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Review Article

Impact of COVID-19 Lockdown on Sedentary Behavior and Changes in Weight in Children: A Systematic Review

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Abstract
The restrictions and lockdown during COVID-19 may result in dangerous consequences and long-term ill health in future. This systematic review explores the impact of lockdown on changes in weight and sedentary behavior in children and adolescents. A comprehensive literature search was done through electronic databases searched from May 2021 to December 2022 including MEDLINE, Google scholar and Ovid Medline. Total of 4162 studies were retrieved, of which 20 studies were found to be eligible. Out of these, there were one case report, five prospective cohorts, 12 cross sectional studies, one trend study, one longitudinal study and one interrupted time series study with a total participants of 183720. These participants were children and adolescents aged less than or equal to 19 years. Pre lockdown weight and difference in weight were mentioned in five studies out of total eight studies and among that five were statistically significant. Pre lockdown physical inactivity or reduced sedentary behaviour were pointed out in nine studies out of 15 and among them seven studies showed significant p value. The findings from these studies collectively indicate that the COVID-19 pandemic has had a significant impact on weight gain, overweight, and obesity across different age groups. Factors such as changes in dietary habits, reduced physical activity, and disrupted routines likely contributed to these outcomes. These findings underscore the importance of promoting healthy lifestyles, including balanced nutrition and regular physical activity, to mitigate the negative effects of prolonged periods of restricted movement and altered routines.

Introduction
COVID-19 lockdown imposed by many countries may result in long term consequences as lifestyle diseases in future due to reduced movements or reduced physical activity (PA). These restrictions, naturally reduced movement and accelerated to have enduring impacts especially on adolescents. Globally, pandemic restrictions have had widespread impacts on the PA, sedentary behaviour (SB), screen time, and sleep of school-aged children and youth.[1] Parental encouragement and support, parental engagement in PA, and family dog ownership were positively associated with healthy movement behaviours.[2] Children typically obtain their daily PA through active travel to school; physical education and recess, organised sports, games, and dance; active play; and spending time in playgrounds and parks. Conversely, most of their sedentary time and sleep are accumulated at home. The lockdown disrupted the everyday routine of children, adolescents, and young adults. To protect them, health care providers should highlight the risk of obesity and provide prevention strategies, ensuring also parental participation. Worldwide policies, guidelines and

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precautionary measures should ideally be established.[3] The lockdown social-distancing strategy, including seven weeks of strict lockdown, enabled an extraordinary test of stay-at-home regulations, which forced a SB on all children and adolescents.[4] Studies reported that during the lockdown, PA levels have significantly reduced with concurrent increase in SB.[5-8] Engaging in PA can be a challenge while staying at home and it is possible and important to be PA while social distancing. PA reduces blood pressure and anxiety and helps to sleep better. It can also help to improve mood and energy level. Children and adolescents aged six to 17 years need at least 60 minutes of moderate to vigorous intensity PA.[9] The aim three of sustainable development points on healthy living and hence child and adolescent health plays a pivotal role which could be achieved through healthy life style. Healthy youth and children could bring about a wealthy world hence pointing on the health-related behaviour of children and adolescents and is the key rationale of this review.

Objective

The objectives of the systematic review are

1. Synthesize the existing evidence of impact of COVID-19 lockdown on changes in weight among children and adolescents.
2. Synthesize the existing evidence of impact of COVID-19 lockdown on SB among children and adolescents.

Review question

What is the impact of COVID-19 lock down on change in weight and SB among children?

Methods and analysis

Design and methods used for this systematic review comply with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review protocol is registered in the PROSPERO International Register of Systematic Reviews (Registration number - CRD42021258976). This systematic review did not need approval from the ethics committee or required informed consent from the study population as the data were retrieved from open-source databases and internet searches.

Eligibility criteria

(S) Sample: Children and adolescents aged < 19 years.
(PI) Phenomenon of interest: Impact of lockdown on change in weight and SB in children

(E) Evaluation: Changes in weight and SB

(D) Design: All types of observational study; cross sectional, cohort, case control, single case studies

(R) Research type: Quantitative

Electronic databases searched from May 2021 to December 2022 including MEDLINE, Google scholar, Ovid Medline with the span of search from Jan 2020 to May 2021.

Search strategy

The search strategy included the study population using terms and keywords derived from scoping search and expertise in the subject field. Study population terms: COVID-19 OR "Novel Coronavirus" OR "2019 novel coronavirus" OR 2019-nCoV OR SARS-CoV-2 and isolation or lock* or self-isolation and "Physical activity" or exercise or walking or running or cycling or swimming or sports or sedentary or "sedentary behaviour" or activity or "screen time" or sitting and weight gain or increased weight or body weight increase and child or children or adolescent or adolescents. Table 1 shows the search items and terms.

Table 1: Search Details

Data Base	Search Item
Pubmed	((((Impact[tiab] OR effect[tiab]) AND ("COVID-19"[MeSH Terms] OR COVID 19 pandemic [tiab])) OR (("pandemics"[MeSH Terms] OR pandemic[tiab]) OR confinement [tiab] OR ("quarantine" [MeSH Terms] OR quarantine[tiab]))) AND (("weights and measures" [MeSH Terms] OR "body weight" [MeSH Terms] OR weight [tiab]) OR BMI[tiab])) AND ("sedentary behavior"[MeSH Terms] OR ("sedentary behavior"[MeSH Terms] OR physical inactivity[tiab]) OR (change [tiab] AND ("exercise"[MeSH Terms] OR physical activity[tiab])) OR (change [tiab] AND "sedentary behavior" [MeSH Terms]))) AND (("child" [MeSH Terms] OR Children [tiab]) OR ("adolescent" [MeSH Terms] OR adolescents[tiab]) OR ("child" [MeSH Terms] OR child [tiab]) OR (("schools" [MeSH Terms] OR school [tiab]) AND ("child" [MeSH Terms] OR children[tiab]))
Google scholar	(Impact OR effect) AND ("COVID-19" OR COVID 19 pandemic) OR (("pandemics" OR pandemic) OR confinement OR ("quarantine" OR quarantine)) AND (("weights and measures "OR "body weight" OR weight OR BMI) AND ("sedentary behavior" OR physical inactivity) OR AND ("exercise") AND (("child" OR Children) OR ("adolescent" OR adolescents) OR ("child" OR child) OR ("schools" OR school) AND ("child" OR children)
Ovid Medline	((Impact OR effect) AND COVID-19 OR Novel Coronavirus OR 2019 novel coronavirus OR 2019-nCoV OR SARS-CoV-2) AND (isolation OR lockdown* OR self-isolation) AND (Physical activity OR sedentary behavior" OR physical inactivity OR activity OR sitting))

