal studies with a larger sample size are needed to better understand the associations between gross motor skills, adiposity and BMD of obese/overweight and non-overweight children.
Acknowledgments

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Conflicts of Interest: None declared.
Chapter 8: General discussion and recommendations

This doctoral thesis originally sought to examine the associations between 24-hour movement behaviours and health among children in the Kingdom of Saudi Arabia. However, as a result of the impact of COVID-19, the thesis was revised to address the following aims: i) systematically reviewed the relationship between 24-hour movement behaviours and health indicators in school-aged children in Arabic countries; ii) investigated the impact of the COVID-19 outbreak on 24-h movement behaviours among Saudi children aged 6-12 years seven months after the World Health Organization (WHO) declared COVID-19 a global pandemic; iii) examined the changes in 24-h movement behaviours of Saudi children 12 months after the WHO declared COVID-19 a global pandemic; and iv) investigated the association between adiposity, gross motor skills and bone density- radius z-score among overweight/obese boys compared with non-overweight boys in Saudi Arabia.

8.1 Overview of findings

The main findings of the systematic review (Chapter 4) indicated that low levels of PA and sleep and high SB were unfavourably associated with adiposity outcomes, behavioural problems, depression and low self-esteem. The findings also showed a lack of research assessing the relationship between sleep and adiposity outcomes and a lack of research in Arab speaking countries. The results from Chapter 5 showed that only 3.4% of Saudi children met all components of the 24-hour movement guidelines seven months into
COVID-19. Compared with before COVID-19, children’s PA levels declined, they slept more, and their use of electronic screen devices significantly increased. The findings in Chapter 6 showed that at Time 2 (1 March – 15 May 2021) only 1.8% of children met all components of the 24-h guidelines, compared to 3.4% in Time 1 (1 October – 11 November 2020) and that healthy levels of PA, SB and sleep further declined in Saudi children five months after the baseline survey. Finally, Chapter 7 showed that non-overweight and overweight/obese boys did not significantly differ in their locomotor standard scores ($p=0.093$), object control standard scores ($p=0.876$) and BMD radius $z$-scores ($p=0.343$). BMI was moderately and negatively correlated with locomotor standard scores ($r = -0.32$, $p = 0.025$), while BMD radius $z$-scores were not associated with BMI ($r = -0.245$, $p > 0.05$).

### 8.2 Discussion of findings

As highlighted in Chapter 4, studies from Arabic countries, including Saudi Arabia, reported that low levels of PA and sleep and high levels of SB were associated with higher levels of adiposity, behavioural problems, depression and low self-esteem. Furthermore, most studies used self- or parent proxy-reported methods to assess PA, sleep and SB and assessed movement behaviours in isolation from each other (Alanazi et al., 2021) due to the prior emphasis on MVPA (Tremblay et al., 2010) and the lack of availability of funds in low-income Arab countries to support device-based measures (Baskaran., 2016). Moreover, due to the common use of self- or parent-reported assessments of PA (Poitras et al., 2016) and emphasis on MVPA (Tremblay et al., 2010), no study from Arabic countries examined different PA intensities such as light-intensity physical activity (LPA), although emerging
evidence suggests that engaging in LPA is an easier way to reduce SB (Chaput et al., 2017) and provides important health benefits for children (Chaput et al., 2017; Tremblay et al., 2016; Poitras et al., 2016). Furthermore, to date, no Arab-speaking countries, including Saudi Arabia, have developed 24-h movement guidelines (Parrish et al., 2020). There is a need for such guidelines as studies from non-Arab countries have shown that meeting all the guidelines during a 24-hour period is associated with better health (Sampasa-Kanyinga et al., 2017). Compared with meeting none, one or two recommendations, meeting all recommendations was associated with lower BMI z-score, waist circumference, fewer behavioural difficulties scores and lower aerobic fitness (Carson et al., 2017).

The findings from Chapter 5 showed that compared with before COVID-19, children’s PA levels declined, they slept more, and their use of electronic screen devices significantly increased seven months after the WHO declared COVID-19 a global pandemic. Only 3.4% of Saudi children met all components of 24-hour movement guidelines at this time and this declined to 1.8% at the end of the pandemic. These results are similar to a study conducted in nine European countries (Kovacs et al., 2022) which showed that children who met the WHO PA recommendations declined from 19% pre-COVID to 9.3% 13 months later, while the proportion of children who did not meet recreational sedentary screen time recommendations was high in both timepoints (60.6% (weekdays) and 47.7% (weekend days) in Time 2 compared to 69.5% (weekdays) and 64% (weekend days) in Time 1). Similar results were reported in 24-h movement behaviours in a Canadian study (Moore et al., 2021) which found a decrease in the proportion of children who met movement guidelines from 4.8% at the start of the pandemic to 4.5% six months later due to the
impact of COVID-19. However, Saudi children’s movement behaviours decreased more compared to the findings of Moore et al (2021) and Kovacs et al (2022) studies. This may be attributed to the weather in Saudi Arabia, which is moderate in the west and the southwestern areas, hot in the interior areas, and hot and humid in the coastal areas (General Authority for Statistics., 2019). PA levels are affected by seasonal periods across the year and decrease in specific climatic conditions such as summer (Harrison et al., 2017), winter, sandstorms areas, humidity and rain (Al-Mohannadi and Moahhed., 2015; Tucker and Gilliland., 2007). In addition, extreme weather conditions (high or low temperatures) increase SB (Edwards et al., 2015) and decrease sleep efficiency (Quante et al., 2019).

These results were somewhat expected as tighter government restrictions were introduced over the course of the COVID-19 pandemic which further limited children’s opportunities to play outdoors (Kovacs et al., 2021). School closures may be a reason for the decrease in children’s PA levels. A study involving 785 Canadian children (10.57 ± 0.7 years) (Faulkner et al., 2013) and a systematic review of 68 Studies (Larouche et al., 2014) showed that not walking to school was associated with a decrease in PA levels. Furthermore, the closure of playgrounds and sport facilities may have reduced children’s PA levels further. Closing outdoor facilities for PA limited children’s engagement in structured and unstructured PA (Kovacs et al., 2021).

Children’s movement behaviours are less regulated during non-school periods such as school holidays compared to structured days (e.g. school days). A study investigated the
changes in sleep and PA of 154 US school-aged children (5–9 years) showed that a 1-week holiday had a negative impact on sleep, while a 3-week holiday increased children’s SB (33 min) and decreased MVPA (12 min) per day (Weaver et al., 2019). Therefore, opportunities for children to meet the 24-h movement guidelines during school holidays during COVID-19 may have been reduced as children during normal school holidays children may go to parks and play sports and walk around their neighbourhoods, while during COVID-19 they could not do these activities.

The findings from Chapter 7 showed that non-overweight and overweight/obese boys did not differ in their gross motor skills. This could be partly explained by their age. A study conducted by Cheng et al (2016) on 668 children (5 to 10 years) showed that the differences between normal weight, overweight and obese children in their total and gross motor skills increased as they aged. This is consistent with the findings from D’Hondt et al in two studies, the first with 954 Belgian children (5 to 12 years) (D’Hondt et al., 2011) and the second with 100 Belgian children (6 to 10 years) (D’Hondt et al., 2013) which reported that BMI-related differences in gross motor coordination become more pronounced at older ages.

After categorizing weight status into non-overweight and overweight/obese categories, there were no significant differences between non-overweight and overweight children in their locomotor skills and object control skills. This may be statistically attributed to the small sample size which may result in decreased statistical power (Knudson, 2017; Mullineaux et al., 2001). It was challenging to establish statistically significant differences
between non-overweight and overweight children given small sample size. Further, reducing one of the variables (BMI), into two categories may have resulted in a loss of variability.

Children’s BMI was moderately and negatively correlated with locomotor skills. This could be explained by their PA levels, which unfortunately was unable to be assessed in this study due to the impact of COVID-19. PA promotes gross motor skills (Dapp et al., 2021), therefore, obese/overweight children with low levels of PA may find it difficult to participate in such activities due to their larger body mass and moving against gravity (Riddiford-Harland et al., 2006), which in turn may affect their locomotor skills performance. Another factor may affect children’s gross motor skills performance could be the foot structure of overweight children. Mickle et al reported that overweight/obese children had a significantly lower plantar arch height (0.9 +/- 0.3 cm) than their non-overweight counterparts (1.1 +/- 0.2 cm; p = 0.04) due to lowering of the longitudinal arch as their feet continually bearing excess mass (Mickle et al., 2006). In correlational studies, significant findings can occur using small samples as both variables are continuous in nature and that the minimum acceptable sample size for a correlational study was larger than 30 (Fraenkel et al., 2012).

The findings of this research also showed that there was no relationship between BMI and object control skills. A possible explanation for this is that object control skills tend to be more static and do not require children to move their body compared with locomotor skills.
Gross motor skills are more impacted by excessive body weight than object control skills, therefore, they appear to be relatively independent of the effect of excessive body weight (Marmeleira et al., 2017). Moreover, as children are still developing their motor skills in this age, and locomotor skills develop before the object control skills (Stodden et al., 2014), the differences in object control skills may become more obvious as children aged and these skills become more complex and diversified (Castetbon et al., 2012).

BMD radius z-scores were not associated with BMI. The relationship between weight status and BMD remains unclear as some studies reported that overweight and obese children have a higher BMD compared with healthy-weight children (Ferrer et al., 2021; Thamyongkit et al., 2020; van Leeuwen et al., 2017), while other studies showed that BMD decreased in obese children (Gállego Suárez et al., 2017; Goulding et al., 2000). Dolan and colleagues (2017) conducted a systematic review and meta-analysis to quantify correlations between absolute and relative adipose tissue mass and BMD in overweight and obese populations (after adjusting for age). The results showed that children’s and adolescent’s adiposity is negatively correlated with BMD compared to those aged 25 years and over (Dolan et al., 2017). Furthermore, it was reported that as children increasing in weight status from a normal weight to overweight and then to obese, the impact of body fat on BMD decreases or disappears (López-Peralta et al., 2022).

Regarding the association with BMI, age was added as a covariate (6-10 years) as this period is important for children as they move towards young adolescence. During this
period, children have many physiological and hormonal changes in their growth and development (Murdoch Children Research Institute, 2015) that may partly explain the lack of an association with BMI in this research. Studies have shown that children (6-12 years old) increase in height more than gaining weight during this period and that they start to gain weight (boys gain more muscle tissue, while girls gain more fat tissue) when they mature (Paediatrics & Child Health, 2004; Nemours KidsHealth, 2019).

8.3 Limitations

One of the main limitations is that face-to-face data collection could not be completed due to COVID-19 as the baseline data collection for the longitudinal study was suspended in March, 2020 and schools remained closed until January, 2022. Therefore, an online cross-sectional study focusing on changes in movement behaviours due to COVID-19 was undertaken as an alternative to the longitudinal study. As a result, it was not possible to collect data using device-based measures on a large sample. Moreover, due to the nature of this doctoral thesis design having cross-sectional studies, the associations found between the analyzed variables may not reflect the long-term impact of COVID-19 on children's movement behaviours. Additionally, as this sample was not nationally representative, the results are not generalizable for children in Saudi Arabia. The findings of Chapters 5 and 6 may have been affected by selection bias as it may occurs in online surveys, which in turn may have affected our results. Moreover, when conducting the systematic review, there might be some studies that could not be identified due to the small number of Arabic databases available. Using BMI as a measure of overweight and obesity is another
limitation as it is not entirely accurate and does not discriminate between fat and lean body mass. Finally, having a small sample size for the cross-sectional study may result in decreased statistical power.

8.4 Conclusion and recommendations for future research

The findings from this thesis provide new evidence to advance the understanding of the associations between 24-hour movement behaviours (sleep, sedentary behaviour and physical activity) and health among children in the Kingdom of Saudi Arabia, with particular reference to the period encompassing the COVID-19 pandemic. Further studies to address the dearth of literature from Arab-speaking countries on 24-hour movement behaviours and health across childhood are needed. Longitudinal studies with larger sample sizes are recommended to better understand how gross motor skills, adiposity and BMD may be associated with weight status among children. The COVID-19 pandemic unfavourably affected Saudi children’s movement behaviours. Furthermore, policies that support the promotion of healthy levels of PA, SB and sleep by encouraging outdoor PA (where possible), minimizing children’s use of screen devices when sedentary, educating parents about the importance of meeting movement behaviour guidelines will help to ameliorate the long-term effects of the COVID-19 and better prepare for future pandemics to lessen their impact on children’s movement behaviours in Saudi Arabia. Finally, girls’ physical education classes were only introduced in 2018, as a part of the Kingdom’s vision (The Quality-of-Life Program). Therefore, more of a focus on promoting PA for girls is recommended as it is associated with better health outcomes.
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Appendices

Appendix A: UOW Ethics Approval

APPROVAL LETTER
In reply please quote: 2019/288
Further Enquiries Phone: 4221 3386

3 September 2019

Dear Professor Okely,

I am pleased to advise that the Human Research Ethics application referred to below has been approved.

Ethics Number: 2019/288
Approval Date: 03/09/2019
Expiry Date: 02/09/2020

Project Title: Associations between 24-hour movement behaviours (physical activity, sedentary behaviour, and sleep) and health among children in the Kingdom of Saudi Arabia.

Researchers: Alanazi Yazeed; Parrish Anne-Maree; Okely Anthony

Documents Approved:
- UOW Application Form rec. 26/08/2019
- Research Ethics Responses-2 rec. 26/08/2019
- Consent Form For Teachers V2 29082019
- Consent Form For Parent V2 16082019
- Consent Form For Principals V2 16082019
- Letter Information For Teachers V2 29082019
- Letter Information For Parent V2 16082019
- Letter Information For Principals V2 16082019
- Letter of District Approval V1 20082019
- Actigraph Information Sheet V1 03072019
- MiniOmmi Information Sheet
- Appendix L_TGMD-2 Assessment rec. 26/08/2019
- Appendix L_BeamMed-Sunlight rec. 26/08/2019
- Appendix L_seca_pst_213_en rec. 26/08/2019
- Appendix H_seca_803_product_sheet_US rec. 26/08/2019
- Appendix M_Backward Span Task Instructions rec. 26/08/2019
- Appendix N_Stroop_Instructions rec. 26/08/2019
- Appendix O_Wisc Card Sorting Test rec. 29/08/2019
- Appendix P Teacher Strengths and Difficulties Questionnaire rec. 26/08/2019

Ethics Unit, Research Services Office
University of Wollongong NSW 2522 Australia
Telephone (02) 4221 3386
Email: rso-ethics@uow.edu.au Web: www.uow.edu.au
Appendix U Parent Questionnaire rec. 26/08/2019

Sites
King Saud Uni - Primary School
Principal Investigator for site – Hammad Alwohaibi

Aluyaynah Primary School - Saudi Arabia
Principal Investigator for site – Fawwaz Aldawoud

The HREC has reviewed the research proposal for compliance with the National Statement on Ethical Conduct in Human Research and approval of this project is conditional upon your continuing compliance with this document. Compliance is monitored through progress reports; the HREC may also undertake physical monitoring of research.

Approval is granted for a twelve month period; extension of this approval will be considered on receipt of a progress report prior to the expiry date. Extension of approval requires:

- The submission of an annual progress report and a final report on completion of your project.
- Approval by the HREC of any proposed changes to the protocol or investigators.
- Immediate report of serious or unexpected adverse effects on participants.
- Immediate report of unforeseen events that might affect the continued acceptability of the project.

If you have any queries regarding the HREC review process or your ongoing approval please contact the Ethics Unit on 4221 3386 or email rso-ethics@uow.edu.au.

Yours sincerely,

Emma Barkus

Associate Professor Emma Barkus,
Chair, UOW & ISLHD Social Science Human Research Ethics Committee

The University of Wollongong and Illawarra and Shoalhaven Local Health District Social Sciences HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research.
Appendix B: UOW Ethics amendment approval

HREC Approval of Amendment to Application 2019/288
rso-ethics@uow.edu.au <rso-ethics@uow.edu.au>
Tue 2/2/2021 3:02 PM
To: Tony Okely <tokely@uow.edu.au>
Cc: Anne-Maree Parrish <aparrish@uow.edu.au>; Yazeed Alanazi <yana918@uowmail.edu.au>; Tony Okely <tokely@uow.edu.au>; RISO Ethics rso-ethics@uow.edu.au

Dear Professor Okely,

I am pleased to advise that the amendment request submitted on 25/01/2021 to the application detailed below has been approved.

Please be aware that prior to conducting any part of this research face-to-face, the current UOW requirement is that all researchers must complete a COVID-19 Safe Work Plan and have the document signed off by an appropriate WHS signatory. This plan is a mandatory requirement and was introduced by University Management on 2 July. The COVID-19 Safe Work Plan document is accessible from the Intranet here https://intranet.uow.edu.au/coronavirus/returning-to-campus/index.html, and should be submitted to whs-admin@uow.edu.au. Please add your HREC reference number to the document. Once endorsed, WHS will forward the plan onto the Ethics Office for final approval.

