Review Article

Long-COVID and post-COVID effects on childhood related to physical inactivity: A home-based exercise prescription

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Abstract

The prevalence of obesity among children and adolescents is one of the most serious public health challenges of the 21st century. Implementing social distancing policy measures, such as the stay-at-home order, to control the spread of coronavirus disease 2019 (COVID-19) not only has affected lifestyles and weights in children but has also created an obesity-inducing environment, leading to modifications in the patterns of interactions between this age group and their surrounding environment. Therefore, the COVID-19 pandemic has been effective in childhood obesity and its prevalence rate may continue increasing. This narrative review aimed to synthesize evidence from global studies on physical inactivity, and obesity among children and adolescents during COVID-19, and then prescribe an evidence-based home exercise guideline for this age group. The study findings revealed that the COVID-19 restrictions have drastically multiplied physical inactivity and obesity in children. It has been further established that childhood obesity leads to numerous chronic diseases, including diabetes mellitus, cardiovascular diseases (CVDs), psychosomatic disorders, lung diseases, and other metabolic problems in childhood and even as children grow up. Physical activity/exercise at home during and after COVID-19 has been correspondingly demonstrated to mitigate the problems associated with obesity. A wide range of resistance, aerobic, balance, flexibility and other types of exercises have been accordingly shown to protect against the negative effects of the pandemic on child health. Hence, efforts to facilitate such exercises are suggested to continue and be scaled up to prevent childhood obesity and relevant diseases during and after this unusual period.

Key Words: **Obesity, COVID-19, Pandemic, Children, Exercise**

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Introduction

Obesity has been prevalent worldwide since 1975, and the number of children living with this condition has multiplied almost eightfold (Gil & Takourabt, 2017). The prevalence of obesity is 25.8% in women and 14.9% in men. Also, the results of the experimental study and Health National; NHANES Survey Examination Nutrition reported that the year 2015 to 2016 approximately 18.5% of American children and adolescents aged 2 to 19 years became obese, 5.6% became severely obese and 16.6% are overweight (Azizi, Hoseini, & Hoseini, 2021). Prevalence of overweight and obesity in 8 to 12 years old students in Shiraz respectively 11.9% and 7.1%; In 7-12-year-old students of Sanandaj city (Iran), 9.8% and 13.2%, and in students of Semnan city (Iran), 14.3% and 18.8% have been reported (Sarokhani, Sarokhani, Dehkordi, Gheshlagh, & Fakhri, 2020). Obesity in children can thus augment the risk of various diseases, especially cardiovascular diseases (CVDs), diabetes mellitus (DM), obstructive sleep apnea (OSA), certain types of cancer, and osteoarthritis (An, 2017). In addition, it has been shown that childhood obesity persists into adulthood, and it is obvious that adult obesity conveys a higher risk of metabolic syndrome (Lloyd, Langley-Evans, & McMullen, 2012). It has been also confirmed that childhood and adolescent obesity add to the risk factors for CVDs, which can be associated with higher mortality in adulthood (Fakhouri, 2014). Furthermore, childhood obesity has been established to be linked to CVDs such as ischemic heart disease, stroke, and non-ischemic diseases (Sommer & Twig, 2018). It is worth noting that adults who are obese as children have higher rates of morbidity and mortality, even if they lose weight in adulthood (Deckelbaum & Williams, 2001). Childhood obesity is thus an independent risk factor for hyperlipidemia, insulinemia, metabolic syndrome, and type II DM in adulthood. It is generally assumed that an earlier onset and longer duration of obesity can be associated with a greater cardiovascular risk, increasing concerns about childhood obesity trends (Lloyd et al., 2012).

The growing prevalence rate of overweight is, to some extent,

related to systematic societal changes, such as rapid urbanization and industrialization, leading to higher consumption of high-energy foods and physical inactivity. Thus, living in today's societies is connected with an increased risk of childhood obesity in developing and developed countries (Aryeetey et al., 2017). It has been also indicated that sedentary behaviors, such as watching too much television and playing video games, are stimulants for overeating, resulting in increased energy intake and obesity risk (Tremblay & Willms, 2003).