Selection process

The selection process was facilitated by grading each eligibility criterion as eligible, not eligible, or potentially eligible. Subsequently, potential relevance was determined through a thorough review of the full text. This iterative process was employed when studies could not be definitively excluded based solely on their title and abstract. In instances where abstracts provided insufficient information or disagreement arose, a third reviewer intervened to facilitate consensus on the inclusion or exclusion of studies in the review. All observational studies conducted in English language on children below 19 years were included observational studies conducted among those with mental and physical disabilities or any diseases and ecological studies were excluded. Using a standardized form, two reviewers extracted the data independently (CRD, 2009). A third reviewer independently checked the data for consistency and clarity. Two reviewers (SSA and AMR) independently screened the references at both the title / abstract (N = 4164) and full-text level (N = 20). A third reviewer (AD) resolved any conflicts. The reference list of included articles was hand screened after deduplication.

Data Extraction

Data were extracted by two reviewers independently including: first author, year, country, aims of the study, type of the study (cross-sectional), number of participants, participant demographic characteristics, inclusion criteria, type of recruitment, type and definition of PA and SB investigated, type of measurement of PA and SB and change in weight. Out of 4162 studies after deduplication we could include 502 unique studies. After title and abstract screening, 127 studies were included.

Prisma flow chart 2020 in Figure 1 shows the identified studies from different databases. The included studies had the following countries of origin under different geographical areas like Asia, Europe, South America, North America and Australia which include Israel[4], Tunisia[6], Turkey[7], Palestine[10], Spain[11-13], Brazil[16,17], Bosnia and Herzegovina[19], China[20,21], USA[22-24], Germany[25], Australia[26] and Saudi Arabia[27]

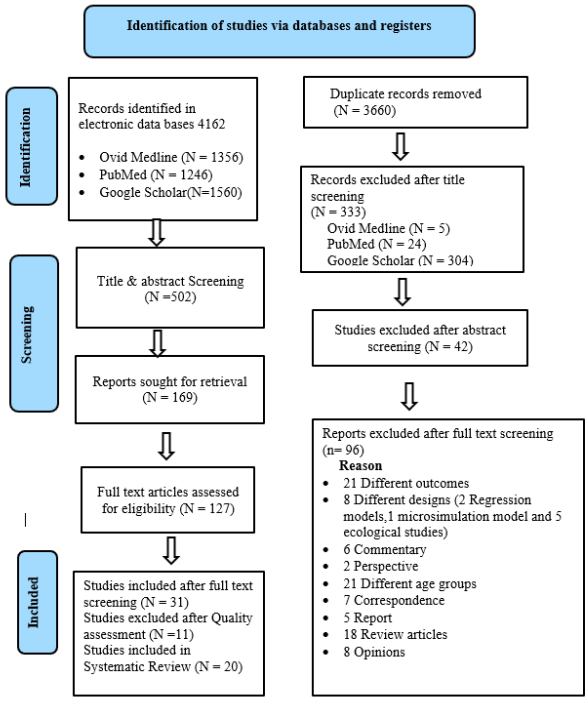

Figure 1: Prisma Flow Chart 2020

Quality Assessment

Risk of bias for each study was assessed independently by the same initial reviewers. The third reviewer mediated in situations of disagreement. Cohen's κ was used to assess agreement between reviewers. Risk of bias was assessed using the Newcastle-Ottawa Scale (Deeks et al, 2003). Quality scores obtained via the Newcastle–Ottawa scale for cross-sectional, cohort studies were used to assess selection, comparison, and outcomes. Studies with six or more were considered as high quality and score of five or above is considered as satisfactory ones and studies with a score of five or above were included in the review. The quality of the included studies was assessed and after quality assessment twenty studies were included. Details of the assessment are included in Table 2.