Please note, as COVID-19 is an ever evolving health crisis, there may be times when it is necessary to cease face-to-face research activities again in the future. With this in mind, we ask that you regularly refer to the UOW COVID-19 webpage for up to date information regarding UOW research activities.

Ethics Number: 2019/288
Amendment Approval Date: 02/02/2021
Project Expiry Date: 02/09/2021
Project Title: Associations between 24-hour movement behaviours (physical activity, sedentary behaviour, and sleep) and health among children in the Kingdom of Saudi Arabia.
Researcher/s: Parrish Anne-Maree; Alanazi Yazeed; Okely Anthony
Documents Approved: Parent Questionnaire V4 - 25012021
Amendments Approved: Permission to collect follow-up phase data of 24-hour movement behaviours

The HREC has reviewed the research proposal for compliance with the National Statement on Ethical Conduct in Human Research and approval of this project is conditional upon your continuing compliance with this document. Compliance is monitored through progress reports; the HREC may also undertake physical monitoring of research.
Please remember that in addition to submitting proposed changes to the project to the HREC prior to implementing them the HREC requires:

- Immediate report of serious or unexpected adverse effects on participants.
- Immediate report of unforeseen events that might affect the continued acceptability of the project.
- The submission of an annual progress report and a final report on completion of your project.

If you have any queries regarding the HREC review process or your ongoing approval please contact the Ethics Unit on 4221 3366 or email riso-ethics@uow.edu.au.

Yours sincerely,

Natascha Klockner

Associate Professor Natascha Klockner,
Chair, UOW & ISLHD Social Sciences Human Research Ethics Committee

The University of Wollongong and Illawarra and Shoalhaven Local Health District Social Sciences HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research.
Appendix C: UOW Ethics renewal approval

Renewal Approval for Application 2019/288
rso-ethics@uow.edu.au <rso-ethics@uow.edu.au>
Mon 8/30/2021 10:24 AM
To: Tony Okely <tckely@uow.edu.au>
Cc: Anne-Maree Parrish <aparrish@uow.edu.au>; Yazeed Alanazi <yana918@uowmail.uow.edu.au>; RSO Ethics rso-ethics@uow.edu.au

Dear Professor Okely,

Thank you for submitting the progress report. I am pleased to advise that renewal of the following Human Research Ethics application has been approved.

Currently face-to-face research is not permitted. Please see the ‘Stay at home orders’ for details.

If you have been undertaking or planning face-to-face research this must pause. Face-to-face research cannot resume until a formal directive has been published by the University. There are some limited situations where research may not contravene ‘Stay at home orders’, for example where it is taking place in the context of existing clinical care and does not require people leaving their residence for anything other than clinical care. If you think your research may not be in contravention of the current health orders, please submit a ‘risk assessment request’ through UOW WHS for consideration.

When face-to-face research resumes, if it has not been approved in your original protocol you must submit an amendment to the HREC for approval at that time. Please be aware that for any future data collection that occurs face-to-face, the current UOW requirement is that all researchers must complete a COVID-19 Safe Work Plan and have the document signed off by an appropriate WHS signatory. The document is accessible from the Intranet here https://intranet.uow.edu.au/coronavirus/returning-to-campus/index.html, and should be submitted to whs-admin@uow.edu.au. The COVID-19 Safe Work Plan also requires Ethics approval prior to face-to-face research commencing/recommencing.

Ethics Number: 2019/288

Project Title: Associations between 24-hour movement behaviours (physical activity, sedentary behaviour, and sleep) and health among children in the Kingdom of Saudi Arabia.

Researcher/s: Parrish Anne-Maree; Alanazi Yazeed; Okely Anthony

Renewed From: 03/09/2021

New Project Expiry Date: 02/09/2022
Please note that approvals are granted for a twelve month period. Further extension will be considered on receipt of a progress report prior to the expiry date.

This certificate relates to the research protocol submitted in your original application and all approved amendments to date. Please remember that in addition to completing an annual report, the Human Research Ethics Committee also requires that researchers immediately report:

- proposed changes to the protocol including changes to investigators involved
- serious or unexpected adverse effects on participants
- unforeseen events that might affect continued ethical acceptability of the project

A condition of approval by the HREC is the submission of a progress report annually and a final report on completion of your project. This progress report must be submitted by accessing the IRMA system prior to the expiry date.

Yours sincerely,

Natascha Klocker

Associate Professor Natascha Klocker,
Chair, UOW & ISLHD Social Sciences Human Research Ethics Committee

The University of Wollongong and Illawarra and Shoalhaven Local Health District Social Sciences HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research.
Appendix D: Ethics approval (The Ministry of Education in Saudi Arabia)

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عنوان الدراسة: (الاتصالات بين سلوكيات الحركة على مدار 24 ساعة (النشاط البدني، التوأم، السلوكي المستمر) وصحة الأطفال في المملكة العربية السعودية.)

عينة الدراسة: طلاب وطالبات

ال المحكمة قائد المدرسة الإبتدائية

السلام عليكم ورحمة الله وبركاته ، وبعد:

إشارة إلى قرار مجلس ووزير التعليم رقم 287/2012 و6/09/2012، بشأن تدوين السلامة健康管理chart_18748c.jpg

لمديرية التعليم، وبناءً على قرار إعادة مدير عام التعليم بمنطقة الرياض رقم 287/2012 و6/09/2012، بشأن تدوين السلامة健康管理chart_18748c.jpg

الإدارة العامة للتعليم، وتنوي العام للتعليم، وتنوي العام للتعليم.

في هذه الظروف، نأمل تسهيل مهامه.

مع ملاحظة أن الباحثة تحتوي حالة المسؤولية المتعلقة بمختلف جوانب البحث، ولا يعني سماح الإدارة العامة للتعليم موافقتها بالضرورة على مشكلة البحث أو على الطرق والأساليب المستخدمة في الأبحاث وعلاجه.

شكراً لكم ونقبلوا تحياتنا.

سعود بن راشد العبد الصغير

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Appendix E: Ethics approval of online parent questionnaire (The Ministry of Education in Saudi Arabia)
LETTER INFORMATION AND CONSENT FORM FOR PARENTS/LEGAL GUARDIANS

Dear Parent/Legal Guardian

You are invited to participate in a research project conducted by a student pursuing a doctoral degree from the University of Wollongong, Australia. The project is entitled *Associations between 24-hour movement behaviours (physical activity, sedentary behaviour, and sleep) and health among children in the Kingdom of Saudi Arabia.*

PURPOSE OF THE RESEARCH

The purpose of the research is to investigate whether the 24-hour composition of movement behaviours (sleep, physical activity, sedentary behaviour) are associated with children’s health and development.

INVESTIGATORS

Professor Anthony Okely  
Chief Investigator  
Faculty of Social Sciences  
(02) 4221 4641  
tokely@uow.edu.au

Dr Anne-Maree Parrish  
Co-investigator  
Faculty of Social Sciences  
(02) 4221 5098  
aparrish@uow.edu.au

Yazeed Alanazi  
PhD Student  
Faculty of Social Sciences  
0413362469  
yana918@uow.edu.au

METHOD AND DEMANDS ON PARTICIPANTS

Parent/legal guardian who choose to participate in this study will be asked to do the following:

1. Parent questionnaire

You will be asked to report your child’s use of electronic media, bed and wake times, sleep quality, and restrained sedentary time, and physical activity during COVID-19 virus. We will also ask about your education background and your relationship to the child. This questionnaire should not take more than 10 minutes.

FUNDING AND BENEFITS OF THE RESEARCH

This research is being funded by the Saudi Arabian Cultural Mission in Canberra, Australia, and will provide valuable information about how children spend time in different movement behaviours and how this relates to their health and wellbeing. Findings from this research will be used in a doctoral thesis, published in academic journals and presented in conferences. The research will not report on any details of an individual student or school. All aspects of your child’s information will remain confidential and he/she will not be identified in any part of the
research. All information pertaining to the measures will be securely stored at the University of Wollongong and will only be accessed by the research team.

I have been advised of the potential risks and burdens associated with this research. I have had an opportunity to ask the researcher any questions I may have about the research.

I am aware that if I have enquiries about the research, I can contact Yazeed Alanazi on or yana918@uowmail.edu.au. If I have any concerns or complaints regarding the way this research has been conducted, I can contact the UOW Ethics Officer, Social Sciences Human Research Ethics Committee of the University of Wollongong on (02) 4221 3386 or email iso-ethics@uow.edu.au.

By starting this online questionnaire, I am indicating my consent to participate in this research. I understand that the data collected from me and my child will be used primarily for a doctoral thesis, and also will be used in summary form for conference presentations and journal publications, and I consent for it to be used in that manner. I understand that any individual data about my child will not be published.

Thank you for your interest in this study.
CONSENT FORM FOR PARENTS/LEGAL GUARDIANS

Research Title: Associations between 24-hour movement behaviours (physical activity, sedentary behaviour, and sleep) and health among children in the Kingdom of Saudi Arabia.

Researchers: Professor Anthony Okely, Dr Anne-Maree Parrish, and Mr. Yazeed Alanazi
I have been given information about the above entitled research, which is part of a PhD project for Yazeed Alanazi supervised by Professor Anthony Okely, Dr Anne-Maree Parrish in the Faculty of Social Sciences at the University of Wollongong, Australia. I understand that the data collected will be used to provide information about how children spend their time during a 24-hour period when they are asleep, sitting and being physically active, and whether the 24-hour composition of movement behaviours (sleep, physical activity, sedentary behaviour) associated with children’s health and development.

I understand that, if I consent to my child participating in this project, he/she will be asked to participate in the following activities in the two phases (baseline and 12-month follow-up):

1. **Weight and height measurements.**
Body mass and height will be measured following the WHO standardized procedures with the participants in light clothing and without shoes.

2. **Generative accelerometers.**
GENEActiv is small, wrist-worn, lightweight (16g), and waterproof device.

3. **Gross motor skills** will be assessed using the third edition of the Test of Gross Motor Development (TGMD-2).

4. **Bone mineral density** will be assessed (in the arm) by using the Sunlight MiniOme device to measure the amount of minerals (mostly calcium and phosphorous).

5. **Executive Function** will be assessed using the Backward Span Task (working memory), Stroop Task (inhibition), and Trail-Making Test (shifting) to measure young children’s emerging cognitive, self-regulatory.

6. **Parent questionnaire**
I understand that I, as the parent/legal guardian, will be asked to do the following:

1. Provide demographic information such as my child’s sex, date of birth, cultural background, and home postcode for the purpose of data analysis by completing questions at the end of this consent form.
2. Report my child’s use of electronic media, bed and wake times, sleep quality, and restrained sedentary time.
I have been advised of the potential risks and burdens associated with this research. I have had an opportunity to ask the researcher any questions I may have about the research and my child’s participation.

I understand that my child’s participation in this research is voluntary; this means that he/she is free to refuse to participate and is free to withdraw from the research at any time.

I am aware that if I have enquiries about the research or my child wishes to withdraw from the study, I can contact Yazeed Alanazi on . . . . . . . If I have any concerns or complaints regarding the way this research has been conducted, I can contact the UOW Ethics Officer, Social Sciences Human Research Ethics Committee of the University of Wollongong on (02) 4221 3386 or email rso-ethics@uow.edu.au.

By signing below I am indicating my consent for my child ___________ to participate in the research. I understand that the data collected from my child will be used primarily for a doctoral thesis, and also will be used in summary form for conference presentations and journal publications, and I consent for it to be used in that manner. I understand that any individual data about my child will not be published.

I hereby consent to my child ___________ (School), _______ (Class) participating in the study “Associations between 24-hour movement behaviours (physical activity, sedentary behaviour, and sleep) and health among children in the Kingdom of Saudi Arabia “, conducted by the University of Wollongong.

_________________________ Date: _________
Signed on behalf of Parent/Guardian:
Name of parent/guardian: ____________________________ Date: __________

Signature of Child
Name of child: ____________________________

Please complete the following details:
Sex of the child: □ Male □ Female
Date of birth: ______ Day ______ Month ______ Year
Cultural background: ____________________________ Home postcode: __________
Mobile phone number (For SMS reminders purpose):
□ Parent: ____________________________ □ Child: ____________________________
What is your preferred method of contact for the delivery of consent form during follow-up phases?
□ Postage (Please provide your residential address: ____________________________)

□ Email (Please provide your email address: ____________________________
LETTER OF INFORMATION TO SCHOOL PRINCIPALS

Dear Principal

We would like to invite Second Grade students at your school to participate in a research project conducted by a student pursuing a doctoral degree from the University of Wollongong, Australia. The project is entitled *Associations between 24-hour movement behaviours (physical activity, sedentary behaviour, and sleep) and health among children in the Kingdom of Saudi Arabia.*

We write to seek your approval and assistance to conduct this research.

PURPOSE OF THE RESEARCH

The purpose of the research is to investigate whether the 24-hour composition of movement behaviours (sleep, physical activity, sedentary behaviour) are associated with children's health and development.

METHOD AND DEMANDS ON PARTICIPANTS

The students who choose to be involved will participate in the following activities in two phases (baseline and 12-month follow-up). (Trained research staff from King Saud University will conduct all assessments):

1. **Weight and height measurements.**
   Body mass and height will be measured following the WHO standardized procedures with the participants in light clothing and without shoes.

2. **Generative accelerometers.**
   GENEActiv is small, wrist-worn, lightweight (16g), and waterproof device.

3. **Cross motor skills** will be assessed using the third edition of the Test of Gross Motor Development (TGMD-2). It will take ~15 min to assess each child.

4. **Bone mineral density** will be assessed (in the arm) using *Beammed Sunlight MiniOmni* device to measure of the amount of minerals (mostly calcium and phosphorous).

5. **Executive Function** will be assessed using the Backward Span Task (working memory), Stroop Task (inhibition), and Trail-Making Test (shifting) to measure young children's emerging cognitive, self-regulatory.
6. Teacher questionnaire

Self-regulation
The child’s classroom teacher will be asked to complete the Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997). This questionnaire is designed to gather information on positive and negative psychological attributes across five scales in 3-16 year olds: emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems and prosocial behaviour. This questionnaire should not take more than 10 minutes (per child).

7. Parent questionnaire
Parents will report their child’s use of electronic media, bed and wake times, sleep quality, restrained sedentary time, and sociodemographic information.

POSSIBLE RISKS, INCONVENIENCES AND DISCOMFORTS
Apart from 50 minutes of student’s time for the activities at school and wearing an activity device, there are no risks involved. However, if a student experience feelings of distress as a result of participation in this study, he/she can tell the research staff and they will provide him/her with assistance. Trained research staff from King Saud University will conduct all assessments.

FUNDING AND BENEFITS OF THE RESEARCH
This research is being funded by the Saudi Arabian Cultural Mission in Canberra, Australia. The findings of this research will provide valuable information about how children spend time in different movement behaviours and their relationship with health and wellbeing. Findings from this research will be used in a doctoral thesis, published in academic journals and presented in conferences. The research will not report on any details of an individual student or school. All information pertaining to the measures will be securely stored at the University of Wollongong and will only be accessed by the research team.

WHAT IS REQUIRED OF SCHOOL?
As the Principal of your school, we encourage you to support your students to participate in this research project. The school will be required to distribute and collect the information sheets and consent forms to and from parents, and allow the research team to visit the school for two days in each phase to complete the assessments as described in this letter.

WITHDRAWAL FROM THE STUDY
Participation in this research is voluntary and any student may decline to participate or withdraw at any time. Every effort will be made to protect the privacy of students. School and students information will remain anonymous. If you have inquiries about the research, please contact Yazeed Alanazi by phone on (04) 13362469.

If you have any concerns or complaints regarding the way this research has been conducted, you can contact the UOW Ethics Officer on (02) 4221 3386 or email rso-ethics@uow.edu.au.

Yours sincerely,
Professor Anthony Okely
Chief Investigator
Faculty of Social Sciences
(02) 4221 4641
tckely@uow.edu.au

Dr Anne-Marie Parrish
Co-investigator
Faculty of Social Sciences
(02) 4221 5098
aparrish@uow.edu.au

Yazeed Alanazi
PhD Student
Faculty of Social Sciences
Faculty of Social Sciences
yana918@uowmail.edu

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CONSENT FORM FOR SCHOOL PRINCIPALS

Research Title: Associations between 24-hour movement behaviours (physical activity, sedentary behaviour, and sleep) and health among children in Saudi Arabia.

Researchers: Professor Anthony Okely, Dr Anne-Maree Parrish, and Mr. Yazeed Alanazi.