Since 2019, the world has been in the coronavirus disease 2019 (COVID-19) pandemic, caused by severe acute respiratory syndrome coron¬avirus 2 (SARS-CoV-2) (Banitalebi, et al., 2021). Implementing measures such as the stay-at-home order to control the spread of COVID-19, has dramatically affected the lifestyles and weights of children and adolescents, leading to lower physical activity and increased risk of obesity (Bagherian, Ghahfarrokhi, & Banitalebi, 2021; Jia, 2021). The pandemic has similarly led to long-term restrictions and quarantines, decreasing the levels of physical activity and expanding the time spent on various media platforms (Mardaniyan Ghahfarrokhi, et al., 2020; Pinto et al., 2020). Researchers have further pointed to a descending trend in children's physical activity during the COVID-19 pandemic (Bates et al., 2020; Moore et al., 2020; Shahidi, Stewart Williams, & Hassani, 2020; Xiang, Zhang, & Kuwahara, 2020; Zhou et al., 2021). For example, Moore et al. (Moore et al., 2020) reported that the given condition had detrimentally affected the physical activity of Canadian children and youth. Thus, it had been recommended that children get engaged in daily physical activities to decrease the risk of obesity during the COVID-19 era (Hammami et al., 2020). Due to the direct effect of physical activity on the immune system, it seems that moderate-intensity exercise has a protective effect, while repeated periods of vigorous exercise cause dysfunction of the immune system. It seems that intense long-term aerobic exercise training, probably due to the production of oxidants and cortisol along with cytokine suppression of the immune system, may cause upper respiratory tract infections (URTIs), which are closely related to exacerbating COVID-19 in obesity conditions (Rahmati-Ahmadabad & Hosseini, 2020). Therefore, the best advice is to do regular moderate-intensity exercise (da Silveira et al., 2020). On the other hand, vigorous-intensity activities may harm the growth and development of children's immune systems, since they do not have the capacity for such exercises (Hamosh, 1995; McMurray et al., 2007).

The main purpose of this study was to first review the existing literature on the effect of long-COVID and post-COVID on physical inactivity and childhood obesity and then to design an appropriate exercise prescription for inactive children.

Materials and Methods

Search methods

The present study was a Recommendations review. Searches were conducted using the following electronic databases: PubMed, Medline, Cochrane Library, as well as the Google Scholar search engine. The following keywords were used: adolescents, Children, exercise, training, physical activity, and Randomized clinical trials in Persian and English. The search period was limited to the period from inception to 2022.

Inclusion and exclusion criteria

The following inclusion criteria were used: (1) the primary objective of the study was to evaluate the randomized controlled trials of physical exercise on obesity-related diseases in Children and adolescents and (2) full papers published in English and Persian. Studies were excluded in the following sequence: any article that did not involve obesity; studies that evaluated obesity in other conditions, rather than Children and adolescents, and interventions that did not involve physical exercise.

Data extraction

Final included articles reviewed and pre-prepared by a checklist and the required data was extracted. Data extraction for each article was: sample size, Age of subjects, the protocol of exercise (training type, time of each session, training frequency, and volume).

Results

While home quarantine is effective in preventing the spread of COVID-19, the destructive effects of this restriction on children are still unknown. The prevalence of this disease harms children's physical activity as well as their participation in outdoor activities, physical education classes, and sports (Lang, 2014). An important question about physical activity and exercise is whether it is appropriate to exercise during a pandemic or not. First, research has shown that moderate-intensity exercise can have beneficial effects on the immune system responses against viral respiratory infections (Harsha & Berenson, 1995). It has been established that neutrophil and natural killer (NK) cell counts are enhanced following moderate-intensity physical activity (Halabchi, Ahmadinejad, & Selk-Ghaffari, 2020). As well, stress hormones are reduced, which in turn relieve extreme inflammation. These conditions alter the T-helper 1 (Th-1)/T-helper 2 (Th-2) cell responses and increase immunity to viral infections. However, prolonged high-intensity physical activity leads to immunosuppression (Halabchi et al., 2020). Second, children, who engaged more in standard physical activity, have a better body composition and lipid profile. As the risk factors for CVDs, like obesity, persist from childhood to adulthood, encouraging children to take part in regular physical activity promises to be less likely to develop CVDs in adulthood (Harsha

& Berenson, 1995). Unfortunately, mandatory instructions to prevent outdoor physical activity will disrupt children's daily routines and regular exercise. This condition increases the risk of weight gain in children who are prone to be overweight. Thus, it is recommended to take healthy eating and physical activity seriously (Calcaterra, Vandoni, Pellino, & Cena, 2020), because plays and physical activities are essential to protect the physical and emotional health of children during growth periods. In particular, physical activity increases lean body mass (LBM), metabolic profile, and psychological status by boosting the total daily energy expenditure (TDEE) (Kohl III & Cook, 2013).

In a study by McManus et al., no difference had been found between normal-weight and obese children, during moderate-to-severe physical activity, but the difference in the TDEE between the two groups was due to the lack of light-intensity exercise in obese children (McManus & Mellecker, 2012). Since obese children do not usually engage in low-intensity activities, studies suggest that plays and active lifestyles in small and confined environments are essential (Pitanga, Beck, & Pitanga, 2020). During quarantine and COVID-19, increased sedentary behaviors and limited exercise can thus minimize the TDEE and ultimately give rise to overweight. Based on these facts, engaging in recreational games and physical activities at home is one of the basic needs of children (Calcaterra et al., 2020).