Table 2: Quality Assessment- New Castle Ottawa Scale

S. No.	Author	Title	Representativeness of sample	Sample Size	Non- respondents	Ascertainment of the exposure	Comparability	Assessment of the outcome	Statistics	Total Stars
1	Vinker-Shuster M, Grossman ES, Yeshayahu Y[4] Israel	Increased Weight Gain of Children during the COVID-19 Lockdown	0	0	0	1	2	2	1	6
2	Abid R, Ammar A, Maaloul R,[6] Tunisia	Effect of COVID-19-Related Home Confinement on Sleep Quality, Screen Time and Physical Activity in Tunisian Boys and Girls: A Survey	1	1	0	1	2	2	1	8
3	Demirci N, Demirci PT, Koz H[7] Turkey	The Impact of COVID-19 Lockdown Process on Dietary Behaviours and Physical Activity Habits of High School Students	1	1	0	0	1	1	1	5
4	Allabadi H, Dabis J, Aghabekian V, Khader A, Khammash U,[10] Palestine	Impact of COVID-19 lockdown on dietary and lifestyle behaviours among adolescents in Palestine	1	1	0	1	2	2	1	8
5	Alonso-Martínez AM, Ramírez Vélez R, García Alonso Y, Izquierdo M, García-Hermoso A.[11] Spain	Physical Activity, Sedentary Behavior, Sleep and Self-Regulation in Spanish Preschoolers during the COVID-19 Lockdown	1	1	0	1	2	1	1	6
6	Cachón-Zagalaz J, Zagalaz-Sánchez ML,Arufe-Giráldez V,SanmiguelRodríguez A, González-Valero G,[12] Spain	Physical Activity and Daily Routine among Children Aged 0 – 12 during the COVID-19 Pandemic in Spain. 2021	0	0	0	1	2	2	1	7
7	López-Bueno R, López-Sánchez GF, Casajús JA, Calatayud J, Gil Salmerón A, Grabovac I, et al[13] Spain	Health-Related Behaviors Among School-Aged Children and Adolescents During the Spanish Covid-19 Confinement.	0	0	1	0	1	1	2	5
8	Alshehri LM, Al Agha AE, [14] Saudi Arabia	Impact of Covid-19 Lockdown on the Unhealthy Dietary Habits and Physical Activity of Children and Adolescents Living in the Kingdom of Saudi Arabia	0	0	0	1	2	2	1	7

9	Androutsos O, Perperidi M, Georgiou C, Chouliaras G,[15] Greece	Lifestyle Changes and Determinants of Children's and Adolescents' Body Weight Increase during the FirstCOVID-19 Lockdown in Greece: The COV-EAT Study	0	0	0	1	2	2	1	7
10	Brazendale K, Garcia J, Hunt ET, Blankenship M, Eisenstein D, Leon A,[16] USA	Preliminary Evidence of Children's Weight Gain From 5 Months of Home Quarantine During the COVID-19 Pandemic	0	0	0	1	1	2	1	6
11	Malta DC, Gomes CS, Barros MBA, Lima MG, Silva AGD, Cardoso LSM, et al[17] Brazil	The COVID-19 pandemic and changes in the lifestyles of Brazilian adolescents	1	1	0	1	2	2	1	8
12	Gilic B, Ostojic L, Corluka M, Volaric T, Sekulic D,[19] Bosnia and Herzegovina	Contextualizing Parental / Familial Influence on Physical Activity in Adolescents before and during COVID-19 Pandemic: A Prospective Analysis	0	0	1	1	2	2	1	7
13	Guo YF, Liao MQ, Cai WL, Yu XX, Li SN, Ke XY, et al[20] China	Physical activity, screen exposure and sleep among students during the pandemic of COVID-19	1	1	1	1	2	2	1	9
14	Vogel M, Geserick M, Gausche R, Beger C, Poulain T, Meigen C, et al,[21] Germany	Age-and weight group-specific weight gain patterns in children and adolescents during the 15 years before and during the COVID-19 pandemic	0	1	1	1	2	2	1	8
15	Weaver R, Hunt E, Armstrong B,[22] South Eastern U.S	COVID-19 leads to accelerated increases in children's BMI z-score gain: An interrupted time-series study. Elsevier.	1	1	0	1	2	2	1	8
16	Mulugeta W, Hoque L,[24] USA Massachusetts	Impact of the COVID-19 lockdown on weight status and associated factors for obesity among children in Massachusetts.	0	0	1	1	2	2	1	6
17	Xiang M, Zhang Z, Kuwahara K,[25] China	Impact of COVID-19 pandemic on children and adolescents' lifestyle behavior larger than expected	1	1	0	1	2	2	1	8
18	Nathan A, George P, Ng M, Wenden E, Bai P, Phiri Z, et al,[26] Western Australia	Impact of COVID-19 Restrictions on Western Australian Children's Physical Activity and Screen Time.	0	0	1	0	2	2	1	6

19	Giannini DT, Tavares CM, Takey M, Aloise MLR, da Costa AJ, de Carvalho DS, et al[29] Brazil	Adolescents Emotional State and Behavioral and Dietary Habit Changes during Isolation Due to the COVID-19 Pandemic	0	0	0	0	2	2	1	6
20	Ventura PS, Ortigoza AF, Castillo Y, Bosch Z, Casals S, Girbau C, Siurana JM, Arce A, Torres M, Herrero FJ.[33] Spain Catalonia	Children's health habits and covid-19 lockdown in Catalonia: Implications for obesity and non-communicable diseases.	1	1	0	0	2	2	1	7

After full text review and quality assessment 20 studies were included. We excluded 11 studies based on quality assessment and 96 based on various reasons.

Study characteristics

Table 3: picturizes the characteristics of the studies included in the review.

Author, country	Title	Study design	Instrument used Validation	Age group	Sample size	Change in weight	SB/ Reduction in PA
Vinker-Shuster M, Grossman ES, Yeshayahu Y.[4] Israel	Increased Weight Gain of Children during the COVID-19 Lockdown.	Retrospective prospective cohort study	Weight for age standardization was calculated according to the U.S. Centers for Disease Control and Prevention and the World Health Organization growth tables. (Validated)	0 - 18 years	229	Total mean weight-percentile was significantly higher following the lockdown (40.44 vs. 38.82, respectively, P = 0.029). 95% confidence interval (0.16 to 3.07)	
Abid R, Ammar A, Maaloul R,[6] Tunisia	Effect of COVID-19-Related Home Confinement on Sleep Quality, Screen Time and Physical Activity in Tunisian Boys and Girls: A Survey	Cross sectional	Ricci and Gagnon sedentary behavior questionnaire (Validated)	5 – 12 years	106		Level of PA of the participants. Showed a significant main effect of confinement on all items of the PA questionnaire ($p < 0.001$) as well as on the total PA score ($p < 0.001$) in both genders. SB Before 1.06 ± 0.24 During 2.29 ± 1.03 Change 1.23 (p value < 0.001) % of Change in sedentariness + 133.33 %