I have been given information about the above entitled research, which is part of a PhD project for Yazeed Alanazi supervised by Professor Anthony Okely, Dr Anne-Maree Parrish in the Faculty of Social Sciences at the University of Wollongong, Australia. I understand that the data collected will be used to provide information about how children spend their time during a 24-hour period when they are asleep, sitting and being physically active, and whether the 24-hour composition of movement behaviours (sleep, physical activity, sedentary behaviour) are associated with children’s health and development. I have been advised of the potential risks and burdens associated with this research. I have had an opportunity to ask the researcher any further questions I may have had about the research. I understand that the research will be fully explained prior to its implementation and that I will be able to ask questions about its delivery at that time. I understand that my student’s participation in this research is voluntary and they can withdraw from the study at any time without it affecting their relationship with the University of Wollongong in any way. I am aware that if I have enquiries about the research, I can contact Yazeed Alanazi on

If I have any concerns or complaints regarding the way this research has been conducted, I can contact the UOW Ethics Officer, Social Sciences Human Research Ethics Committee of the University of Wollongong on (02) 4221 3386 or email rso-ethics@uow.edu.au.

By signing below, approval is given for our school to participate and for teachers to complete questionnaires.

__________________________________________  Date: ____________________
Signature

Name: ______________________________________

School: ____________________________________
استبيان أربعة الأموات

معلومات لوالدي الأموات والإقرار بالموافقة على المشاركة في الدراسة

عازبة فيبنى في إناء الأمي، أحبها طقوس في...

له قبول المشاركة في دراسة تلقيها على مستوى المملكة ثم إجراءها بواسطة آليات م_beذين الطرفي المدنى (شاهد مكونات في جامعة وولونغونغ، أستراليا)، وحضور في كلما علم الإرشاد والنشاط الفني بخاطب النكورة في جامعة وولونغونغ.

الإعدادات، وضخامة في كلما علم الإرشاد والنشاط الفني بخاطب النكورة في جامعة وولونغونغ، أستراليا. لإعدادات "الإرشاد بين مراكز العمل على مر 24 ساعة (النشاط الفني، الانتقال البحري، والدوم) وصحة الأطفال في المملكة العربية السعودية خلال فترة جائحة كورونا (فيفير-19).

الناجحين من الدراسة: إنهاء هذه الدراسة من أجل وقوع الارتباك بين مراكز العمل (النشاط الفني، الانتقال البحري، والدوم) على مدار 24 ساعة وصحة وسلامة بيوم الأطفال في المملكة العربية السعودية خلال فترة جائحة كورونا.

الآراء:

• trollv@uow.edu.au

• sparrish@uow.edu.au

• yama919@uowmail.edu.au

كلية الآداب والعلوم الاجتماعية والبيئية، جامعة وولونغونغ، أستراليا
كلية الآداب والعلوم الاجتماعية والإنسانية، جامعة وارسو، استراليا.

المتوجهة: ستقع نكول كولز تجربة من خلال هذا الاستنتاج بناءً على مجموعة من الأسئلة التي تتعلق بمشاركة النساء في شؤون الأعمال في تجربة COVID-19، استدلال الأجهزة الإلكترونية. أوقات الاستماع والمسمى: جودة الوقت. أوقات السيطرة الشاملة (الحركة أو الجريمة). والثقافة المنهجية. الوقت المتوقع لاستكمال هذا الاستنتاج هو 5 دقائق. نتائج هذه الدراسة تشير إلى معلومات قيمة حول كتلة النساء والأعمال. ولاتباع، نحن نستدعي نتائج هذه الدراسة في أطراف المرأة الخاصة بالأعمال. وسوف نستثير بناءً على المعتقدات والمفاهيم المعدة. ستستفيد جميع المعلومات تلك سرية. وإن يتم تحديد موعدها نهائياً، ستتلمحز.

جميع المعلومات المقدمة بشكل مناسب من جامعة وارسو، وننتمي الوصول إليها إلا من خلال مكتب البحث.

لا يوجد أي مخاطر أو آثار ملموسة أو مرتبطة بهذا الاستنتاج. إذا كانت لدينا أي احتمالات حول الدخول المحتمل للدخول مع إجراء الجريزيTel: 05533881220 النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصلة، يرجى الاتصال بالمدرس الإقليمي أو الدور الإداري الإقليمي في إذاعة النشر في القسم لرسائل البحث أو الأعمال. إذا أتاحت للاستثناءات حول البحث في إثبات الصل
Appendix G: Parent questionnaire

PARENT QUESTIONNAIRE

*This questionnaire is to be administered/completed by the MAIN caregiver of the child who lives with them and is 6-12 years old at the time of interview. If you have more than one child aged between 6-12 years, please complete the questionnaire for the child whose birthday is next.*

### MODULE OF CHILD AND CAREGIVER BACKGROUND

<p>| | |</p>
<table>
<thead>
<tr>
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</table>
| .1 | What is the date of birth of the child?  
   | (dd/mm/yyyy)   /   /   |
| .2 | What is the sex of the child?  
   | □ Boy   □ Girl |
| 3. | Parent/caregiver’s relationship to the child participating in the study?  
   | □ Mother   □ Father   □ Other (please specify): …………………………………………….. |
| 4. | In which region in Saudi Arabia do you live?  
   | □ Riyadh   □ Makkah   □ Madinah   □ Qassim   □ Eastern región   □ Asir   □ Tabuk   □ Hail   □ The northern Border   □ Jazan   □ Najran   □ Al-Baha   □ Aljouf |
| 5. | What is the (parent/caregivers) date of birth?  
   | (dd/mm/yyyy)   /   /   |
| 6. | What is the highest level of parental education?  
   | □ No formal schooling   □ Primary school   □ High school   □ Bachelor’s degree   □ Master’s degree   □ PHD degree |
   | What is your monthly income (SAR)?  
   | □ 0-3000   □ 3000-7000   □ 7000-10,000   □ 10,000-15,000   □ 15,000-20,000   □ More than 20,000 |
| 7. | What is your nationality?  
   | □ Saudi   □ Non-Saudi |

The next questions ask about your child’s physical activity, sedentary behavior and sleep.

### Physical activity:

Physical activity is any activity that increases your child’s heart rate and makes them get out of breath some of the time. Physical activity can be done in sports, school activities, playing with friends, walking to school, brisk walking, riding a bike, skateboarding or scootering safely, and helping to dig in the garden.

For the next question, please add up all the time your child spent in physical activity each day.

**A:** Over the past 7 days, on how many days was your child physically active for a total of 0 days 1 day
at least 60 minutes per day?

Some examples of activities which strengthen muscles and bones are skipping, running, hopping and jumping, climbing or swinging on monkey bars, climbing frames, playing games like tug-o-war and hopscotch, doing structured activities like gymnastics and martial arts.

B- During the past 7 days, on how many days did your child do activities to strengthen their muscles and bones?

C- During the past 7 days, on average how much time per day did your child play outside?

<table>
<thead>
<tr>
<th>A</th>
<th>Over the past 7 days, on how many days did your child watch TV/ videos/ Internet using a smart phone or tablet or play video or computer games for entertainment for less than two hours while sitting or lying down?</th>
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<tr>
<td>0 days</td>
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<tr>
<td>1 day</td>
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<td>2 days</td>
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</tr>
<tr>
<td>7 days</td>
<td>days</td>
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9. **Sedentary behaviour:**

Sitting or lying down, (with the exception of sleeping), are what we call ‘sedentary’ behaviours. You can be sedentary at work, at school, at home, when travelling or during leisure time. Sedentary behaviour requires little energy expenditure. Examples of sedentary behaviour include:

- Sitting or lying down while watching television or playing electronic games.
- Sitting while being a passenger in a vehicle, or while travelling on a bus or train.
- Sitting or lying down to read, study, write, or work at a desk or computer.

For the next question, please add up all the time your child spent watching TV/ videos/Internet using a smart phone or tablet or playing video or computer games for entertainment each day.

<table>
<thead>
<tr>
<th>B</th>
<th>Over the past 7 days, on how many days did your child do activities to strengthen their muscles and bones?</th>
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<td>0 days</td>
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<td>7 days</td>
<td>days</td>
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<th>C</th>
<th>During the past 7 days, on average how much time per day did your child play outside?</th>
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<tr>
<td>0-&lt;1 hour</td>
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<td>1-&lt;2 hours</td>
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<td>2-&lt;3 hours</td>
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<td>3-&lt;4 hours</td>
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<td>4-&lt;5 hours</td>
<td>6</td>
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<td>5-&lt;6 hours</td>
<td>7</td>
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<tr>
<td>6 or more hours</td>
<td>days</td>
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<th>D</th>
<th>During the past 7 days, on how many days did your child do activities to strengthen their muscles and bones?</th>
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<th>E</th>
<th>During the past 7 days, on average how much time per day did your child play outside?</th>
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<tbody>
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<td>7</td>
</tr>
<tr>
<td>6 or more hours</td>
<td>days</td>
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10. Does your child use electronic screen devices (e.g. TV, video game, computer, tablet or smartphone) in the 2 hours before bedtime on a daily basis?
   □ Yes  □ No  □ Don’t know

11. If Yes, how close to bedtime does your child usually use these devices?
   □ Closer than 30 minutes before bedtime
   □ 30 mins to less than 1 hour before bedtime
   □ Between 1 and 2 hours before bedtime

12. Does your child have electronic screen devices in the room where he/she sleeps (e.g. TV, video game, computer, tablet or smartphone)?
   □ Yes  □ No

13. How often do you use a smartphone to make calls, text messages, check email, watch a video during meals with your child?
   □ Never  □ Less than once a week  □ Once a week  □ Most days  □ Every day  □ Don’t know

14. How often do you use a smartphone to make calls, text messages, check email, watch a video during bedtime routine with your child?
   □ Never  □ Less than once a week  □ Once a week  □ Most days  □ Every day  □ Don’t know

15. Sleep:
   What time did your child go to bed and turn the lights out to go to sleep last night?
   What time did your child wake up today?
   ……pm  ……am

16. On a scale of 1 to 7, with the higher number indicating higher quality, how would you rate the quality of your child’s sleep?
   1 would indicate very difficult to settle, wakes many times during the night for prolonged periods and is very restless (tosses and turns, throw off bedclothes) while 7 would indicate settles and drifts off to sleep with a few minutes, sleeps right through the night, and has a very sound, deep sleep)
   □ 1  □ 2  □ 3  □ 4  □ 5  □ 6  □ 7  □ Don’t know

17. How many hours of sleep does your child get in a typical 24-hours day (including naps)?
   ……hrs ……min

18a. Does your child have a consistent bedtime?
   □ Yes, bedtime does not vary by more than 30 minutes each day
   □ No, bedtime can vary more than 30 minutes each day

18b. Does your child have a consistent wake-up time?
   □ Yes, wake-up time does not vary by more than 30 minutes each day
   □ No, wake-up time can vary more than 30 minutes each day

19a. In the past three days, has your child: **Not** got enough sleep?
   □ Yes  □ No

19b. If Yes, was it because of: **(tick as many as appropriate)**
   □ Outside noise (like traffic/train/street noises)  □ Indoor noise
   □ Too Hot  □ Too cold  □ Too much light coming in to the room
   □ Other (please specify):
<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
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</thead>
<tbody>
<tr>
<td>Has your child or a member of your household been diagnosed with COVID-19 during the past 6 weeks?</td>
<td>☐ Yes ☐ No</td>
</tr>
<tr>
<td><strong>Compared to before the COVID-19 outbreak and related restrictions</strong>, my child is doing physical activities or sport outside?</td>
<td>☐ A lot less ☐ A little less ☐ About the same ☐ A little more ☐ A lot more</td>
</tr>
<tr>
<td><strong>Compared to before the COVID-19 outbreak and related restrictions</strong>, my child is doing physical activities or sport inside?</td>
<td>☐ A lot less ☐ A little less ☐ About the same ☐ A little more ☐ A lot more</td>
</tr>
<tr>
<td><strong>If your child is spending any time outside during the COVID-19 outbreak</strong>, where are the common places this outside time is being spent?</td>
<td>☐ Yard or driveway ☐ Parks within walkable distance ☐ Parks where you have to drive ☐ Sidewalks, or neighbourhood streets ☐ Other (Specify) ☐ Not Applicable</td>
</tr>
<tr>
<td><strong>Compared to before the COVID-19 outbreak and related restrictions</strong>, my child watches TV, movies, uses the computer for leisure or plays sedentary video games?</td>
<td>☐ A lot less ☐ A little less ☐ About the same ☐ A little more ☐ A lot more</td>
</tr>
<tr>
<td><strong>Compared to before the COVID-19 outbreak and related restrictions</strong>, my child uses social media?</td>
<td>☐ A lot less ☐ A little less ☐ About the same ☐ A little more ☐ A lot more</td>
</tr>
<tr>
<td><strong>Compared to before the COVID-19 outbreak and related restrictions</strong>, my child sleeps?</td>
<td>☐ A lot less ☐ A little less ☐ About the same ☐ A little more ☐ A lot more</td>
</tr>
<tr>
<td><strong>Compared to before the COVID-19 outbreak and related restrictions</strong>, my child’s sleep quality is?</td>
<td>☐ A lot worse ☐ A little worse ☐ About the same ☐ A little better ☐ A lot better</td>
</tr>
<tr>
<td><strong>Compared to before the COVID-19 outbreak and related restrictions</strong>, the balance of my child’s overall healthy movement behaviours (i.e., physical activity, sedentary behaviours, and sleep) are?</td>
<td>☐ A lot worse ☐ A little worse ☐ About the same ☐ A little better ☐ A lot better</td>
</tr>
<tr>
<td><strong>As a result of the COVID-19 outbreak and related restrictions</strong>, is there an inside leisure activity or hobby that your child is doing a lot more now?</td>
<td>☐ Yes (please specify): ☐ No</td>
</tr>
<tr>
<td><strong>As a result of the COVID-19 outbreak and related restrictions</strong>, is there an outside leisure activity or hobby that your child is doing a lot more now?</td>
<td>☐ Yes (please specify): ☐ No</td>
</tr>
<tr>
<td><strong>As a result of the COVID-19 outbreak and related restrictions</strong>, has there been a decrease in your child’s health (e.g., existing condition worsened or new condition developed)?</td>
<td>☐ Yes (please specify): ☐ No</td>
</tr>
</tbody>
</table>
Appendix H: Authors’ Contributions

Article 1 (Chapter 4)
Yazeed Alanazi was involved in developing the research question, developing the PROSPERO protocol, development and testing of the search strategy, extraction of literature from databases, reviewing literature, conducting the risk of bias assessment, synthesizing results and drafting the manuscript. Dr. Eduarda Sousa-Sá and Dr. Kar Hau Chong were involved in reviewing literature and conducting the risk of bias assessment. Professor Anthony Okely and Dr. Anne-Maree Parrish were involved in developing the research question, developing the PROSPERO protocol, reviewing the search strategy and providing advice on the risk of bias assessment. All authors reviewed and approved the final manuscript.

Article 2 (Chapter 5)
Yazeed Alanazi was involved in developing the research question, gaining ethical approvals, data collection, data cleaning, development of the analytic strategy, analysis of data, interpretation of findings and drafting the manuscript. Professor Anthony Okely and Dr. Anne-Maree Parrish were involved in developing the research question, providing advice on data analysis and interpreting findings. All authors reviewed and approved the final manuscript.

Article 3 (Chapter 6)
Yazeed Alanazi was involved in developing the research question, gaining ethical approvals, data collection, data cleaning, development of the analytic strategy, analysis of data, interpretation of findings and drafting the manuscript. Professor Anthony Okely and Dr. Anne-Maree Parrish were involved in developing the research question, providing advice on data analysis and interpreting findings. All authors reviewed and approved the final manuscript.

Article 4 (Chapter 7)
Yazeed Alanazi was involved in developing the research question, gaining ethical approvals, data collection, cleaning, development of the analytic strategy, analysis of data, interpretation of findings and drafting the manuscript. Professor Anthony Okely and Dr. Anne-Maree Parrish were involved
in developing the research question, providing advice on data analysis and interpreting findings. All authors reviewed and approved the final manuscript.

Co-authors signatures

*The candidate and all co-authors hereby agree with the author contributions statement*

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<th>Yazeed A. Alanazi</th>
<th>Professor Anthony D. Okely</th>
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<th>Assoc. Prof. Anne-Maree Parrish</th>
<th>Dr. Eduarda Sousa-Sá</th>
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<th>Dr. Kar Hau Chong</th>
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Appendix I: The published article - Systematic Review of the Relationships between 24-Hour Movement Behaviours and Health Indicators in School-Aged Children from Arab-Speaking Countries

Systematic Review of the Relationships between 24-Hour Movement Behaviours and Health Indicators in School-Aged Children from Arab-Speaking Countries

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Abstract: The Australian and Canadian 24-hour movement guidelines for children and youth synthesized studies in English and French or other languages (if able to be translated with Google translate) and found very few studies published in English from Arabic countries that examined the relationship between objectively measured sedentary behaviour (SB), sleep and physical activity (PA) and health indicators in children aged 5–12 years. The purpose of this systematic review was to investigate the relationships between 24-hour movement behaviours and health indicators in school-aged children from Arab-speaking countries. Online databases MEDLINE, EMBASE, SPORTdiscus, CINAHL, PsycINFO and Scopus were searched for English, French and Arabic studies (written in English), while Saudi Digital Library, ArabBase, HumanIndex, KSUP, Pan-Arab Academic Journal, e-Marefa, Al Manhal eLibrary and Google Scholar were searched for Arabic studies. The Grading of Recommendation Assessment, Development and Evaluation framework was used to assess the risk of bias and the quality of evidence for each health indicator. A total of 16 studies, comprising 15,346 participants from nine countries were included. These studies were conducted between 2000 and 2019. In general, low levels of PA and sleep and high SB were unfavourably associated with adiposity outcomes, behavioural problems, depression and low self-esteem. Favourable associations were reported between sleep duration and adiposity outcomes. PA was favourably associated with adiposity outcomes, withdrawn behaviour, attention and externalizing problems. PA was favourably associated with improved self-esteem and adiposity outcomes. Further studies to address the inequality in the literature in the Arab-speaking countries to understand the role of 24-hour movement behaviours and its positive influence on health outcomes across childhood are urgently needed.