Physical inactivity among children

inactive behavior is defined as any activity while sitting or lying down that consumes 1.5 metabolic equivalents (METs, [1]) (Runacres et al., 2021). Guidelines on global activity recommend that preschool children (aged 3-4) should engage in at least 180 min of physical activity a day, with no more than 60 min of screen time per day, and about 10-13 h of quality sleep a day (Guan et al., 2020). It is also suggested that children and adolescents of school age (5-17 years) should take part in moderate to high-intensity physical activities for at least 60 min per day, no more than 2 h of sedentary behaviors including screen time, and they should have 9-11 h of quality sleep a day (Guan et al., 2020). Children typically have physical activities daily, such as going to school actively, receiving physical education, doing sports, playing games, dancing, and attending playgrounds and parks.

Conversely, most of the inactivity, screen time, and sleep in children occur at home (Guan et al., 2020). Since the COVID-19 outbreak, the rate of inactivity in children has naturally increased, but limited information has been reported in this domain. However, some studies have shown that children's physical activity has dangerously reduced. Initial evidence also reports that physical activity has significantly dropped during this period. On the contrary, sedentary behaviors have compounded, and even quality sleep patterns in children and adolescents have been disrupted (Bates et al., 2020).

Whereas, the younger the children, the greater their desire for physical activity, research has proven that the average daily spontaneous PA in children and adolescents aged 14 to 17 years is 20 minutes a day, and the age range of 11 to 13 years needs 22 minutes a day, children 7 to 9 years old 47 minutes a day and children 4-5 years old is 57 minutes (Cicchella, 2022). Therefore, planning for physical activity in children is necessary.

Home-based exercise prescription for children

Aerobic exercise for children

For health promotion, the recommendation is at least 150 min of aerobic exercise per week (Chagas et al., 2020); however, 10 min per day is enough to promote health benefits (Chagas et al., 2020). Due to the social quarantine conditions caused by the COVID-19 outbreak, children can participate in aerobic activities such as walking, cycling, or running outdoors, however, it is possible to perform aerobic exercises, stepping up and down, continuously for at least 10 min daily if they want to exercise at home (Chagas et al., 2020). To encourage the adoption of active lifestyles, the American College of Sports Medicine (ACSM) developed guidelines for the level of physical activity required to produce health benefits. The main recommendations for young people and adults are 3-5 sessions per week of continuous and intense activity for 20-60 min. All children should thus participate in more than 60 min of low-intensity physical activity each day, and approximately 30 min/day of cardiovascular fitness exercises with 50% or more of the heart rate reserve (HRR) (Epstein et al., 2001). Jump rope is also the most affordable and widely used aerobic exercise for children. This exercise is an individual activity with an adjusted load of training, increasing physical activity by boosting physical strength. Moreover, music jump rope is a special type of exercise that is done with music (Table 1, Supplementary file) (Seo, 2017). This model of jump rope exercise requires the coordination of the hands and the feet with music and enhances the body's agility, endurance, speed, and flexibility. In this sense, Kang (2017) further reported that music jump rope could decrease obesity in elementary school students (Seo, 2017). Table 1 provides an example of aerobic training sessions for children.

Another effective exercise method in improving the indicators of CVDs in children is high-intensity interval training (HIIT). These exercise includes interval training protocols with different durations and high intensities that are separated by recycling periods involving "repeated sprint training" (RST) with a duration of about 3-7 sec and rest periods of less than 60 sec, "sprint interval training" (SIT) with about 30 sec of all-out exercises and

Table 1. Examples of aerobic training sessions for children.

Exercise	Type	Times in week	Time (min)	Intensity
Warm-up	Static stretching (Walters & Martin, 2000)		5 minutes	-
Main session	Jump roping program (Seo, 2017)	3	30 min	50–85% HRmax
	Jump roping (Walters & Martin, 2000)	5	30-40 min	50–85% HRmax
	Aerobic dance (Walters & Martin, 2000)	5	30-40 min	50–85% HRmax
	Jogging (Walters & Martin, 2000)	5	30-40 min	50–85% HRmax
	Stretching and aerobic walking (Best, 2010)		15 min	
	Stationary biking while watching TV (if available) (Best, 2010)		40 min	(63% of max HR)
	Treadmill walking (if available) (Best, 2010)		20 min	(60% of max HR)
	Jumping jacks (Rodríguez, Crespo, & Olmedillas, 2020)			
	Walk briskly around the house, or up and down the stairs (Rodríguez et al., 2020)	2-3 times/d	10-15 min	
	Jogging/marching in place		30-40 min	50–85% HRmax
	Stair climbing or step-ups (Rodríguez et al., 2020)		30-40 min	50–85% HRmax
	High Knees (Rodríguez et al., 2020)		30-40 min	50–85% HRmax
	Mountain climbers (Rodríguez et al., 2020)		30-40 min	50–85% HRmax
	Stair jumps (Rodríguez et al., 2020)		30-40 min	50–85% HRmax
	Burpees (Rodríguez et al., 2020)		30-40 min	50–85% HRmax
	walk around the house (Rodríguez et al., 2020)		30-40 min	50–85% HRmax
	Run down the Hall, crawl on all Fours, side jumps (Rodríguez et al., 2020)		30-40 min	50–85% HRmax
	Do an online exercise class (Rodríguez et al., 2020)		30-40 min	50–85% HRmax
	Knee to elbow (Rodríguez et al., 2020)		30-40 min	50–85% HRmax
	Side knee lifts (Rodríguez et al., 2020)		30-40 min	50–85% HRmax
	Active breaks (Rodríguez et al., 2020)		30-40 min	50–85% HRmax
	Aerobic (Rodríguez et al., 2020)		30-40 min	50–85% HRmax