Demirci N, Demirci PT, Koz H.[7] Turkey	The Impact of COVID-19 Lockdown Process on Dietary Behaviours and Physical Activity Habits of High School Students	Cross sectional-Online Survey	Self-administered Questionnaire (Not Validated)	(4 - 18 years).	490	During the quarantine both females and males underwent weight gain. Overweight status changed from 3.9% to 6.7% and obesity increased from 2.1% to 4.7%	Those who spent time sitting in the COVID -19 process was 79.8% (0.041***) 54.9%stated decrease in PA level during COVID 19 and 48% did PA for < 30 minutes in a week. (0.001)
Allabadi H, Dabis J, ghabekian V, Khader A, hammash U,[10] Palestine	Impact of COVID-19 lockdown on dietary and lifestyle behaviours among adolescents in Palestine	Telephonic Survey	Structured questionnaire developed by the author (Partially validated)	10 - 19 years	600	Among the total sample, 250 (41.7%) reported that they gained weight	Days of physical activity conducted per week. Physical activity increased by 21.8% and decreased by 18.8% 14.3% showed no change and 45.0% had no PA
Alonso-Martínez AM, Ramírez-Vélez R, García-Alonso Y, Izquierdo M, García-Hermoso A,[11] Spain	Physical Activity, Sedentary Behavior, Sleep and Self-Regulation in Spanish Preschoolers during the COVID-19 Lockdown	Cohort	Objectively measured physical activity, sedentary time, and sleep were collected using a wrist-worn GENEActiv tri-axial accelerometer (Validated)	4 to 6 years	268		During the lockdown, preschoolers showed a decrease in total physical activity (mean difference (MD) = −43.3 min per day, 95% confidence interval (CI) −68.1 to −18.5) and an increase in sedentary time (MD = 50.2 min per day, 95% CI 17.1 to 83.3)
Cachón-Zagalaz J, Zagalaz-Sánchez MªL, Arufe-Giráldez V, Sanmiguel-Rodríguez A, González-Valero G, [12] Spain	Physical Activity and Daily Routine among Children Aged 0 – 12 during the COVID-19 Pandemic in Spain.	Cross sectional-Online	Children and Lockdown questionnaire was developed by seven experts from the fields of general didactics, psychology, body expression and sport (Partially validated)	0 – 12 years	837	NA	34.8 % had no PA with a Mean of 12.40& SD 17.69

López-Bueno R, López-Sánchez GF, Casajús JA, Calatayud J, Gil-Salmerón A, Grabovac I, et al,[13] Spain	Health-Related Behaviors among School-aged children and adolescents during the Spanish COVID-19 confinement.	An online survey	Parental report & self-report by children (Not Validated)	3 and 16 years 516 parents & 860 children and adolescents	516 & 860		Significant differences were found for a reduction of weekly minutes of physical activity during the confinement (−102.5, SD 159.6) ($p < 0.001$) In overall physical activity all gender and age subgroups display significant reduction in PA
Alshehri LM, Al Agha AE, [14] Saudi Arabia	Impact of COVID-19 Lockdown on the unhealthy dietary habits and physical activity of children and adolescents living in the Kingdom of Saudi Arabia	Cross sectional	Clinical interview questions via lecommunication (Not)	2 to 18 years	452		During COVID 19 19% of them do not exercise. While for the entire age of 2-18 years, 43% does not exercise before COVID -19 whereas 42% are those who do not exercise during COVID -19
Androutsos O, Perperidi M, GeorgiouC, Chouliaras G,[15] Greece	Lifestyle changes and determinants of children's and adolescents' body weight increase during the first COVID -19 Lockdown in Greece: The COV-EAT Study	Cross sectional	Parents self-reported (Not)	Children & adolescents and their parents 2 – 18 years	397	Body weight increased in 35% of children / adolescents.	Physical activity decreased in 66.9% during the COVID -19 lockdown ****
Brazendale K, Garcia J, Hunt ET, Blankenship M, Eisenstein D, Leon A,[16] Southeast region of the United States	Preliminary evidence of children's weight gain from 5 months of home quarantine during the COVID-19 Pandemic.	Case Report	Anthropometric Assessments (Validated scales)	9 years	29	Percent of children who were overweight or obese increased from 27.5% to 44.8% Median difference is 0.6& SD is 1.2	NA
Malta DC, Gomes CS, Barros MBA, Lima MG, Silva AGD, Cardoso LSM, et al[17] Brazil	The COVID-19 pandemic and changes in the lifestyles of Brazilian adolescents	Cross sectional – E Survey	Self-administered questionnaire using a smartphone or computer with Internet access. (Not)	12 to 17 years	9,470		Sedentary behavior increased from 44.57 to 70.15%