Keywords: movement behaviours; child; sleep; sedentary behaviour; physical activity; Arab

1. Introduction

For years, movement guidelines for children and adolescents have concentrated on moderate- to vigorous-intensity physical activity (MVPA) [1]. However, focusing on PA per se and omitting other movement behaviours, such as SB and sleep, has reduced our perception of how these daily movement behaviours interact to affect children’s health [2].
Hence, an approach that integrates all components of movement behaviours is required to review their combined influence on health and development [2].

In 2016, the Canadian Society for Exercise Physiology released the world’s first integrated 24-hour movement guidelines for children and youth (5–17 years) [3]—a new concept describing the integration of PA, SB and sleep over the 24-hour period. This terminology is regarded as a shift in daily movement behaviour research and illustrates an evolution in PA guidelines [3]. These guidelines were launched based on the results of four systematic reviews, investigating associations between PA, SB, sleep, and movement combinations, each one with health indicators [3]. The authors found that children’s total PA was favourably associated with physical, psychological/social, and cognitive health indicators [4]. Higher levels of TV and screen time viewing were associated with unfavourable body composition, cardio-metabolic disease risk scores, hostile behavioural conduct/pro-social behaviour indicators, lower fitness and self-esteem in children [5]. Shorter sleep duration was associated with poorer health outcomes [6]. Children who had higher levels of PA and sleep and less SB had more desirable measures of adiposity and cardiometabolic health when compared with those with a combination of low PA and low sleep and high SB. Similarly, those with high PA and high sleep or high PA and low SB profiles demonstrated favourable health indicators compared with low PA and low sleep, or low PA and high SB profiles [7].

In 2018, the literature on 24-hour movement guidelines was updated as part of the development of Australian 24-Hour Movement Guidelines for Children and Young People [8]. These guidelines were launched as evidence-based guidelines to address movement behaviours observed over the whole day instead of focusing on these behaviours in isolation. Previous studies only captured specific movement behaviours (e.g., MVPA) during waking hours—which accounts for a small portion of children’s daily activity (~5%) in the 24-hour period; while sleep (~40%), SB (~40%) and LPA (~15%) make up nearly 95% of the day [2]. Furthermore, these guidelines were launched based on the results of systematic reviews that synthesized studies in English and French or other languages if able to be translated with Google translate, and found very few studies published in English or French from Arabic countries that examined the relationship between objectively measured SB, sleep and PA and health indicators in children aged 5–12 years. The search criteria did not elicit any studies published in Arabic from Arab countries.

Even though more than 140 million children live in the 22 Arabic countries [9], where there are high and increasing levels of childhood obesity and sedentary behaviour [10,11], the lack of evidence from these countries confirms that research is needed to address this gap in the literature, to understand the role of 24-hour movement behaviours and its influence on important health outcomes (obesity, executive functions, motor development and bone health) across the years of primary school. Moreover, it is likely there may be cultural differences in 24-hour movement behaviours in Arabic countries compared to Western countries, necessitating a separate review. Therefore, the purpose of this systematic review was to investigate the relationship between 24-hour movement behaviours and health indicators in school-aged children in Arabic countries.

2. Methods

This systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO; Registration no. CRD42020143101). It was conducted and reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement for reporting systematic reviews and meta-analyses [12]. The protocol of this study was adopted partly from the systematic review performed by Saunders et al. [7].

2.1. Eligibility Criteria

Eligible participants included apparently healthy children aged 5 to 12 years old. Overweight and/or obese children were also included. Studies where the sample were aged
above 12 years or below 5 years were included if the mean age was between 5-12 years. To be included, studies had to be peer-reviewed, published, written in Arabic, English or French and reported subjective or objective measurement of PA or SB or sleep or their combination. Grey literature, student dissertations or conference abstracts were excluded. The main outcomes were adiposity, cardiometabolic biomarkers, fitness, behavioural conduct/pro-social behaviour, emotional regulation/psychological distress, cognition (academic achievement), quality of life and injuries. Secondary outcomes included bone density, motor skill development and self-esteem. The review was limited to full manuscripts. There was no minimum sample size. All study designs were included. Twenty-four-hour movement behaviours incorporate sleep, SB and PA, which are independently defined as:

Sleep: “a naturally recurring state of body and mind characterized by altered consciousness, relatively inhibited sensory activity, inhibition of nearly all voluntary muscles and reduced interactions with surroundings”. [13]

SB: “any waking behaviour characterized by an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture”. [14]

PA: “any bodily movement produced by skeletal muscles that results in energy expenditure above the resting metabolic rate”. [15]

2.2. Search Strategy

Six electronic databases were searched from January, 1990 to January, 2021 to identify relevant articles that were written in English or French: MEDLINE, EMBASE, SPORTdiscus, CINAHL, PsycINFO and Scopus. Eight electronic databases were searched for Arabic studies: Saudi Digital Library, ArabBase, Human Index, KSUP, Pan-Arab Academic Journal, e-Marefa, Al Manhal eLibrary and Google Scholar. Search terms can be seen in the Appendix A.

2.3. Data Extraction

Studies were imported into Endnote X9 software (Thomson Reuters, San Francisco, CA, USA). After de-duplication, three authors (YA, ESS and KHC) screened titles and abstracts for relevant studies. Full-text copies of the eligible studies were assessed for final inclusion. Any disagreement between the three authors was resolved through a discussion and, when necessary, included a fourth author. The reference lists of all included studies were screened for additional studies not listed in the database search. Data were extracted for each study using an Excel spreadsheet; each study included article, author, study design, publication year, location, sample size, age, mean age, gender, outcomes and measures, study instrument and results (Table 1).

2.4. Quality Assessment

Three authors (YA, ESS and KHC) independently assessed the risk of bias (ROB) using the GRADE framework (Grading of Recommendations Assessment, Development, and Evaluation), which was also used to assess the quality of evidence for each health indicator. GRADE does not have an official tool for assessing ROB in observational studies but recommends the types of study characteristics to be evaluated [16]. The quality of evidence was assessed for each included study design based on selection bias, attrition bias, detection bias, performance bias, and selective reporting bias. Quality of evidence scores were considered “low” for experimental and observational studies. Scores above 6/8 were considered as having low risk of bias.
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<tr>
<th>Literature Reference and Country</th>
<th>Study Design</th>
<th>Sample Size (% Female); Mean Age or Age Range (Years)</th>
<th>Type of Behaviour</th>
<th>Exposure and Assessment Instrument</th>
<th>Outcomes</th>
<th>Statistical Analysis &amp; Confounders (if Reported)</th>
<th>Main Results</th>
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<tr>
<td>Al-Hazzaa et al., (2019) Saudi Arabia [17]</td>
<td>Cross-sectional</td>
<td>1055 (51.1% female); mean age = 9.2 ± 1.7</td>
<td>Sleep</td>
<td>Sleep: Parent-proxy reported average sleep duration per night (&lt; 9 h vs. ≥ 9 h).</td>
<td>Adiposity: body weight (kg) and BMI.</td>
<td>Logistic regression analysis. Confounders: body weight, age and gender.</td>
<td>No significant association between sleep duration and overweight or obesity status (OR = 1.00; 95% CI 0.71 to 1.64; p = 0.77).</td>
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<td>Al-Hazzaa, (2007) Saudi Arabia [18]</td>
<td>Cross-sectional</td>
<td>296 (100% male); mean age = 10.3 ± 1.3</td>
<td>PA</td>
<td>PA: Pedometer measured steps taken/day.</td>
<td>Adiposity: BMI, skinfold measurements (triceps and subscapular, body fat %, FMI and FMFI).</td>
<td>Pearson’s correlation. Confounders: age, gender, daily pedometer counts and total energy expenditure.</td>
<td>Significant negative associations between step counts/day and body fat% (r = −0.207; p = 0.006), BMI (r = −0.214; p = 0.006), but not with FMI (r = −0.089; p = 0.251).</td>
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<tr>
<td>Hassan and Al-Kharaysy, (2006) Oman [19]</td>
<td>Pilot study</td>
<td>109 (100% male); mean age = 9.68 ± 0.42</td>
<td>PA and SB</td>
<td>PA: Leisure time spent activities personal activity score (hours/week) assessed with 2.6-km run/walk. SB: Parent-proxy reported duration of TV watching and/or playing video or computer games.</td>
<td>Fitness: cardiorespiratory endurance. Adiposity: Log sum of 5 skinfold measurements (triceps, subscapular, suprailiac, abdominal and thigh).</td>
<td>Pearson correlation coefficients.</td>
<td>Personal activity score has a strong negative correlation with the time to complete the 2.6 km run/walk and the sum of skinfolds (r = −0.40; p = 0.001). No significant associations between TV watching hours and fitness or fitness (p = n.s.).</td>
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<td>Hadhood et al., (2016) Egypt [20]</td>
<td>Cross-sectional</td>
<td>711 (54.5% female); mean age = 10.36 ± 1.9</td>
<td>PA</td>
<td>PA: Parent-proxy reported weekly practice of physical exercise.</td>
<td>Adiposity: BMI and body weight.</td>
<td>Chi square test.</td>
<td>No significant association between physical exercise and overweight and/or obesity (p = 0.19).</td>
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<tr>
<td>Badawi et al., (2013) Egypt [21]</td>
<td>Cross-sectional</td>
<td>852 (50.2% female); mean age = 9.5 ± 1.8</td>
<td>PA and SB</td>
<td>PA: Parent-proxy reported practice of sports, and transportation to school. SB: Parent-proxy reported time spent watching TV.</td>
<td>Adiposity: BMI and body weight.</td>
<td>t-test, ANOVA test.</td>
<td>Significant association between low PA and BMI (p &lt; 0.001). Significant association between SB and BMI (p &lt; 0.001).</td>
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<tr>
<td>Al-Lhabban et al., (2019) Palestine [22]</td>
<td>Cross-sectional</td>
<td>1320 (48% female); mean age = 9.5 ± 1.5</td>
<td>PA and SB</td>
<td>PA: Parent-proxy reported daily PA (min), mode of transport to school. SB: Parent-proxy reported screen time (min).</td>
<td>Adiposity: BMI and body weight.</td>
<td>Chi square test. Confounders: transporting means to school, total screen time, total PA time and age.</td>
<td>Significant association between levels of PA (transportation means only) and BMI (p = 0.031). Screen time had no significant effect on BMI, however, it had a borderline effect (p = 0.009).</td>
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<td>Literature Reference and Country</td>
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<td>Jemas et al. (2018), Tunisia [23]</td>
<td>Cross-sectional</td>
<td>40 (47.5% female); mean age = 9.34 ± 0.94</td>
<td>PA and SB</td>
<td>PA and SB: Accelerometer measures (IPA, MPI, VPA, MVPA); Subjective measures (from PA Questionnaire for Older Children (PAQ-C) score and intensity classification).</td>
<td>Adiposity: % fat mass.</td>
<td>Pearson Correlation coefficient.</td>
<td>The average MFVPA showed a negative significant correlation with body fat% (r = −0.343, p = 0.030). The score of PA determined by PAQ-C was not significantly correlated with the body fat% (r = −0.227, p = 0.138).</td>
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<td>Alatt et al. (2009), Iraq [24]</td>
<td>Case-control</td>
<td>2184 (male and female); 7-13 (age range)</td>
<td>SB</td>
<td>SB: Parent proxy reported watching TV (≥3 h/day) via questionnaire.</td>
<td>Adiposity: BMI-defined overweight/obese.</td>
<td>Chi-square test. Confounders: age, birth rank, type of feeding during infancy, dietary patterns, pattern of PA, and working after school time.</td>
<td>Watching TV (≥3 h/day) was a significant factor for overweight in 7-9 year males (χ² = 19.69, 95% CI 1.79 to 6.97, p &lt; 0.005).</td>
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<tr>
<td>Alam (2008), Saudi Arabia [25]</td>
<td>Cross-sectional</td>
<td>1072 (100% female); 8-12 (age range)</td>
<td>SB</td>
<td>SB: Parent proxy reported duration of TV watching via questionnaire.</td>
<td>Adiposity: BMI and body weight.</td>
<td>Chi-square test.</td>
<td>Watching TV (≥2 h/day) was significantly higher among obese students (χ² = 12.96, p = 0.011).</td>
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<tr>
<td>Alexa et al. (2018), Qatar [30]</td>
<td>Cross-sectional</td>
<td>204 (62.1% female); mean age = 9.0 ± 1.2</td>
<td>Sleep and SB</td>
<td>Sleep: weekday sleep duration. SB: SB time assessed with wrist Actigraphy/Technology Use Questionnaire.</td>
<td>Adiposity: BMI z-score, waist circumference, neck circumference, body fat% and fat mass.</td>
<td>Multiple linear regression. Confounders: objective estimate of sedentariness, dietary habits, age, sex, ethnicity and total technology use.</td>
<td>Significant associations between sleep duration and sleep insufficiency (≤8 h) and all indicators of obesity (p &lt; 0.001) except for neck circumference. Waist circumference (cm) yielded the largest effect: β = 4.99, p &lt; 0.001 (average sleep duration) and β = 6.29, p &lt; 0.001 (≤8 h). Sleep duration variation (light-to-heavy sleep duration variability) was not significantly associated with any outcome. Poor sleep efficiency was positively associated with body fat percentage (β = 2.20, p = 0.028).</td>
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<tr>
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<td>Al-Kutbe et al., (2017) Saudi Arabia [27]</td>
<td>Cross-sectional</td>
<td>206 (100% female); 8-11 (age range)</td>
<td>PA and SB</td>
<td>PA and SB: Number of steps taken/day with accelerometer (WCGES-RFA/Actigraph).</td>
<td>Adiposity: body weight (kg).</td>
<td>Multiple linear regression. Confounders: daily energy intake, daily total energy expenditure, body weight, age and family income.</td>
<td>No association between the number of steps or the time spent in MVPA and body weight (β = 0.014; p = 0.575), body height (β = 0.368).</td>
</tr>
<tr>
<td>Al-Hazzaa and Almohaidi, (2017) Saudi Arabia [28]</td>
<td>Cross-sectional</td>
<td>226 (53.6% female); mean age = 5.19 ± 0.85</td>
<td>PA and SB</td>
<td>PA, Pedometer measured steps taken/day: SB: Parent proxy reported duration of TV watching/day via questionnaire.</td>
<td>Adiposity: BMI, skinfold measurements (triceps, subscapular, suprailiac and ratio), FMI%, FMF%, FMR and FMII.</td>
<td>One-way ANOVA and post hoc test (Schete). Confounders: body size for FMI and FMII only.</td>
<td>No significant differences between obese and non-obese children in steps counts/day (p = 0.309). No significant difference between active and inactive preschool children in any of the measured anthropometric and body composition variables (body weight (p = 0.644), BMI (p = 0.193), triceps skinfold (p = 0.730), subscapular skinfold (p = 0.814), subscapular/suprailiac ratio (p = 0.648), fat mass (p = 0.644), fat-free mass (p = 0.744), FMI (p = 0.859), FMF (p = 0.886). Obese children spent significantly more time watching TV (197.5 ± 89.3 min/day) than their non-obese peers (150.0 ± 60.9 min/day) (p = 0.001).</td>
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<tr>
<td>Al-Qaderi et al., (2016) Kuwait [29]</td>
<td>Longitudinal study</td>
<td>837 in 1st phase and 6,060 in 2nd phase (61.4% female); 8-11 at visit 1, 10-12 at follow up (age range)</td>
<td>Sleep</td>
<td>Sleep: Lifestyle habits interview reported daily sleep hours, TV and video game use.</td>
<td>Adiposity: Waist circumference.</td>
<td>Multilevel longitudinal linear regression model. Confounders: age and gender.</td>
<td>Short sleep duration was significantly associated with increased waist circumference (β = -0.115; 95% CI 0.14 to 0.17; p &lt; 0.005).</td>
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<td>Al-Ghamdi, (2013) Saudi Arabia [39]</td>
<td>Case control</td>
<td>397 (44.3% female); mean age = 11.4 (SD: n/a)</td>
<td>PA and SB</td>
<td>PA and SB questionnaire interviews reported watching TV (&gt;3 h/day) and daily exercise.</td>
<td>Adiposity: BMI</td>
<td>Chi-square test. Confounders: TV, VG, and daily exercise/day.</td>
<td>Watching TV (&gt;3 h/day), especially over the weekend, was significantly associated with childhood obesity ($\chi^2 = 4.136, p = 0.042$). No significant associations between the rate of exercising at school, home, and outdoors and obesity ($\chi^2 = 1.240, 1.012, 2.604, p = 0.603, 0.965, 0.066$).</td>
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<tr>
<td>Yousef et al., (2013) UAE [31]</td>
<td>Cross-sectional</td>
<td>359 (44.1% female); mean age = 8.7 ± 2.1</td>
<td>SB</td>
<td>SB: Parent proxy reported watching TV (&gt;2 h/day).</td>
<td>Behavioral problems.</td>
<td>Chi-square test, logistic regression. Confounders: birth order and number of siblings.</td>
<td>Watching TV/viddee game &gt;2 h/day was associated with withdrawal behavior ($OR = 0.275, 95% CI: 0.106$ to 0.712; $p = 0.009$), attention problem ($OR = 0.488, 95% CI: 0.241$ to 0.996; $p = 0.057$), externalizing problems ($OR = 0.396, 95% CI: 0.201$ to 0.777; $p = 0.010$) and Child Behavior Checklist total score ($OR = 0.441, 95% CI: 0.229$ to 0.849; $p = 0.014$).</td>
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<tr>
<td>Zayed and Kilani, (2014) Oman [32]</td>
<td>Cross-sectional</td>
<td>325 (86% female); 10-13 age range</td>
<td>PA</td>
<td>PA: Number of occurrences and the duration of the practice of PA per week assessed with PA interview questionnaire.</td>
<td>Depression and low self-esteem.</td>
<td>One-way ANOVA and post hoc test (Scheller).</td>
<td>Regular PA was significantly associated with improved self-esteem; differences were seen between those who were exercising regularly and those who exercised regularly and those who exercised regularly and those who exercised regularly.</td>
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**Abbreviations:** SD = standard deviation; BMI = body mass index; FM = fat mass index; FMF = fat free mass; WC = waist circumference; PA = physical activity; MVPA = moderate to vigorous physical activity; SB = sedentary behavior; n/a = not reported; OR = odds ratio; CI = confidence interval.
3. Results