Gilic B, Ostojic L, Corluka M, Volaric T, Sekulic D,[19] Bosnia and Herzegovina.	Contextualizing parental/familial influence on physical activity in adolescents before and during COVID-19 Pandemic: A Prospective Analysis.	Prospective Analysis	The Physical Activity Questionnaire for Adolescents (PAQ-A) (Validated)	15 – 18 years	688		PA decreased significantly from baseline to the follow-up testing period in the sample (from 2.98 ± 0.71 to 2.31 ± 0.68; t-test: 11.88, $p < 0.001$
Guo YF, Liao MQ, Cai WL, Yu XX, Li SN, Ke XY, Tan SX, et al[20]China	Physical activity, screen exposure and sleep among students during the pandemic of COVID-19.	cross-sectional online survey	Structured questionnaire was designed and distributed through WeChat to Parents & children (Not Validated)	First grade to high school	10,416		The daily duration of physical activity was assessed by the time child spend in doing light and vigorous activities. 58.7% reported decreased time participating in physical activity after the COVID -19.
Vogel M, Geserick M, Gausche R, Beger C, Poulain T, Meigen C, Körner A,[21] Germany	Age-and weight group-specific weight gain patterns in children and adolescents during the 15 years before and during the COVID -19 pandemic.	Trend study	Current German guidelines, BMI was calculated and transformed to standard deviation scores (BMI-SDS) using the references by Kromeyer-Hauschild (Validated)	1 to 18 years	150152	During the COVID -19 pandemic, substantial weight gain across all weight and age groups, reflected by an increase in mean BMI-SDS ($\beta = 0.05$, 95% CI 0.036 to 0.055; $p < 0.001$).	
Weaver R, HuntE,Armstrong B,[22] South Eastern U.S	COVID-19 leads to accelerated increases in children's BMI z-score gain: An interrupted time-series study.	Interrupted time series	BMI was calculated (BMI = kg / m^2) and transformed into age- and sex specific z-scores according to the WHO BMI for age growth charts. (Validated)	Mean age 8.7	1,770	Before the COVID-19 pandemic, children's yearly BMI z-score change was +0.03 (95% CI = 0.10, 0.15).	
Mulugeta W, Hoque L,[24] USA Massachusetts	Impact of the COVID-19 lockdown on weight status and associated factors for obesity among children in Massachusetts.	Retrospective prospective cohort study	Obesity (BMI percentile ≥ 95th) and overweight in accordance with (CDC) age-sex-specific child growth standards in the USA. (Validated)	8 to 16 years	701	4.2% increase in obesity. Mean BMI (SD) in kg/m^2.Before 21.07 (6.25) After 21.57 (6.36). Post lockdown, the mean (BMI) increased among all participants from 21.07 kg/m2 to 21.57 kg/m2 ($p < .001$).	

Xiang M, Zhang Z, Kuwahara K.[25] China	Impact of COVID -19 pandemic on children and adolescents' lifestyle behavior larger than expected	Natural experimental longitudinal study	Moderate- and vigorous-intensity PA was measured based on Global Physical Activity Questionnaire (GPAQ) developed by the World Health Organization (Validated)	6 to 17 years	2426		Overall, the median time spent in PA decreased drastically, from 540 min/week (before the pandemic) to 105 min/week (during the pandemic), yielding 435 min reduction on average. Prevalence of physically inactive students extensively increased from 21.3% to 65.6% with absolute change of +44.3% (P0.001.)
Nathan A, George P, Ng M, Wenden E, Bai P, Phiri Z, Christian H.[26] Western Australia	Impact of COVID-19 Restrictions on Western Australian Children's Physical Activity and Screen Time.	Retrospective Cohort	Online survey instrument for parents (Validated)	Parents of children aged 5 to 9 years who lived in Western Australia	157		Frequency and total duration of organized physical activity significantly declined during COVID -19 distancing. Organized physical activity (minutes/week) before COVID -19 distancing - Mean 189.7 SD 178.5 During COVID -19 Distancing - Mean 65.1 SD 170.6 Mean Difference – (−124.6) Percentage Difference - (- 65.7) p value <0.001
Giannini DT, Tavares CM, Takey M, Aloise MLR, da Costa AJ, de Carvalho DS, et al,[29] Brazil	Adolescents Emotional State and Behavioral and Dietary Habit Changes during Isolation Due to the COVID-19 Pandemic	Cross sectional	questionnaire prepared on Google Forms (Not validated)	mean age of 15.3 years	208		86.5% were inactive adolescents with less than 300 min of physical activity a week are considered inactive)

Ventura PS, Ortigoza AF, Castillo Y, Bosch Z, Casals S, Girbau C,[33] Spain Catalonia	Children's health habits and COVID-19 lockdown in Catalonia: Implications for obesity and non-communicable diseases.	Online structured survey	Parental Response (Not validated)	Age group- < 17 years	3464		After the implementation of lockdown, almost 70% of children reported not doing a minimum of an hour of PA on any day of the week, and only 10.3% reported an adequate PA

Results

COVID-19 pandemic had made the everyone to be confined indoors and led to increased SB which is manifested in this review.[6,7,11]Among 15 studies that examined PA changes in healthy children and adolescents, all except one were measured using subjective questionnaires, with five using validated questionnaires, six not validated and four partially validated. Three studies examined the PA and SB using a parent reported questionnaire.[13] Two studies used International Physical Activity Questionnaire and Global Physical Activity Questionnaire to measure the level of PA.[19,24] Three studies measured SB especially time spent sitting and one study measured sedentary time objectively using wrist worn accelerometer and other two used questionnaire.[11] These studies showed a significant increase in the time spent in sitting. Most children reported not doing a minimum of an hour of PA on any day of the week, it was observed that the minutes spent on PA week was significantly reduced.[10,13,19,26,29]

The study investigating the effect of COVID-19 restrictions on sleep quality, screen time and PA with a special focus on gender differences among 106 Tunisian school children of five to 12 years of age showed a significant main effect of "Confinement" on all items of the PA questionnaire ($p < 0.001$) as well as on the total PA score ($p < 0.001$). Particularly, in both genders' leisure ($\Delta\% -35\%$), daily ($\Delta\% = -16\%$ for boys and -27% for girls) and total PA ($\Delta\% = -7\%$ for boys and -17% for girls) decreased from "before" to "during" home confinement ($p < 0.001$). The study also revealed an increase in SB with a mean change of 1.23 and % of change in SB of +133.33%. The resulted change was significant at 0.001.[6] It was observed that those who spent time sitting was 79.8% which is significant at 0.041and 54.9% participants stated decrease in PA level and 48% did PA for < 30 minutes in a week (0.001***).[7] In a telephonic survey among 600 adolescents, around 45% reported no PA, 18.8% reported decreased PA and 21.8% reported increase in PA.[10] In a cohort study among 268 preschoolers revealed that SB increased from 605.6 to 659.8 minutes per day with a mean difference of 50.2 (17.1 to 83.3) at 95% CI.[11] A cross-sectional survey among 452 children and adolescents conducted in Saudi Arabia revealed that 42% did not exercise during the confinement.[14] An online survey conducted among 397 children / adolescents and their parents across 63 municipalities in Greece in April to May 2020 found that PA was decreased in 66.9%.[15] To analyze the PA and daily routine among children aged 0 – 12 years during lockdown using "Children and Lockdown" questionnaire, it was shown that 34.8% reported no PA.[12] SB (≥ 3 hours) increased from 44.57% [95% CI (42.92 – 46.23)] to 70.15% [(95% CI) (68.56 – 71.70)] in adolescents with a change in SB of 25.58 % (< 0.001).[17] Adolescents with less than 300 min of PA a week are considered inactive. Physical inactivity was reported in 86.5% of adolescents.[29] In a prospective analysis among 688 adolescents, it was noted that PA decreased significantly from baseline to the follow-up testing period in the sample (From 2.98 ± 0.71 to 2.31 ± 0.68; t-test: 11.88, $p < 0.001$), (measured by the Physical Activity Questionnaire for Adolescents–PAQ-A which is a seven day recall and self-administered questionnaire).[28] In an online cross-sectional survey undertaken among 10,416 first grade to high school students / caregivers, 41.4% students reported that they spent 16 – 30 min / day for light activity and 53.6% and 53.7% reported they spent only 0 – 15 min / day for moderate and vigorous activities respectively. More than half (58.7%) reported decreased time participating in PA after the outbreak of COVID-19.[20] Among 157 children aged five to nine years who lived in Western Australia, the frequency and total duration of organised PA which is measured as minutes spent per week significantly declined. The mean difference was (−124.6) and percentage difference was (−65.7) which is significant at p value < 0.001.[26] Significant differences were found for a reduction of weekly minutes of PA during the confinement (−102.5, SD 159.6) ($p < 0.001$). Overall, PA and all gender and age subgroups display significant reduction in PA and between the subgroup of participants aged between six and 12 years displays the highest reduction of weekly minutes [−120.4 (SD 159.0)].[33] Before lockdown, more than 50% children did PA after school for at least one hour per day for three or more days per week and 19% of children met the requirements for adequate PA (At least one hour of PA per day for more than four days per week). After lockdown, almost 70% children reported not doing a minimum of an hour of PA

on any day of the week, and only 10.3% reported an adequate frequency of PA.[31] Among the 2426 children and adolescents (boys, 51.2%; girls, 48.8%) overall, the median time spent in PA decreased drastically, from 540 min / week (before the pandemic) to 105 min / week (during the pandemic), yielding 435 min reduction on average and prevalence of physically inactive students extensively increased from 21.3% to 65.6% with absolute change + 44.3% with p value 0.001.[22] Table 4 indicates the characteristics and results of studies indicating change in SB among children and adolescents

Table 4: Change in sedentary behaviour

Author	SB type and units of measurement	SB Pre-lockdown Mean (SD)	SB During lockdown Mean (SD)	Change	P value (if applicable)
Abid R, Ammar A, Maaloul R, Souissi N, Hammouda O.[6]	Ricci and Gagnon sedentary behavior questionnaire.	1.06 ± 0.24	2.29 ± 1.03	1.23 Mean change change in sedentariness +133.33 %	P value <0.001)
Demirci N, Demirci PT, Koz H.[7]	Time spent sitting- Self reported		79.8% spent more time sitting		0.041
Allabadi H, Dabis J, Aghabekian V, Khader A, Khammash U.[10]	Self-reported days of physical activity conduct per week; increase/decrease in physical activity.		45% No Physical Activity		
Alonso-Martínez AM, Ramírez-Vélez R, García-Alonso Y, Izquierdo M, García-Hermoso A,[11]	Objectively measured physical activity, sedentary time were collected using a wrist-worn GENEActiv tri-axial accelerometer. Sedentary time, minutes per day	609.6 (69.4)	659.8 (116.6)	50.2 (17.1 to 83.3) (Mean Differences (95% CI)	0.006
Cachón-Zagalaz J, Zagalaz-Sánchez MªL, Arufe-Giráldez V, Sanmiguel-Rodríguez A, González-Valero G[12]	"Children and Lockdown" questionnaire		34.8% reported No PA No daily activity-390.77 (Mean) 215.34 (SD)		
López-Bueno R,López-Sánchez GF, Casajús JA, Calatayud J, Gil-Salmerón A, Grabovac I, Tully MA, Smith L[13]	Parent-reported questionnaire-weekly minutes of physical activity	198.6 (180.9)	96.1 (123.0)		< 0.001
Alshehri LM, Al Agha AE[14]	Self-reported duration of PA	43% Does not exercise	42% Does not exercise		
Androutsos O, Perperidi M, GeorgiouC, Chouliaras[15]	Parental report of child's PA		66.9% reported decrease in PA		
Malta DC, Gomes CS, Barros MBA, Lima MG, Silva AGD, Cardoso LSM, Werneck AO, Silva DRPD, et al[17]	Sedentary behavior (≥3 hours) Self-administered questionnaire	44.57 % (95% CI) (42.92 – 46.23)	70.15% (95% CI) (68.56 – 71.70)	25.58 % Change in sedentariness	< 0.001