A total of 612 studies were eligible for inclusion. After title and abstract screening, 102 studies were assessed for full-text review. Of those, 86 were excluded for the following reasons: did not contain measures of PA or SB or sleep as an independent variable (n = 21); did not contain a measure of a health indicator and its association with PA or SB or sleep (n = 13); out of range for age (n = 37); dissertation (n = 7); studies conducted in non-Arab countries (n = 4); unavailability of the full article (n = 3); and lack of statistical data (n = 1). After all exclusions, 16 studies met the inclusion criteria (Figure 1). These studies provided results from 15,346 participants from 9 Arab countries: Saudi Arabia, n = 6, United Arab Emirates, n = 1, Egypt, n = 2, Oman, n = 2, Kuwait, n = 1, Iraq, n = 1, Tunisia, n = 1, Qatar, n = 1 and Palestine, n = 1 (Table 1). Of all included studies, 12 were cross-sectional, two were case-control, one was longitudinal and one was a pilot study. These studies were conducted between 2000 and 2019 and included children between 3.4 and 14 years of age (mean age 5.19–11.4 years). Sample sizes ranged from 40 to 8317 participants. Out of the 16 included studies, 14 reported data on adiposity [17–30], one on behavioural problems [31], one on depression and low self-esteem [32] and one on fitness [19]. Out of the sixteen studies included in this review, eight studies (50%) were classified as having a low ROB and eight as having a high ROB (50%). All studies had a reliable and/or valid tool to assess movement behaviours and health outcomes. The criteria used to assess ROB can be seen in Table 2. It was not possible to conduct meta-analyses due to heterogeneity of the data, therefore, narrative syntheses were conducted.

![Flow diagram for the identification, screening, eligibility, and inclusion of studies.](image)

**Figure 1.** PRISMA Flow Diagram.
Table 2. Risk of bias for included studies.

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<td>Clear Criteria for Those included and/or Excluded?</td>
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<td>Did an Adequate Proportion (At Least 70%) of Those Consenting to Participate in the Study Have Complete Data? (Incomplete Follow-Up: High Loss to Follow-Up: Missing Data)</td>
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<td>Did the Study Report the Sources and Details of the Tool Used in the Study to Assess the Outcomes?</td>
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<td>Did the Tool Used in the Study to Assess the Outcomes?</td>
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<td>Were the Measurements of Movement Behaviours in This Study Reliable and/or Valid?</td>
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<td>Did the Study Have Complete Data and/or Reports All Outcomes and Not Others Based on the Results?</td>
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<tr>
<td>Al-Hazzaa et al., 2019 [17]</td>
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<tr>
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</tr>
<tr>
<td>Hadhood et al., 2016 [20]</td>
<td>1</td>
<td>1</td>
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<td>1</td>
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</tr>
<tr>
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<td>1</td>
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<td>1</td>
<td>1</td>
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</tr>
<tr>
<td>Al-Lithum et al., 2019 [22]</td>
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<tr>
<td>Jemaa et al., 2018 [23]</td>
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<td>1</td>
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</tr>
<tr>
<td>Liith and Kadhim, 2005 [24]</td>
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<td>1</td>
<td>0</td>
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<tr>
<td>Albi, 2008 [25]</td>
<td>1</td>
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<tr>
<td>Aoun et al., 2016 [26]</td>
<td>1</td>
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<tr>
<td>Al-Kuiber et al., 2017 [27]</td>
<td>1</td>
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<tr>
<td>Al-Hazzan and Al-Ahmed, 2007 [30]</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Al-Qaderi et al., 2016 [31]</td>
<td>0</td>
<td>1</td>
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<td>Al-Ghanim, 2013 [32]</td>
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<tr>
<td>Youssef et al., 2013 [33]</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
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<td>1</td>
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<tr>
<td>Zayed and Kajani, 2014 [32]</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
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</tr>
</tbody>
</table>

0 = No or unclear; 1 = Yes. * Scores above 6/8 were considered as having low risk of bias.
3.1. Measurement of Movement Behaviours

Sleep was objectively measured by wrist actigraphy in one study [26] and subjectively measured using questionnaires in two studies [17,29]. SB was measured using screen time in eight studies [19,21,22,24,25,28,30,31] and objectively measured using accelerometers in two studies [23,27], and by both methods (wrist actigraphy and a questionnaire) in one study [26].

PA was measured using an accelerometer in one study [27] and by pedometer in two studies [18,28]; whereas five studies measured it subjectively using parent proxy-reports [20–22]. Two studies combined both report and device-based methods: accelerometers plus questionnaire [23] and cardiorespiratory endurance (1.6 km run/walk) plus questionnaire [19].

3.2. Health Indicators

3.2.1. Adiposity

As shown in Table 3, adiposity was assessed through the following indicators: BMI, body weight, % fat mass, BMI z-score, and waist circumference. It was reported in 14 studies, of which 10 were cross-sectional [17,18,20–23,25–28], one was longitudinal [28], two were case control [24,30] and one was a pilot study [19]. Three studies investigated the relationship between sleep and adiposity outcomes. Of the three studies, two reported significant positive associations [26,29] while one found no significant relationship [17].

Nine studies examined the relationship between SB and adiposity outcomes. SB was positively associated with adiposity outcomes in six of the nine studies [21,24–26,28,30]. The remaining three studies found no associations with adiposity outcomes [22,23,27].

Nine studies examined the adiposity relationship with PA. Of the nine studies, five found favourable associations between adiposity outcomes and PA [18,19,21–23] while four studies reported null associations [20,27,28,30].

3.2.2. Behavioural Problems

Behavioural problems were reported in only one cross-sectional study [31] involving 197 subjects (mean age 8.7 ± 2.1), which studied the relationship between SB and behavioural problems in school-aged children. The results showed that watching TV/playing VC for more than two hours were positively associated with withdrawn behaviour and externalizing problems.

3.2.3. Depression and Low Self-Esteem

One study examined the association between PA and depression and low self-esteem [32]; it involved 165 female subjects with age range of 10–13 years. The results indicated that regular PA (number of occurrences and the duration of the practice of PA per week) was significantly associated with improved self-esteem.

3.2.4. Fitness

One study assessed the relationship between SB and fitness and reported null associations [19]. The results showed that the personal activity score had a strong negative correlation with the time to complete the 1.6 km run/walk and the sum of skinfolds. There were no significant associations between TV watching hours and fitness or fatness.

There were no studies investigating the associations with the rest of the primary outcomes, namely cardio metabolic biomarkers, psychological distress, cognition (academic achievement), quality of life, injuries, nor on secondary outcomes including bone density and motor skill development.
Table 3. Results of studies.

<table>
<thead>
<tr>
<th>Study</th>
<th>Outcomes</th>
<th>Exposure: Favorable Associations</th>
<th>Exposure: Null Associations</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Kurbe et al., 2017</td>
<td>Body weight</td>
<td>PA</td>
<td>SB</td>
<td>5/14 studies showed favorable associations between PA and adiposity outcomes.</td>
</tr>
<tr>
<td>Al-Hazzaa et al., 2019</td>
<td>Body weight and BMI</td>
<td></td>
<td></td>
<td>4/14 studies showed null associations between PA and adiposity outcomes.</td>
</tr>
<tr>
<td>Jemaa et al., 2018</td>
<td>% fat mass</td>
<td>✔</td>
<td></td>
<td>6/14 studies showed favorable associations between SB and adiposity outcomes.</td>
</tr>
<tr>
<td>Hadhoodet al., 2016</td>
<td>BMI and body weight</td>
<td></td>
<td></td>
<td>3/14 studies showed null associations between SB and adiposity outcomes.</td>
</tr>
<tr>
<td>Badawi et al., 2013</td>
<td>BMI and body weight</td>
<td>✔</td>
<td>✔</td>
<td>2/14 studies showed favorable associations between sleep and adiposity outcomes.</td>
</tr>
<tr>
<td>Al-Lahham et al., 2019</td>
<td>BMI and body weight</td>
<td>✔</td>
<td></td>
<td>1/14 studies showed null association between sleep and adiposity outcomes.</td>
</tr>
<tr>
<td>Al-Hazzaa, 2007</td>
<td>BMI, skinfold measurements (triceps and subscapular, body fat %, FMI and FFM/L)</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arora et al., 2018</td>
<td>BMI z-score, waist circumference, neck circumference, body fat % and fat mass.</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Alam, 2008</td>
<td>BMI and body weight</td>
<td>✔</td>
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<tr>
<td>Al-Hazzaa and Alraheem, 2007</td>
<td>BMI, skinfold measurements (triceps, subscapular (sum and ratio), FM %, FFM %, FMI and FFM/L)</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Lefta and Kadhim, 2005</td>
<td>BMI-defined overweight/obese.</td>
<td>✔</td>
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<td>Al-Ghamdi, 2013</td>
<td>BMI</td>
<td></td>
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<tr>
<td>Alqaderi et al., 2016</td>
<td>Waist circumference</td>
<td></td>
<td></td>
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<tr>
<td>Hassan and Al-Kharasy, 2000</td>
<td>Log sum of 5 skinfold measurements (triceps, subscapular, suprailliac, abdominal and thigh).</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yousef et al., 2015</td>
<td>Behavioural problems</td>
<td>✔</td>
<td></td>
<td>1/1 studies showed favorable association between SB and behavioural problems.</td>
</tr>
<tr>
<td>Zayed and Kilani, 2014</td>
<td>Depression and low self-esteem</td>
<td>✔</td>
<td></td>
<td>1/1 studies showed favorable association between PA and depression and low self-esteem.</td>
</tr>
<tr>
<td>Hassan and Al-Kharasy, 2000</td>
<td>Fitness: cardiopulmonary endurance</td>
<td></td>
<td></td>
<td>1/1 studies showed null association between SB and fitness measures.</td>
</tr>
</tbody>
</table>
4. Discussion

This study systematically reviewed the relationships between the movement behaviours of physical activity, sedentary behaviours and sleep and health indicators among school-aged children in Arab-speaking countries. Most of the included studies in this review were cross-sectional (75%). The sample sizes ranged from 40 to 8317 participants. These studies reported mostly favourable and some null associations between PA, SB, and sleep and adiposity, behavioural problems, depression and low self-esteem and fitness outcomes. Low levels of PA and sleep and high SB were associated with higher levels of adiposity, behavioural problems, depression and low self-esteem.

Reasons for the small number of studies investigating these movement behaviours in school-aged children in Arab-speaking countries are that this field of research is still in its early stages of development in these countries, with most child health research focusing on more pressing issues such as infectious diseases. In addition, the unstable political environment in some of the Arab countries, has made conducting such research challenging [33]. The availability of funds is another reason that limited the number of studies. For instance, in 2013, the gross domestic product (GDP) in North America was $427 billion (28.9%) of the worldwide GDP ($1477.7 billion), while Arab countries collectively only spent $15.4 billion (1%) [34]. Finally, although the Arabic databases were searched for relevant studies in this systematic review, there might be some studies that could not be identified due to the small number of Arabic databases available.

Existing Arabic studies assessed movement behaviours in isolation from each other. Of these studies, most used subjective methods to assess PA, sleep and SB. On the other hand, the Canadian [3,4,6,7] and the Australian 24-Hour Movement Guidelines [9] indicated that focusing on movement behaviours across the entire day is more important than focusing on movement behaviours in isolation. For example, a Canadian study investigating the health outcomes associated with meeting the 24-hour movement behaviour guidelines for children and youth showed that meeting none, one and two recommendations were associated with higher BMI z-score, waist circumference, behavioural strengths and difficulties scores and lower aerobic fitness in a gradient pattern ($p_{trend} < 0.05$), while meeting all the guidelines during a 24-hour period was associated with better health [35].

Furthermore, due to the prior emphasis on MVPA [1] and the common use of subjective assessments of PA [4], no study in the present review examined different PA intensities such as light-intensity physical activity (LPA), although emerging evidence suggests that LPA may provide some important health benefits for children and adolescents [2–4]. Moreover, children cannot participate in MVPA during all waking hours. Therefore, engaging in LPA (e.g., walking) is considered achievable and an easier way to reduce SB, that also provides health benefits [2].

Few studies in this systematic review assessed the relationship between sleep and adiposity outcomes. A possible explanation of this gap is that sleep and SB are new areas of research in this region when compared to the PA field as the SB included studies were published between 2005–2019, while sleep studies were published in the last five years. Therefore, the Arab countries are urgently in need to conduct more studies that focus on sleep and SB to better understand their impact on school-aged children’s health.

Despite the importance of the weather and its impact on movement behaviours [36], no study in the present review assessed the relationship between 24-hour movement behaviours and climatic factors, although most of the Arab countries have a hot and dry climate [37]. Previous research in other countries indicates that children’s PA levels are affected by seasonal periods across the year and this varies between countries, with PA levels decreasing in specific climatic conditions such as winter, summer, sandstorms, areas, humidity and rain [38,39]. Moreover, extreme weather conditions (high or low temperatures) increase SB [40] and decrease sleep efficiency [41], therefore, conducting more studies investigating the association between the weather and movement behaviours...
and potential interventions may help children in these regions to meet movement behaviour recommendations.

4.1. Areas for Future Research

The lack of evidence from the Arab countries confirms that research is needed to address the inequality in the literature, especially with the high and still increasing levels of childhood obesity and SB in the 22 countries. Moreover, it is important to use different types of study designs (longitudinal and experimental) with larger sample sizes to better understand the role of 24-hour movement behaviours, to improve health outcomes. Studies included in this review focused on obesity, however, the field of PA is broader than this health outcome, therefore, it is recommended to conduct more studies reflecting on all movement behaviours across the 24-hour period.

4.2. Strengths and Limitations

To our knowledge, the present review is the first study investigating current research assessing the association between movement behaviours and health indicators in school-aged children in the Arab-speaking countries. A lack of Arabic databases is also a potential limitation. Meta-analyses were not possible to conduct due to heterogeneity of the data, therefore, narrative syntheses were conducted.

5. Conclusions

Most of the included studies reported favourable associations between movement behaviours and health outcomes. Low levels of PA and sleep and high SB were unfavourably associated with adiposity outcomes, behavioural problems, depression and low self-esteem. Further studies to address the inequality in the literature in the Arab-speaking countries to understand the role of 24-hour movement behaviours and its positive influence on health outcomes across the early years of primary school are urgently needed. Based on the differences between societies and their needs, as well as environmental differences, it might be beneficial to also understand associations between weather conditions and children’s movement behaviours. Conducting more studies on different types/intensities of PA, SB and sleep for both boys and girls, and using different types of study designs (longitudinal and experimental) with larger sample sizes will improve the quality of future studies.

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Conflicts of Interest: The authors declare that they have no competing interests.

Appendix A. Supplementary Information

“Physical activity” OR “Movement behaviours” OR “physical inactivity” OR exercise OR “physical fitness” OR “energy expenditure” OR “sedentary” OR “sit” OR “sitting” OR “lifestyle” OR “television viewing” OR “tv viewing” OR “screen time” OR “electronic media” OR Sleep* OR Bedtime OR “Bedtime” OR Nap* OR “Time on bed” OR “Night rest” Child* Arab* OR “Saudi Arabia” OR “United Arab Emirates” OR “Bahrain” OR “Kuwait” OR “Oman” OR Qatar OR Egypt OR “Sudan” OR “Palestine” OR Jordan OR Iraq OR Lebanon OR Syria
OR Yemen OR Libya OR Morocco OR Tunisia OR Algeria OR Comoros OR Djibouti OR Mauritania OR Somalia.

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RESEARCH ARTICLE

Impact of the COVID-19 virus outbreak on 24-h movement behaviours among children in Saudi Arabia: A cross-sectional survey

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Abstract

Background: In March 2020, the World Health Organization (WHO) declared the coronavirus (COVID-19) outbreak as a pandemic. This led many governments to place restrictions on population movement to aid in pandemic control. These restrictions were expected to produce some type of impact on the daily lives of children and their families. The purpose of this study was to investigate the impact of COVID-19 on 24-h movement behaviours among Saudi children aged 6-12 years, during the pandemic.

Methods: An online survey of Saudi parents (n = 1021) was conducted between 1 October to 11 November 2020 to gather information about the impact of the COVID-19 outbreak on children’s 24-h movement behaviours, parent and child factors that may be associated with movement behaviours, and perceived changes in children’s movement behaviours.

Results: Only 3.4% of Saudi children met all components of 24-h movement guidelines. Compared with before COVID-19, children’s PA levels declined, they slept more, and their use of electronic screen devices significantly increased. The perceived changes in PA and SB were more unfavourable among girls than boys. Children of older parents, mothers, and those with higher education levels and lower monthly incomes were more likely to meet 24-h movement guidelines.

Conclusion: The COVID-19 virus outbreak unfavourably affected Saudi children’s movement behaviours, more specifically, girls, which should be taken into account in future research. The results provide an insight into what has changed because of the COVID-19 restrictions and could be considered as part of the response strategies in Saudi Arabia.

Keywords
child, COVID-19, physical activity, sedentary screen time, sleep
1 | INTRODUCTION

In March 2020, the World Health Organization (WHO) declared the coronavirus (COVID-19) outbreak as a pandemic (WHO, 2020). Many governments placed restrictions on population movement to aid in pandemic control (Han et al., 2020). These restrictions likely impacted children's physical activity (PA), sedentary behaviour (SB), and sleep. Children spent less time outdoors, which is associated with PA levels (Mitra et al., 2020). School closures, which affected more than 1.5 billion children globally (Bates et al., 2020), also reduced opportunities for PA (Guan et al., 2020).

COVID-19 restrictions affected children’s opportunities to meet 24-h movement guidelines (Guerrero et al., 2020). Studies have found that during COVID-19, most children did not meet PA or screen time (ST) guidelines, and there was an increase in ST, social media use and in sleep duration, compared with before COVID-19 (Al Hourani et al., 2021; Kovacs et al., 2021; Moore et al., 2020; Xiang et al., 2020).

More than 140 million children live in the 22 Arab countries, including Saudi Arabia (Child Labour in Arab States & International Programme on the Elimination of Child Labour (IFEC), n.d.). Across these countries, childhood obesity and sedentary behaviour levels are high and increasing (Farrag et al., 2017; Shaarara et al., 2018). Further, there is a lack of evidence from these countries on the impact of COVID-19 on 24-h movement behaviours and on important health outcomes (obesity, executive function, motor development, and bone health) across the years of primary school. Assessing the impact of COVID-19 during the elementary school years is important to monitor prevalence and changes in adequate motor development (Simons et al., 2008; Valenti, 2012).

To our knowledge, no studies have examined the impact of COVID-19 on movement behaviours among school-aged children in an Arabian country. By January 2022, the number of COVID-19 cases has exceeded 575,293 in Saudi Arabia with more than 8892 deaths (Johns Hopkins University, 2021). These are the highest of any Arabian country and have prompted long-term government restrictions such as school closures and home quarantines. Schooling was conducted remotely for a long period of time (from March to November 2020), and, thus, along with the other restrictions imposed, likely resulted in changes in the time spent in movement behaviours. Given the high and increasing rates of child obesity in Saudi Arabia, these changes due to COVID-19 could have significant impact on children’s health and development. Therefore, the purpose of this study was to investigate the impact of the COVID-19 outbreak on 24-h movement behaviours among Saudi children aged 6–12 years.

2 | METHODS

This online cross-sectional survey aimed to recruit children from all 13 regions of Saudi Arabia. The survey was promoted to parents through the Saudi Ministry of Education and on social media.

Key Messages
- This research examined the impact of COVID-19 on 24-h movement behaviours among Saudi children during the COVID-19 pandemic.
- Children’s PA levels declined, they slept more, and their use of electronic screen devices significantly increased.
- The perceived changes in PA and SB were more unfavourable among girls than boys.
- The Ministry of Education, parents, and children need to work together to address the adverse impact of COVID-19 on Saudi children’s movement behaviours.

2.1 | Data collection

Eligible parents who resided in Saudi Arabia with a child aged between 6 and 12 years completed the survey between 1 October to 11 November 2020. The survey comprised (a) parental and child demographics, (b) child’s movement, and (c) changes in the child’s movement due to COVID-19. Questions used in the current analyses are shown in Table 1. An online parent information sheet and consent form were completed before commencing the survey. Parents with more than one child were asked to complete a separate questionnaire for each child.

2.2 | Survey

The survey was based on a parental survey of young children’s movement behaviours during COVID-19 (Okely et al., 2021) and the Children and Youth Movement and Play Behaviours Survey (Moore et al., 2020). It was translated into Arabic and back-translated into English to ensure appropriateness of the questions. Approval was obtained from the Ministry of Education in Saudi Arabia (42640/2020) and the Human Research Ethics Committee at The University of Wollongong (HE288/2021).

Child and parent birth, sex, region of residence, parental education, and income were assessed using standard questions. PA duration was assessed through parents’ responses to questions related to their children’s time spent playing outside, doing activities to strengthen their muscles and bones, and being physically active for a total of ≥60 min per day in the past 7 days. SB was assessed through questions related to child’s time spent watching TV, using a smart phone, using social media, or playing video games (VG) for entertainment for <2 h while sitting or lying down, over the past 7 days. Sleep duration was assessed through questions related to children’s wake up and sleep times, while sleep quality was assessed based on a scale of 1 to 7. Parents reported the balance of their child’s overall healthy movement behaviours compared with before COVID-19 using a 5-point
TABLE 1  Selected items used in the current analysis from the child survey during COVID-19 virus outbreak

| Survey details | | Module of child and caregiver background Option response |
|---|---|
| | | What is the date of birth of the child? [dd/mm/yyyy] |
| | | What is the sex of the child? [dropdown, boy/girl] |
| | | What is the highest level of parental education? [dropdown, specify] |
| | | In which region in Saudi Arabia do you live? [dropdown, specify] |
| | | What is your monthly income [SAR]? [dropdown, specify] |

**Current movement behaviours**

- Over the past 7 days, on how many days was your child physically active for a total of at least 60 min per day? [dropdown, 0–7 days]
- During the past 7 days, on how many days did your child do activities to strengthen their muscles and bones? [dropdown, 0–7 h]
- Over the past 7 days, on how many days did your child watch TV/videos/Internet using a smartphone or tablet or play video or computer games for entertainment for less than 2 h while sitting or lying down? [dropdown, 0–7 h]
- During the past 7 days, on average how much time per day did your child play outside? [dropdown, 0–7 h]
- How many hours of sleep does your child get in a typical 24-h/day [including naps]? [dropdown, 0–7 h]
- On a scale of 1 to 7, with the higher number indicating higher quality, how would you rate the quality of your child’s sleep? [dropdown, 0–7]

**Change in movement behaviours**

Compared with before the COVID-19 outbreak and related restrictions:

- My child is doing physical activities or sport outside? [dropdown, yes/no]
- My child is doing physical activities or sport inside? [dropdown, yes/no]
- My child watches TV, movies, uses the computer for leisure or plays sedentary video games? [dropdown, yes/no]
- My child uses social media? [dropdown, yes/no]
- My child sleeps? [dropdown, yes/no]

- My child’s sleep quality is? [dropdown, a lot worse, a little worse, about the same, a little better, a lot better]
- The balance of my child’s overall healthy movement behaviours (i.e., physical activity, sedentary behaviours, and sleep) are? [dropdown, a lot less, a little less, about the same, a little more, a lot more]

As a result of the COVID-19 outbreak and related restrictions:

- Is there an inside leisure activity or hobby that your child is doing a lot more now? [dropdown, yes/no]
- Is there an outside leisure activity or hobby that your child is doing a lot more now? [dropdown, yes/no]
- Has there been a decrease in your child’s health (e.g., existing condition worsened or new condition developed)? [dropdown, yes/no]

Note: Full survey is available in the Supporting Information.

Likert scale ranging from a lot worse (score = 1) to a lot better (score = 5).

Children were classified as meeting 24-h movement guidelines (Bull et al., 2020; Okely et al., 2019; Tremblay et al., 2016) if they reported (per day): (1) ≥60 min of moderate- to vigorous-intensity physical activity (MVPA); (2) ≤2 h of recreational ST; and (3) uninterrupted sleep for 9 to 11 h per night (Bull et al., 2020; Okely et al., 2019; Tremblay et al., 2016).

### 2.3 Statistical analyses

Data were downloaded from Qualtrics and manually checked and cleaned in Excel. Statistical analyses were carried out using SPSS software (version 27, Chicago, IL, USA). Sample characteristics were summarized using the mean and standard deviation and percentage of children meeting 24-h movement guidelines. Pearson correlations were used to test associations between parent age and the time their child spent in PA, SB, using social media, and sleep. Differences between boys and girls in the time parents reported their child spent in PA, SB, using social media and sleep were assessed using independent samples t-tests. Spearman’s rank order correlations were used to assess associations between parent education level and income and time their child spent in PA, SB, using social media, and sleep. A 95% confidence interval for the percentages were calculated by using the formula of proportion:

\[
p \pm z_{0.025} \sqrt{\frac{p(1-p)}{n}}
\]

A forest plot was used to present parent-reported changes in 24-h movement behaviours of the children. Statistical significance was set at \( p < 0.05 \) for all analyses.

### 3 RESULTS

#### 3.1 Parent and child characteristics

A total of 1021 parents completed the survey, of which 78.8% were Saudis. There were 2797 parents who started, but did not complete, the questionnaire. Parents were required to complete all questions before they could submit the survey. Fifty-five per cent of respondents were mothers with an average age of 41 (±9.2) years. The mean age of the children was 8.5 (±1.85) years. Sixty per cent of the study sample were girls. Parents’ average monthly income was $4355. One-quarter of parents had a high school, 41% had a bachelor’s degree, and 14% had a master’s or PhD. Compared with the Saudi population, our sample of parents comprised more mothers and was slightly older. The monthly income and education levels were similar to the Saudi population (General Authority for Statistics, 2017, 2018, 2021) (Table 2).
### TABLE 2  Characteristics of parents and children

<table>
<thead>
<tr>
<th>Parents demographic profile</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), M (SD)</td>
<td>40.5 (7.58)</td>
</tr>
<tr>
<td>Parent/caregivers relationship to the child participating in the study, n (%)</td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td>565 (55.3)</td>
</tr>
<tr>
<td>Father</td>
<td>456 (44.7)</td>
</tr>
<tr>
<td>Nationality, n (%)</td>
<td></td>
</tr>
<tr>
<td>Saudi</td>
<td>804 (78.8)</td>
</tr>
<tr>
<td>Non-Saudi</td>
<td>217 (21.2)</td>
</tr>
<tr>
<td>Education level, n (%)</td>
<td></td>
</tr>
<tr>
<td>Primary school</td>
<td>81 (8)</td>
</tr>
<tr>
<td>High school</td>
<td>268 (26)</td>
</tr>
<tr>
<td>Diploma</td>
<td>117 (11.5)</td>
</tr>
<tr>
<td>Bachelor's degree</td>
<td>418 (41)</td>
</tr>
<tr>
<td>Master's degree</td>
<td>103 (9.9)</td>
</tr>
<tr>
<td>PhD</td>
<td>36 (3.6)</td>
</tr>
<tr>
<td>Living region, n (%)</td>
<td></td>
</tr>
<tr>
<td>Al-Riyadh</td>
<td>477 (46)</td>
</tr>
<tr>
<td>Al-Jouf</td>
<td>35 (3.5)</td>
</tr>
<tr>
<td>Al-Qassim</td>
<td>63 (6.2)</td>
</tr>
<tr>
<td>Al-Bahrain</td>
<td>10 (1)</td>
</tr>
<tr>
<td>Asir</td>
<td>18 (1.8)</td>
</tr>
<tr>
<td>Eastern Province</td>
<td>131 (12.9)</td>
</tr>
<tr>
<td>Hail</td>
<td>28 (2.8)</td>
</tr>
<tr>
<td>Jazan</td>
<td>8 (0.8)</td>
</tr>
<tr>
<td>Mecca</td>
<td>79 (8)</td>
</tr>
<tr>
<td>Medina</td>
<td>112 (11)</td>
</tr>
<tr>
<td>Northern Borders</td>
<td>45 (4.5)</td>
</tr>
<tr>
<td>Najran</td>
<td>6 (0.6)</td>
</tr>
<tr>
<td>Tabuk</td>
<td>9 (0.9)</td>
</tr>
<tr>
<td>Monthly income (SAR), n (%)</td>
<td></td>
</tr>
<tr>
<td>0–3000</td>
<td>268 (26)</td>
</tr>
<tr>
<td>3000–7000</td>
<td>186 (18.3)</td>
</tr>
<tr>
<td>7000–10,000</td>
<td>112 (11)</td>
</tr>
<tr>
<td>10,000–15,000</td>
<td>237 (23.2)</td>
</tr>
<tr>
<td>15,000–20,000</td>
<td>155 (15)</td>
</tr>
<tr>
<td>20,000+</td>
<td>63 (6.2)</td>
</tr>
<tr>
<td>Child demographic profile</td>
<td></td>
</tr>
<tr>
<td>Age (years), M (SD)</td>
<td>8.5 (1.85)</td>
</tr>
<tr>
<td>Gender, n (%)</td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>405 (39.7)</td>
</tr>
<tr>
<td>Girls</td>
<td>616 (60.3)</td>
</tr>
</tbody>
</table>

#### 3.2  Children's behaviours and changes in behaviours during COVID-19

Table 3 shows the movement behaviours in Saudi children during the COVID-19 outbreak compared with before COVID-19. Only 3.4% (95% CI 0.00, 9.5) of children met the PA, SB, and sleep recommendations. Slightly more than half the children met the sleep recommendations (95% CI 52.9, 69.9), just over one third met the PA recommendations (95% CI 30.6, 40.8) and 15% met the SB recommendations (95% CI 9.5, 20.9). Boys’ SB was significantly higher than girls (5.6 (2.15) versus 5.3 (2.20) hours, p = 0.013). For other behaviours, there were no significant differences between boys and girls. Sleep quality was reasonably high (average of 5.4 [2.26] points out of 7.0) and children played outside for 2.19 (1.34) h/day. Less boys than girls met the SB recommendations (13.1% [95% CI 4.0, 22.2] and 16.6% [95% CI 9.4, 23.8], respectively, p = 0.002). During COVID-19, children spent less time in outdoor PA than before COVID-19 (average of 2.16 [1.22] points out of 5.0, respectively). Forty per cent of children had a screen device in their bedroom. Parents of girls perceived greater decreases
TABLE 3 Children’s movement behaviours during the COVID-19 virus outbreak and compared with before COVID

<table>
<thead>
<tr>
<th>Children’s movement behaviours, M (SD)</th>
<th>Total (n = 1021)</th>
<th>Girls (n = 616)</th>
<th>Boys (n = 405)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVPA ≥60 min (days/week)</td>
<td>4.52 (2.40)</td>
<td>4.51 (2.39)</td>
<td>4.54 (2.41)</td>
<td>0.865</td>
</tr>
<tr>
<td>Activities to strengthen muscles and bones (number of days)</td>
<td>2.59 (2.37)</td>
<td>2.52 (2.34)</td>
<td>2.70 (2.42)</td>
<td>0.258</td>
</tr>
<tr>
<td>Sleep duration (h/day)</td>
<td>9.67 (2.26)</td>
<td>9.75 (2.42)</td>
<td>9.55 (1.99)</td>
<td>0.136</td>
</tr>
<tr>
<td>Sleep quality</td>
<td>5.40 (2.26)</td>
<td>5.38 (2.04)</td>
<td>5.42 (1.90)</td>
<td>0.697</td>
</tr>
<tr>
<td>Screen time ≥2 h/day (number of days/week)</td>
<td>5.39 (2.19)</td>
<td>5.26 (2.20)</td>
<td>5.60 (2.15)</td>
<td>0.013</td>
</tr>
<tr>
<td>Playing outside (h/day)</td>
<td>2.19 (1.34)</td>
<td>2.15 (1.32)</td>
<td>2.26 (1.35)</td>
<td>0.175</td>
</tr>
</tbody>
</table>