Gilic B, Ostojic L, Corluka M, Volaric T, Sekulic D[19]	The Physical Activity Questionnaire for Adolescents (PAQ-A) was used to assess PALs PAQ-A is a 7-day recall and self-administered questionnaire	PA decreased 2.31 ± 0.68 2.98 ± 0.71			p < 0.001
Guo YF, Liao MQ, Cai WL, Yu XX, Li SN, Ke XY, Tan SX, et al[20]	Structured questionnaire completed by Students & parents		58.7% reported decreased time participating in physical activity.		
Xiang M, Zhang Z, Kuwahara K[25]	PA was measured based on Global Physical Activity Questionnaire (GPAQ) developed by the World Health Organization Inactivity is measured as < 30 min/day	21.3%	65.6%	+ 44.3%	0.001
Nathan A, George P, Ng M, Wenden E, Bai P, Phiri Z, Christian H[26]	The frequency and duration per week their child spent doing unstructured and organised physical activities (Minutes / week	Organised physical activities (Minutes / week 189.7 (178.5)	65.1 (170.6)	−124.6	< 0.001
Giannini DT, Tavares CM, Takey M, Aloise MLR, da Costa AJ, de Carvalho DS, da Silva SC, Pontes MHP, Monteiro CB[29]	Structured questionnaire-less than 300 min of physical activity a week are considered inactive		Physical inactivity was reported in 86.5% of adolescents		0.448
Ventura PS, Ortigoza AF, Castillo Y, Bosch Z, Casals S, Girbau C.[33]	Child exercising between 30 and 60 min a day	PA Never or < one day in a week 23.6%	69.7% of children reported not doing a minimum of an hour of PA on any day of the week	46.1% difference	

Impact of COVID 19 lockdown on changes in weight among children and adolescents

This review was done among 20 studies and among them, 10 studies used validated tool, two of them used partially validated and eight studies used tools which were not validated. Even though all eight studies reviewed show an increase in weight, only four studies showed an increase in weight with significant p value.

One among these eight studies was a self-reported study which indicated 41.7% of increase in weight.[10] Four studies found a significant change in BMI with increasing in overweight, and obesity among different age groups, including children, adolescents.[15,16,22,24] Factors contributing to this increase include changes in dietary habits, such as increased consumption of breakfast, salty snacks, and total snacks, as well as decreased PA.[10,11,13,15] The impact of lockdown process on dietary behaviour and PA habits of high school students were analyzed using a self-administered questionnaire and it was observed that both females and males underwent weight gain and there was an increase in the overweight and obese status. Overweight status changed from 3.9% to 6.7% and obesity increased from 2.1% to 4.7%.[7] A telephonic survey was conducted to find the impact of COVID-19 lockdown on dietary and lifestyle behaviors among 600 Palestinian adolescents. Here, 41.7% reported weight gain during the pandemic but it was not significant.[10] Parents of 387 children and adolescents reported that 35% of the children experienced weight gain due to dietary factors as well as decreased PA.[24] In a case report of 29 children of nine years old, it was revealed that children who were overweight or obese increased from 27.5% to 44.8%. Additionally, the study reported a median difference of 0.6 and a standard deviation (SD) of 1.2 in BMI.[16] In a retrospective prospective cohort among 701 children in the age group of eight to 16 years, it was observed that a 4.2% increase in obesity and a significant rise in mean BMI occurred. The overall burden of obesity and overweight also significantly increased during this period.[24] Yet another retrospective study

reported that the total mean weight-percentile was significantly higher in children following the lockdown (40.44 vs 38.82, respectively, P = 0.029) as calculated from CDC and WHO growth charts.[4] Another trend study from Germany revealed that in children and adolescents during the 15 years before and during the pandemic, there was a substantial weight gain across all age groups, with increase in mean BMI. The proportion of children gaining weight increased, while the proportion of children losing weight decreased.[21] Among 1770 children with a mean age of 8.7 years, a time series study focused on children's BMI z -score change and it was noted that an acceleration in BMI z-score occurred during the pandemic, particularly among girls and boys. For children classified as normal weight, BMI z- score change accelerated by + 0.58 (95% CI = 0.40, 0.76). The acceleration was also observed in lower and upper elementary / primary school children.[22]

Table 5 explains the change in weight in the following studies included in review.

total eight studies and among them, five showed statistically significant p value. Pre lockdown PA or reduced SB were pointed out in nine studies out of 15. Among them, seven studies showed significant p value. The negative impacts can influence the health status among the population and this itself can contribute to long term effects on the body which may manifest in adult life as life style diseases. During quarantine both females and males underwent weight gain, with an increase in the overweight and obese status of the participants.[7]

For girls and boys, BMI z-score change accelerated by + 0.33 (95% CI = 0.16, 0.50) and + 0.29 (95% CI = 0.12, 0.46), respectively, during the pandemic year.[22] It was evident from the review that majority of the studies pointed towards increase in weight among children with increase in overweight and obesity with sudden change in weight percentile and BMI.[4,22]

Table 5: Change in weight

Author	Change in weight units of measurement	Weight pre-lockdown mean (SD) / Median	Weight during lockdown mean (SD) percentage	Change	P value (if applicable)
Vinker-Shuster M, Grossman ES, Yeshayahu Y[4]	Weight percentile	38.82 ± 33.67	40.44 ± 34.43	1.62 ± 0.76	0.029
Demirci N, Demirci PT, Koz H[7]	Weight in Kgs	63.3 ± 11.0	66.9 ± 12.8	3.6 ± 1.8	< 0.01**
Allabadi H, Dabis J, Aghabekian V, Khader A, Khammash U[10]	Weightgain self-reported	NA	41.7% reported weight gain	NA	0.875
Androutsos O, Perperidi M, Georgiou C, Chouliaras G[15]	Parental report of child's weight gain	NA	35% reported weight gain	NA	NA
Brazendale K, Garcia J, Hunt ET, Blankenship M, Eisenstein D, Leon A[16]	Body mass index (BMI)	17.8 ± 6.0	19.1 ± 6.4	0.6 ± 1.2 (outcome change ± SD) (Paired-t test)	< 0.001
Vogel M, Geserick M, Gausche R, Beger C, Poulain T, Meigen C, et al[21]	BMI SDS (SD score)		Mean BMI-SDS (β = 0.05, 95% CI 0.036 to 0.055		NA
Weaver R, Hunt E, Armstrong B22	BMI z-score	+0.03 (95% CI = 0.10,0.15)	+0.34 (95% CI=0.21, 0.47)	BMI z-score change of + 0.31 (95% CI = 0.19, 0.44)	NA
Mulugeta W, Hoque L[24]	BMI kg / m^2	21.07 (6.25)	21.57 (6.36)	0.5 ± 0.11	< 0.001