Proportion of children meeting the WHO/Australian/Canadian guidelines (%) and 95% CI

<table>
<thead>
<tr>
<th></th>
<th>Total (n = 1021)</th>
<th>Girls (n = 616)</th>
<th>Boys (n = 405)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVPA</td>
<td>35.7 (30.6, 40.8)</td>
<td>32.6 (26.1, 39.1)</td>
<td>35.1 (27.2, 43.0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Screen time</td>
<td>15.2 (9.5, 20.9)</td>
<td>16.6 (9.4, 23.8)</td>
<td>13.1 (4.0, 22.2)</td>
<td>0.002</td>
</tr>
<tr>
<td>Sleep3</td>
<td>56.9 (52.9, 60.9)</td>
<td>55.6 (50.3, 60.9)</td>
<td>58.6 (52.5, 65.1)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>24 h combined</td>
<td>3.4 (0.00, 9.5)</td>
<td>3.8 (0.00, 11.6)</td>
<td>2.7 (0.00, 12.3)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Perceived change in child movement behaviours during COVID-19 outbreak, M (SD)

<table>
<thead>
<tr>
<th></th>
<th>Total (n = 1021)</th>
<th>Girls (n = 616)</th>
<th>Boys (n = 405)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical activity or sport outside</td>
<td>2.16 (1.22)</td>
<td>2.19 (1.21)</td>
<td>2.11 (1.23)</td>
<td>0.293</td>
</tr>
<tr>
<td>Physical activity or sport inside</td>
<td>2.78 (1.24)</td>
<td>2.85 (1.24)</td>
<td>2.68 (1.23)</td>
<td>0.037</td>
</tr>
<tr>
<td>Watching TV or playing sedentary video games</td>
<td>3.28 (1.32)</td>
<td>3.49 (1.26)</td>
<td>2.96 (1.35)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Using social media</td>
<td>3.54 (1.48)</td>
<td>4.08 (1.55)</td>
<td>2.72 (0.87)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Sleep duration</td>
<td>3.15 (1.94)</td>
<td>3.17 (1.94)</td>
<td>3.12 (1.90)</td>
<td>0.411</td>
</tr>
<tr>
<td>Sleep quality</td>
<td>3.06 (1.94)</td>
<td>3.07 (1.95)</td>
<td>3.04 (1.92)</td>
<td>0.598</td>
</tr>
<tr>
<td>Overall healthy movement behaviours</td>
<td>2.78 (1.02)</td>
<td>2.83 (1.01)</td>
<td>2.71 (1.04)</td>
<td>0.072</td>
</tr>
</tbody>
</table>

Note: 95% CI = confidence interval. Bold font indicates statistical significance.
Abbreviation: MVPA, moderate to vigorous physical activity.
3Meeting sleep guideline (5-13 years).
4Parents reported the balance of their children’s overall healthy movement behaviours (sleep, SST and PA) as compared with before the COVID-19 outbreak based on responses to a 5-point scale ranging from a lot worse to a lot better.

Parent-perceived changes in child movement behaviours during COVID-19 outbreak

<table>
<thead>
<tr>
<th></th>
<th>Total 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside PA/sport</td>
<td>2.16 [1.96 2.33]</td>
</tr>
<tr>
<td>Inside PA/sport</td>
<td>2.76 [2.63 2.93]</td>
</tr>
<tr>
<td>Watching TV or playing sedentary video games</td>
<td>3.28 [3.12 3.44]</td>
</tr>
<tr>
<td>Social Media</td>
<td>3.54 [3.32 3.70]</td>
</tr>
<tr>
<td>Sleep Time</td>
<td>3.15 [3.03 3.27]</td>
</tr>
<tr>
<td>Sleep Quality</td>
<td>3.06 [2.94 3.18]</td>
</tr>
<tr>
<td>Healthy Movement Behaviours</td>
<td>2.78 [2.65 2.91]</td>
</tr>
</tbody>
</table>

FIGURE 1 Forest plot of parent-reported changes in 24-h movement behaviours of Saudi children (6-12 years) based on a 5-point scale ranging from “a lot less” to “a lot more”. PA = physical activity, VG = video games

In time spent in PA indoors (average of 2.85 points out of 5.0 [1.24] (p = 0.037), greater increases in watching TV or playing sedentary VG (average of 3.49 points out of 5.0 [1.26] (p < 0.0001), and greater increases in using social media (average of 4.08 points out of 5.0 [1.53] (p < 0.0001) than boys.

Tables 4 and 5 show associations between parental demographic factors and children’s movement behaviours. Parent age showed a significant positive, but weak correlation with the time their child spent using social media (r = 0.08, p = 0.007) (Table 4). No other associations between parent age and children’s movement behaviours were significant.

The results of the Spearman correlations (Table 5) showed a significant, but weak negative correlation between parent education level and the time their child spent in outside PA/sport (r = −0.06, p = 0.04), and significant, but weak negative correlations in the quality of their child’s sleep (r = −0.11, p = 0.0001) and in overall healthy movement behaviours (r = −0.14, p = 0.0001). Further, parent education had a significant, but weak positive correlation with the time their child spent indoors (r = 0.09, p = 0.004) and in watching TV or sedentary VG (r = 0.17, p < 0.0001).

Parent income level (Table 5) showed a significant negative correlation with the time their child spent in outside PA/sport (r = −0.06, p = 0.04) and the quality of their child’s sleep (r = −0.06, p = 0.049), and a significant, weak negative correlation in their child’s overall healthy movement behaviours (r = −0.10, p < 0.0001). In addition,
parent income level was positively correlated with the time their child spent in indoor PA ($r = 0.9, p = 0.003$) and in social media use ($r = 0.08, p = 0.099$), and a significant, weak positive correlation in watching TV or sedentary VG ($r = 0.15, p < 0.0001$). However, all of these correlations were weak.

### 3.3 New ways families are approaching movement behaviours

Almost half the parents (42%) indicated that their child was involved in more inside leisure activities during COVID-19 than before COVID-19. These included drawing (32.8%), playing VG (14.9%), playing soccer (13%), playing Intelligence Quotient games (11.1%), reading stories (6.1%), and yoga (4%). Few children were involved in sewing/crafts, house framing, and dancing (3%). Only 17% of parents indicated their child was involved in more outside leisure activity during the COVID-19 outbreak. These included running (23.6%), hiking (17.2%), swimming (14.4%), visiting relatives (11.5%), martial arts (9.8%), photography (9.2%), hiking (8.6%), and gymnastics (5.7%).

### 4 DISCUSSION

This is the first known study from an Arabian country to provide data on school-aged children's 24-h movement behaviour in relation to the COVID-19 pandemic. The results indicate that children spent less time being physically active or playing outdoor sports, more time watching TV, or playing sedentary VG and more time sleeping. Girls were less active, engaged in more social media, and spent more time sleeping than boys.

Our findings are consistent with previous studies which have found that children's PA levels declined, and leisure screen time and social media use, as well as sleeping time increased during the COVID-19 pandemic (Kovacs et al., 2021; Moore et al., 2020; Xiang et al., 2020). We found marked increases in time spent in SB. It is likely these changes are a result of the government restrictions put in place due to COVID-19, which limited children's opportunities to play outdoors (Kovacs et al., 2021). Moreover, as parents were working from home, they likely allowed their children to use electronic devices for longer periods of time to keep them busy as they worked (Okeyo et al., 2022). This finding may explain the significant increase in SB and the decrease in PA levels. School closures may be another reason for the decrease in children's PA levels. These may include not walking to school, which is associated with a decrease in PA levels (Faulkner et al., 2013).

Most children in the study did not have consistent bedtimes or wake-up times during COVID-19. As our data showed, on average children had later bedtimes (after 11 pm) than before COVID-19. This may be explained by their increased use of screen devices in the 2 h before bedtime. However, the starting time for school was much later (15:30) during COVID when schooling was remotely delivered. This much later starting time likely explains the increase in sleep duration.

Moreover, 40% of children had a screen device in their bedroom, and this practice has been shown to be associated with lower sleep duration and quality (Chaput et al., 2014). Further, parents may be inadvertently influencing the quality of their children's sleep by using electronic devices during bedtime routines with their children (El Rafih-Ferreira et al., 2019; Faddil, 2021). These sleep patterns are concerning as inconsistent wake-up and bedtimes and inadequate sleep time may affect children's executive function (Warren et al., 2016) academic performance (Sun et al., 2019) and may have
long-term health consequences including hypertension, dyslipidemia, weight gain, and metabolic syndrome (Medic et al., 2017). As children are influenced by the feelings and behaviours of their parents through observation and imitation (Bandura, 2008), modelling and encouraging these behaviours may help children meet the sleep and SB recommendations.

Internationally, a large proportion of children are not meeting the 24-h movement guidelines (Roman-Vílas et al., 2016). However, the percentage of Saudi children not meeting 24-h movement behaviour guidelines was much lower than international studies conducted before the COVID-19 pandemic. A multinational survey of school-aged children to evaluate adherence to integrated movement behaviours in 12 countries showed that around 7% of children met the three recommendations (Roman-Vílas et al., 2016).

The current study found that girls were less active than boys during the COVID-19 pandemic. The decrease in PA levels can be partially explained by gender differences. For example, it has been reported that boys are more active than girls and that the gender difference in total amounts of activity is mainly due to gender differences in the amounts of self-organized PA (Nielsen et al., 2011). However, it could also be due to lower levels of PE among girls in Saudi Arabia, as during COVID-19 PE classes (remotely) were only provided in boys' schools.

Parents perceived a greater change in boys PA indoors compared with girls. This indicates that boys, in general, were less active indoors than they were before COVID-19. On the other hand, screen-based indoor activities were more favourable among girls than boys. This could be explained by the distribution of girls' time during a 24-h period. For example, the time spent in one behaviour could have displaced the time spent in another behaviour. In this study, girls slept more and spent less time in both MVPA and playing outside compared with boys; therefore, they had more time for indoor activities. Moreover, the culture and tradition of the Saudi society may encourage girls to spend more time watching TV and using social media as they have fewer opportunities to participate in PA compared with boys.

Parental age was positively, albeit weakly, associated with the time their child spent using social media. This could be explained by the differences in contemporary parenting compared with previous generations. Parents today may find it more challenging to control their children's use of social media. Moreover, as children are influenced by the feelings and behaviours of their parents (Bandura, 2008), the use of smartphones by parents could encourage children to use screen devices more (Hoyos Cillero & Jago, 2011; Öztürk Eyılmay & Yalçın İrmak, 2021).

Parents' education levels and income were weakly associated with children's movement behaviours change perceived by parents. In this study, children's sleep quality, the time spent in outdoor PA, and overall healthy movement behaviours decreased as parent education levels and income increased. Conversely, as parents' education level increased, the time their child spent in indoor PA and in watching TV or VG increased. A possible explanation of these results is that educated and high-income parents could be more aware of the effects of COVID-19 outbreak on their children's health. Therefore, they may have promoted their children's indoor PA level to reduce the effects of COVID-19 outbreak.

As no Saudi 24-h movement guidelines currently exist, we recommend the development of such guidelines for children in Saudi Arabia (Parrish et al., 2020). Furthermore, we suggest three strategies that may help Saudi children meet the 24-h movement guidelines during the COVID-19 outbreak. First, we recommend the Ministry of Education consider providing high-quality online PE lessons. Kovacs et al. (2021) found that 57% of children who were active during online PE lessons also met the WHO PA recommendation. Also, when children revert to normal school days after the COVID-19 pandemic, PE lessons should include a focus on time spent in PA during class for boys and girls to recover the decrease level of PA during COVID-19 (Šverdláková et al., 2021). This is especially important for girls, for whom PE classes were only introduced in 2018 as a part of the Kingdom's vision (The Quality-of-Life Program). Second, parents should encourage their children to follow a structured daily schedule, which has been shown to be associated with higher odds of meeting ST and PA recommendations during the COVID-19 (Kovacs et al., 2022). Finally, parents should encourage their children to participate in outdoor play to improve their PA levels (Kovacs et al., 2021; Tu et al., 2017). Parents should be encouraged to be more active with their children as they are a role model for their children (Brouwer et al., 2018).

To our knowledge, this is the first study in Saudi Arabia that investigated the cross-sectional impact of COVID-19 on movement behaviours among Saudi children (aged 6–12 years). A limitation of the study is that movement behaviours were subjectively captured via an online parent questionnaire; however, it was not possible to collect data using device-based measures on a large sample due to the COVID-19 pandemic. Using 24-h movement guidelines from other countries is another potential limitation, highlighting the need to develop country-specific guidelines for Saudi Arabia. Further, just over 70% of parents who started the questionnaire did not complete it, and it is not known if these parents differed from those who did complete the questionnaire.

5 | CONCLUSIONS

The results of the current study demonstrate the impact of the COVID-19 pandemic on Saudi children's 24-h movement behaviours, prompting recommendations to parents, schools, and education decision-makers to reduce the effect of the COVID-19 outbreak and future pandemics on children's movement behaviours. Stakeholders are strongly encouraged to promote healthy levels of PA, SB, and sleep, by encouraging outdoor PA (where possible), minimizing children's use of screen devices when sedentary, educating parents about the importance of meeting movement guidelines by introducing national 24-h guidelines, or promoting the WHO guidelines.

ACKNOWLEDGEMENTS

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CONFLICT OF INTEREST
The authors have no conflicts of interest to declare.

AUTHOR CONTRIBUTIONS
Conceptualization, Y.A.A., A.-M.P., and A.D.O.; methodology, Y.A.A., A.-M.P., and A.D.O.; data collection and management, Y.A.A.; formal analysis, Y.A.A.; writing—original draft preparation, Y.A.A.; writing—review and editing, all authors. All authors have read and agreed to the published version of the manuscript.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

INFORMED CONSENT STATEMENT

Online informed consent was obtained from all subjects involved in the study.

INSTITUTIONAL REVIEW BOARD STATEMENT

The study was conducted according to the guidelines of the Declaration of Helsinki. Approval was obtained from the Ministry of Education in Saudi Arabia [42640/2020] and the Human Research Ethics Committee at The University of Wollongong, Australia [HE288/2021].

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher’s website.

Appendix K: The published article- 24-hour movement behaviours and COVID-19 among children in the Kingdom of Saudi Arabia: A repeat cross-sectional study

24-hour movement behaviours and COVID-19 among children in the Kingdom of Saudi Arabia: A repeat cross-sectional study

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ARTICLE INFO

Abstract

This study investigated how children’s 24-hour (24-h) movement behaviours were affected by SARS-CoV-2 (COVID-19) in the Kingdom of Saudi Arabia. Previous research examining 24-hour movement behaviours in Saudi Arabia seven months after the World Health Organization (WHO) declared COVID-19 a global pandemic. This repeat cross-sectional study examined changes in 24-hour movement behaviours 12 months after the WHO declaration. The Time 2 survey repeated five months after Time 1 (March 15–May 21, 2021) after Time 1 survey (October 11–November 2020). The survey was distributed to parents of children aged 6-12 years across Saudi Arabia via an online survey. Children were classified as meeting 24-hour movement guidelines if they reported uninterrupted sleep for 9-11 hours per night, ≤2 h of recreational sedentary screen time (RST) per day and ≥60 min of moderate-to-vigorous intensity physical activity (MVPA) per day. A total of 1,045 parents from all regions of Saudi Arabia responded (42.4%). Only 1.8% of children met all components of the guidelines compared to 3.4% in Time 1. In the present study, girls spent more days per week in MVPA ≥60 min duration than boys (3.0 vs 2.6; p = 0.025), while boys had spent more days per week engaged in activities that strengthened muscle and bone than girls (3.0 vs 2.8; p = 0.019). Healthy levels of physical activity (PA), sedentary behaviour (SB) and sleep further declined in Saudi children five months after the Time 1 survey. These challenges require urgent intervention to encourage children’s movement behaviours improve as Saudi Arabia moves out of the COVID-19 pandemic.

Introduction

One of the health consequences of lockdowns associated with the COVID-19 pandemic has been on the movement behaviours of school-aged children.1 In this paper, movement behaviours refer to physical activity (PA), sedentary behaviour (SB) – including screen time (ST) and sleep.2 Globally, many countries enforced restrictions that resulted in school-aged children not attending school, with classes delivered remotely.1 A systematic review3 that included six studies from Australia, Croatia, China, Canada, Latin America (Brazil, Chile, Colombia), and Europe (Italy and Spain) investigated changes in PA and SB from before to during COVID-19 lockdowns. These studies reported a decrease in children’s PA levels, and five studies reported increases in SB. A subsequent study from Spain showed similar results.1 We conducted an initial study in the Kingdom of Saudi Arabia4 which investigated the impact of COVID-19 on children’s 24-hour (24-h) movement behaviours early in the pandemic, using the World Health Organization (WHO), Australian and Canadian guidelines (as no Saudi 24-h movement guidelines currently exist).2,5,6 We found that children’s PA levels declined, they slept more, and their use of electronic screen devices significantly increased. To date, only two studies have examined the changes in movement behaviours at two time points during COVID-19 and both reported decreases in PA levels and increases in SB at Time 2 compared to Time 1.1,3,7 Neither of these two studies were from the Eastern Mediterranean region, a region where there has been a noticeable gap in the literature. We hypothesize that COVID-19 has a negative impact on Saudi children’s 24-h movement behaviours. The purpose of this study was to investigate the five-month changes in movement behaviours among children in Saudi Arabia, at a time when there were governmental restrictions.