Discussion

This systematic review emphasized on the impact of COVID-19 confinement on weight change and SB of children and adolescents under the age of 19 years. Pre lockdown weight and difference in weight were mentioned in five studies out of

Obesity is considered a major risk factor for severe complications of COVID-19 infections. Childhood obesity is also a major predictor of adult obesity and other chronic conditions, such as cardiovascular disease. Beyond the short-term effects of the COVID-19 pandemic, forward-thinking

strategies must be developed to prevent unprecedented increase in childhood obesity and unhealthy weight gain following post lock down.[24] Most of the studies in this review showed increases in SB during lockdown among children with increasing screen time. Findings of certain studies pointed out that the COVID-19 lockdown, with the concomitant closure of schools, negatively affected children's lifestyle behaviors, which are some of the predominant risk factors for obesity.[15,32]

As a direct consequence, reduction of PA has been associated with impaired well-being, mental, physical, and metabolic health. In this process, surveys were conducted in many countries to evaluate the effects of lockdown on inactivity. Severe global decline in PA affected high school students during the lockdown period. Before COVID-19, the rate of those who did not participate in the activity was 40.6%, while the most attended activity was determined to be 23.5%.[7] An increase in SB was found among the participants. Most of the studies reported decrease in PA and increase in SB.[6,10,11,33]

This review could also establish certain associated factors like consumption of high calorie food, sleep, increased screen time with decrease PA and consequent weight gain among children and adolescents. Among adolescents who reported increased weight gain were those with increased food intake, intake of sugar-added drinks, fried foods, sweets, those with no PA and those with increased screen time. The adverse effects of the COVID-19 pandemic and school closures could be detrimental for adolescents' long-term health.[10,15] The lockdown led to reduced PA, increased both screen exposure and sleep time, and reduced fruit and vegetable consumption both in children and adolescents.[13] The limited freedom of outdoor movement and the prolonged stay in the house / apartment are circumstances for development of risk of new inactive lifestyle habits.[18] Family conflict was negatively associated with PA before and during the pandemic. It is logical to assume that children who generally disagree with their parents will not get adequate support for PA. In addition, depression, stress, and anxiety, which commonly occur during home-confinement, probably increased existing familial conflicts. The importance of parent–child relationship and parental / familiar support in promoting PA both during regular life and during crises and health challenging situations should never be undermined.[19]

The reduced PA and prolonged SB during lockdown may negatively impact children's and adolescents' physical and mental health which would further reduce PA level and prolong SB.[25] Lockdown could influence changes in children's habits that could lead to risk factors for non-communicable diseases during adulthood if such behavior is sustained over time.[28]

A large percentage of children performed PA during the confinement, especially elementary school children, but they recorded little PA time. SB became ingrained, leading to an increased risk of obesity, diabetes and cardiovascular disease in children.[12,32] In contrast during Western Australian COVID-19 restrictions, there was an increase in young children's unstructured PA and outdoor play and decrease in organised PA.[26] The WHO indicates that children and youngsters aged five to 17 years should invest in at least 60 min per day of moderate-to-vigorous PA.[23]

Evidences suggested that during the period of social distancing, the effects on adolescents' health are likely to be more intense, as young people are isolated at their homes, with no PA and interaction with friends. This resulted in a reduction in sports practices and worsening SB, such as time in front of the computer and TV screens. SB, in addition to increasing cardiovascular risk, decreases energy expenditure and is generally associated with the consumption of caloric foods and soft drinks.[17,30,32,33]

The following evidences must be taken into more research hands as this could become a torch bearer for further research to happen among these population and subpopulation so to prevent damage to the health in future and to reduce the burden of life style diseases.

Strengths

This systematic review evaluated the effects of pandemic confinement on body weight and PA among children and adolescents. This had resulted in an increase in obesity and overweight even among children which must be identified as a silent modifiable risk factor for the younger generation. This review could be an eye opener for the health sector to provide more importance on prevention of these morbidity factors and to increase the PA among the young even during any confinement.

Limitations

Even with the common theme of impact of COVID-19 confinement on body weight changes and SB among children and adolescents, our systematic review could identify marked heterogeneity in the determinants and measured outcomes. This variation could be explained by diversity in the study population and types of measurement tools mainly relied on online surveys, questionnaires and social media platforms were the predominant data collection method, which has been recognized as limitation and biases. It is also limited by the contemporary nature of the pandemic; the literature was primarily related to countries where COVID-19 had an early 'first wave' impact. Even though weight gain is likely during confinement, further research using quantitative data collection techniques is needed to find the holistic impact of confinement to provide evidence-based problem solving in future. Despite our findings, it was hard to emerge with robust

conclusions as reviewed studies were observational studies.

Conclusion

The findings from these studies collectively indicate that the COVID -19 pandemic has had a significant impact on weight gain, overweight, and obesity across different age groups. Factors such as changes in dietary habits, reduced PA and disrupted routines likely contributed to these outcomes. The changing lifestyles among children and adolescents will certainly affect their future health. Therefore, these studies point out the pavement towards encouraging healthy behaviour among these age groups.

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