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Methods

The methods of this study were identical to those reported in the previous (Time 1) study. This repeat cross-sectional study (Time 2) collected data between March and May 2021. The survey was promoted across all 13 regions of Saudi Arabia through the Education Policy Research Centre at the Saudi Ministry of Education in Riyadh to all elementary schools as well as on social media (Twitter and WhatsApp). Approval was obtained from the Ministry of Education in Saudi Arabia (2639/2021) and the Human Research Ethics Committee at the University of Wollongong, Australia (HE22/8/2021).

For the survey to be submitted parents were required to complete all of the survey questions. The Time 1 survey was conducted between October and November 2020 in autumn (temperatures ranged between 24 °C [75 °F] and + 40 °C [104 °F] in September, and between 14 °C [57 °F] and + 27 °C [81 °F] in November), and during school days (remotely delivered classes online), with governmental restrictions due to COVID-19, which resulted in schools suspended. The Time 2 survey was conducted during spring (temperature ranged from +14.5 °C [58 °F] to + 28 °C [83 °F] in March, and from + 24 °C [75 °F] to + 39 °C [102 °F] in May) and during school days (remotely delivered classes) with similar governmental restrictions. During Time 2, there was a 20-day school holiday period. During the remotely delivered classes period in Time 1 and Time 2, there were no active physical education (PE) classes online. Schooling started at 3:30 p.m. (remotely) and ended at 7 p.m.

Data collection

Parents of healthy children aged between 6 and 12 years who were living in Saudi Arabia were invited to participate in the study. A link to an online survey in Arabic, using the Qualtrics platform, was provided to parents. The survey was designed to take approximately 10 minutes to complete and consisted of three parts: parental and child demographics, child’s current movement behaviors, and changes in child’s movement behaviors as a result of COVID-19. Before answering the survey, parents were provided with an online parent information sheet and consent form as the first page of the survey. Parents were asked to complete a separate survey if they had more than one child (aged 6–12 years).

Survey

The survey was based on two previous surveys: a parental survey of young children’s movement during COVID-191 and the Children and Youth Movement and Play Behaviours Survey.2 It was translated into Arabic and back-translated into English to ensure the appropriateness of the questions.

Child and parent data including birth, sex, residence of region, parental education, and income were assessed using standard questions.1,2 Children’s sleep duration, PA duration, and SB were proxy-reported by parents. Using a 5-point Likert scale ranging from “a lot worse” (score = 1) to “a lot better” (score = 5), parents reported the balance of their children’s overall healthy movement behaviors compared to before the COVID-19 outbreak.

Sleep quality was measured on a scale of 1–7, with 1 indicating “very difficult to settle to sleep” and 7 indicating “settles and drifts off to sleep within a few minutes”.

Children were classified as meeting the recommendation of the WHO, Australian and Canadian guidelines, if they reported uninterrupted sleep for 9–11 h per night, meeting the SB recommendation if they reported no more than 2 h of recreational sedentary screen time (RST) per day and meeting the PA recommendation if they reported ≥ 60 min of moderate-to-vigorous-intensity physical activity (MVPA) per day. Selected items that were used in the current study are listed in Appendix A (the full survey is available in Appendix B).

Statistical analyses

Statistical analyses were carried out in Statistical Package for the Social Sciences (SPSS) (version 28, Chicago, IL, USA). Sample characteristics were summarized using means and standard deviations (SD) for all variables and the percentage of children meeting the 24-h movement guidelines.2,2 Gender differences in time spent in PA, SB, and sleep and in using social media were analysed using an independent samples t-test. A forest plot was used to present the parent-reported changes in 24-h movement behaviors of the children during the first (October to November, 2020) and the second time (March to May, 2021) of the COVID-19 pandemic. Statistical significance was set at p < 0.05 for all analyses.

Results

Parents and children characteristics

Table 1 shows the demographics of the parents who responded to the survey. Of those parents who expressed an interest (n = 2,464), 1,045 completed the survey (42.4%). Of these, 88.6% were Saudis and 11.4% were non-Saudis. The respondents included 587 mothers (56.2%) with an average age of 42.6 (± 9.2) years. The parents’ average monthly income was ≥ 355. Most parents had bachelor’s degree (47%). Just under half of the sample of children were boys (49.2%). Compared with the Saudi population, our sample comprised more females, was slightly older, and had a similar monthly income and education level.15-16

Children’s current behaviors and changes in behaviors during COVID-19

Table 2 reports time spent on movement behaviors and the proportion of children meeting the guidelines during the COVID-19 outbreak in Saudi Arabia. Boys spent significantly more days/week in MVPA ≥ 60 min than boys (p = 0.025); however, boys spent more days in activities that strengthened their muscles and bones (p = 0.019). For the remainder of the behaviors (sleep duration and quality; ST and playing outside), there were no significant differences between boys and girls.

Regarding the proportion of children meeting the 24-h movement guidelines, only 1.8% met all three of the 24-h movement behavior recommendations. When examining the behaviors separately, 26.8% of children met the sleep guidelines, 18.2% met the PA recommendation and 12.8% met the SB recommendation. The proportion of girls who met the PA and RST recommendations was significantly higher than boys (p <
Table 1
Parent and child characteristics at Time 2 (n = 1 045).

<table>
<thead>
<tr>
<th>Study sample</th>
<th>Father</th>
<th>Non-Saudi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), M (SD)</td>
<td>42.6 (9.2)</td>
<td>587 (56.2)</td>
</tr>
<tr>
<td>Education level, n (%)</td>
<td>458 (43.6)</td>
<td>926 (88.6)</td>
</tr>
<tr>
<td>Nationality, n (%)</td>
<td>Saudi</td>
<td>419 (40.9)</td>
</tr>
<tr>
<td>Living region, n (%)</td>
<td>419 (40.9)</td>
<td>926 (88.6)</td>
</tr>
</tbody>
</table>

Table 2 also reported parent perceived changes in their child's movement behaviours during the COVID-19 outbreak. Children's perceived combined indoor PA and sport significantly decreased compared to before the COVID-19 outbreak (an average of 2.61 points on a 5-point Likert scale ranging from “a lot worse” [score = 1] to “a lot better” [score = 5] out of 5.0, p = 0.007). Boys were perceived to have significantly more sleeping time than girls (average of 3.93 vs. 3.79 points out of 5.0, p = 0.041). Notably, 70% of children had an electronic screen device in their bedroom.

New ways families are approaching movement behaviours

Parents were asked if there was an inside leisure activity or hobby that their child was doing a lot more during the COVID-19 outbreak, and 22.8% of parents answered yes. These included drawing (25%), playing soccer (18.2%), playing Intelligence Quotient games (21.3%), playing ping pong (11%), playing chess (9.2%), playing in the backyard (8.2%), doing handcrafts (2.9%), reading (2.1%), and learning new languages (2.1%). Only 11% of parents indicated their child was involved in a lot more outside leisure activity or hobbies during the COVID-19 outbreak. These included playing soccer (29%), biking (26.7%), running or walking (24.2%), martial arts (6.1%), hiking (4.9%), playing archery (4.6%), and swimming (4.5%).

Comparison between Time 1 and Time 2 during the COVID-19 outbreak

Table 2 compared the results from Time 1 to Time 2 in terms of how movement behaviours have been affected by COVID-19 among Saudi children. For the entire sample, there were significant differences between Time 1 and Time 2, for all considered variables (p < 0.001), except for sleep quality. These differences showed a decrease in children's MVP and playing outside, and an increase in activities to strengthen muscles and bones, ST, and sleep duration. The analysis of the results for girls and boys separately was in line with the total sample results, with the exception of activities to strengthen muscles and bones, where there was not a significant change for boys. The proportion of the total sample (boys and girls) meeting the MVPA, RST, and sleep, and the 24-h combined guidelines significantly decreased (p < 0.001) in Time 2 compared to Time 1.

As seen in Fig. 1, parents perceived changes in children's movement behaviours from Time 1 to Time 2 significantly decreased (p < 0.001), including children's outside and inside PA and sport and sleep quality, while sleep duration, watching television (TV) or playing sedentary video games, and the use of social media significantly increased (p < 0.001).

Discussion

The findings of this study confirmed our hypothesis that COVID-19 has a negative impact on Saudi children's 24-h movement behaviours. This repeated cross-sectional study assessed the impact of COVID-19 restrictions on movement behaviours of Saudi children during the period March to May, 2021, compared with our initial results from October to November, 2020. The results showed that only 1.8% of children (3.6% of boys and 2.1% of girls) met all recommendations of the 24-h movement guidelines. Twenty-seven percent of children met the sleep recommendation, 18.2% met the PA recommendation and 12.8% met the S8 recommendation compared to Time 1 where 57% met the sleep recommendation, 35.7% met the PA recommendation and 15.2% met the S8 recommendation.

The results of the comparison between Time 1 and Time 2 showed that COVID-19 had a significant impact and affected children's movement behaviours negatively within a short period of time. The percentage of children meeting the combined 24-h movement guidelines in Time 2 decreased significantly when compared to Time 1. Our findings are consistent with the results of a Canadian study which reported a decrease in the proportion of children who met movement guidelines in Time 2 (4.9%) compared to Time 1 (4.8%) due to the impact of COVID-19. However, our results showed that the percentage of girls who met movement guidelines was higher than boys (2.1% vs. 1.6%). Our findings are also consistent with the results from nine European countries which showed that 9.3% of children met the WHO PA recommendation in Time 2 compared to 19% in Time 1, while the proportion of children who did not meet RST recommendation was high in both phases (60.6% [weekdays] and 47.7% [weekends]) in Time 2 compared to 69.5% [weekdays] and 64% [weekends] in Time 1.

These results were somewhat expected as tighter government restrictions were introduced over the course of the COVID-19 pandemic which further limited children's opportunities to play outdoors, which has been shown to be positively associated with children's PA levels. School closures could be another reason for the decrease in children's PA levels, as children, in general, were more physically active at school pre-COVID-19. A study involving 785 Canadian children (10.57 ± 0.7 years) and a systematic review of 68 studies showed that not walking to school was associated with a decrease in PA levels. Furthermore, as there were no active PE classes online, this may have contributed to a further reduction in children's PA levels. A European study showed that 57% of children who were active during online PE classes during the COVID-19 outbreak met the WHO PA recommendations.

The sleep patterns of children in the current study have been affected by policy changes as a result of the COVID-19 pandemic. To ensure working parents could assist children in their schooling, the Saudi Ministry of Education mandated that schooling started at 3:30 p.m. (online) and ended at 7 p.m. These changes to daily routines may also have affected the time that children went to sleep. In addition, the absence of a structured day time schedule could have further hindered opportunities to meet PA recommendations, as shown in a study conducted on 395 children from 10 European countries. In the present study, school-aged children had a school holiday for 20
days during Time 2, which may have negatively impacted their movement behaviours. A study investigated the changes in sleep and PA of 154 United States (US) school-aged children (5-9 years) showed that a 1-week holiday had a negative impact on sleep, while a 3-week holiday had more increase in children’s SB (25 min) and decrease in MVPA (12 min) per day. The structured days hypothesis indicates that during the unstructured days (e.g. school holidays), children’s sleep, SB, and PA are less regulated compared to structured days (e.g. school days), therefore, there might be fewer opportunities for children to meet the 24-h movement guidelines during school holidays. This could be another reason that may explain the decline in children’s movement behaviours.

The number of children in this study who had an electronic screen device in their bedroom increased from Time 1 (40%) to Time 2 (70%). This may explain the decrease in the proportion of children meeting the ST recommendation, as having these electronic screen devices in children’s bedrooms negatively affects their sleep quality and duration. Our numbers align with what was reported in a study from the US which indicated that 75% of children, aged 6-17 years (mean age: 11.4), had an electronic screen device in their bedroom. The authors reported that 90% of children had insufficient sleep time and that having household rules and regular sleep-wake routines may encourage children to have better sleep.

As the data of this repeated cross-sectional study were from all the 13 regions of Saudi Arabia, there may be some differences and disparities between urban and rural areas in meeting the recommendations of movement behaviours due to the level of government restrictions and COVID-19 infections in each region. In addition, there are differences in the climate of the 13 regions in Saudi Arabia due to its large area. The

Fig. 1. Parent-reported changes in 24-h movement behaviours in Saudi children (6-12 years) during the first (October 2020) and second time (March 2021) of the COVID-19 pandemic. Scores are based on a 5-point scale ranging from “a lot less” (score 1) to “about the same” (score 3) to “a lot more” (score 5). Green arrows represent when October 2020 (Time 1) scores ranked less compared with March 2021 (Time 2) within the same variable. Red arrows represent when October 2020 (Time 1) scores ranked higher compared with March 2021 (Time 2) within the same variable. PA = physical activity, VG = video games.
climate is moderate in the west and the southwestern areas, hot in the interior areas, and hot and humid in the coastal areas. These differences in the weather may play an important role in meeting 24-h movement guidelines as reported in a study that examined the relationship between climate indicators and daily detected COVID-19 cases in Saudi Arabia which showed a positive association between the spread of COVID-19 and temperature among the top Saudi cities (Riyadh, Jeddah, Madinah, and Dammam) affected by COVID-19.  

Strengths and limitations

This study is the first known from an Arab nation to provide data on school-aged children’s 24-h movement behaviour at two points of time during the COVID-19 outbreak. Moreover, this study provided data across all the 13 regions of Saudi Arabia since there is no nationally representative data of 24-h movement behaviours during the COVID-19 outbreak. A limitation of the study is that movement behaviours were assessed via a parent survey as collecting data using device-based measures on a large sample was not possible due to the COVID-19 restrictions. As the data were anonymous, the differences from Time 1 to Time 2 could be due to differences in the samples, in addition to COVID-19.

Conclusion

This follow-up study provided evidence of the impact of the COVID-19 restrictions on Saudi children’s movement behaviours and investigated the changes in these behaviours over the two time periods during the COVID-19 restrictions. Due to the difference in the COVID-19 infection rate in several regions of Saudi Arabia, it is recommended for future studies to be conducted by region. As no Saudi 24-h movement guidelines currently exist, we recommend the development of such guidelines for children in Saudi Arabia as they have significant public health benefits. The findings of this study contribute to supporting the efforts to mitigate the negative impact of this pandemic, as part of the response strategies, and for future pandemics.

Submission statement

All authors have read and agree with manuscript content and while this manuscript is being reviewed for this journal, the manuscript will not be submitted elsewhere for review and publication.

Authors’ contributions

Conceptualization, Y.A.A., A.-M.P. and A.D.O.; methodology, Y.A.A., A.-M.P. and A.D.O.; data collection and management, Y.A.A., formal analysis, Y.A.A., writing—original draft preparation, Y.A.A.; writing—review and editing, all authors. All authors have read and agreed to the published version of the manuscript.

Ethical approval statement

The study was conducted in accordance with the Declaration of Helsinki. Approval was obtained from the Ministry of Education in Saudi Arabia (2029/2021) and the Human Research Ethics Committee at the University of Wollongong, Australia (HE08/2020). This survey collected data between March and May, 2021. A link to an online survey in Arabic, using the Qualtrics platform, was provided to parents. Before answering the survey, parents were provided with an online parent information sheet and consent form as the first page of the survey.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to thank the parents and their children whose support and collaboration made this study possible. YA is supported by King Saud University, Riyadh, Saudi Arabia. ADO is supported by a National and Medical Research Council of Australia Investigator Grant (APP1176858).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajbms.2022.05.001.

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19. Larouche R, Saunders TJ, John Faulkner GE, Galley R, Tremblay M. Associations between active school transport and physical activity, body composition, and


Appendix L: The accepted article for publication- Associations between gross motor skills, adiposity and bone mineral density among boys in the Kingdom of Saudi Arabia: a cross sectional study

Date: 1st June, 2022
Journal of Sport Science and Physical Education

Manuscript Acceptance Letter

Dear Mr. Yazeed A. Alanazi
Dear Dr. Anne-Marie Parrish
Dear Prof. Anthony D. Okely

We are pleased to inform you that our reviewers have accepted and recommended your manuscript entitled "Associations between gross motor skills, adiposity and bone mineral density among boys in the Kingdom of Saudi Arabia: a cross sectional study" for publication in the forthcoming issue of the journal.

Thank you for choosing to publish in our journal!

Best Regards,

Editor-in-Chief

Prof. Dr. Khalid S. Almuzaini