Table 2. An example of an HIIT program

Sequence	Type of exercise	Times (seconds)	Rest (seconds)	Bouts (times)	Modifications	Equipment
Sequence1	Bike sprints	20	10	2	Perform seated	Bike
	Spider push-up	20	10	2	Perform from knees	None/mat
	Squat jumps	20	10	2	Squat and explode without jumping	None
	Treadmill sprints	20	10	2	Perform fast walking	Treadmill
One-minute macro break						
Sequence2	Lunge jump right	20	10	1	Lunge and explode without jump	None/mat
	Lunge jump left	20	10	1	Lunge and explode without jump	None/mat
	High knees rope	20	10	1	Keep feet low/mimic rope us	Jump rope
	Squat overhead press	20	10	2	Do not use weights	Dumbbells
	Speed skater	20	10	2	Touch opposite knee	None

Source: M. Olson - ACSM'S Health & Fitness Journal, 2014 (Olson, 2014)

2-4 min of passive recovery periods, and HIIT with either short (<45 sec) or long (2-4 min) interval durations. HIIT also increases the peak oxygen uptake (VO2max) by augmenting the transfer process and the use of oxygen. This upsurge depends on the intensity and duration of the exercise, as well as the number of repetitions and sets of exercises and recovery periods (Tables 2 and 3, Supplementary file) (Engel et al., 2018). Evidence shows that, compared with moderate-intensity continuous training (MICT), HIIT leads to further or equal reductions abdominal and visceral fat mass and improves cardiorespiratory fitness in overweight and obese children. Also, HIIT exercises have a greater effect on reducing metabolic risk factors in type-II DM and are more useful for promoting cardio-metabolic health. A meta-analytic study by Wewege et al. had also shown that short-term HIIT could reduce body fat and waist circumference in overweight and obese individuals so that the duration of these exercises was about 40% less than MICT (Liu, Zhu, & Deng, 2019). Table 2 presents an example of a HIIT program for children.

Strength exercise for children

Because of the above-mentioned issues, when writing a strength-training program, much attention should be paid to what age is appropriate to start it. Moreover, intensity and frequency, rest periods, and training volume should be taken into account (Duhig, 2013). According to the general principles mentioned, it is necessary to reflect on the following points that, depending on the maturity and development of children, the minimum age for starting weight training is around 6-8 years old, 2-3 days a week, on non-consecutive days. Body weight training is also a safe and effective training method for young athletes (6-9 years old). For sure, after establishing a proper training base and progress, these people (15-18 years old) can train with an intensity of 6-15 RM or with an intensity of 50-80% 1RM (one repetition maximum). In children, the rest period should be sufficient (at least 3 min) to allow proper recovery. The total volume of the exercise is usually 1-3 sets for each muscle group and the number of repetitions is 6-15 (Duhig, 2013). Available data suggest that well-developed and supervised resistance training programs may have beneficial health outcomes associated with body composition, cardiorespiratory fitness, blood lipids, bone mineral density, and insulin sensitivity (Benson, Torode, & Fiatarone Singh, 2008). Children, like adults, can also benefit from resistance training. However, this type of training in children should be supervised by qualified fitness professionals, consistent with the needs, interests, and abilities of younger populations (Faigenbaum & McFarland, 2016). The proper initiation of strength training for children is critical. Coaches, trainers, and parents who supervise children's exercise should also remember a few things before starting an exercise program. First, whether the child is psychologically and physically ready to take part in the program. For example, whether the athlete has previously participated in school sports activities or has attended a physician's office (Sewall & Micheli, 1986). An appropriate resi-stance training program also gives girls and boys the opportunity to strengthen their muscle fitness. Despite the importance of prescribing the right dose of resistance training, providing feedback on the quality of athletic performance is also essential (Faigenbaum & McFarland, 2016). Table 3 gives an example of a resistance training session for children.

Flexibility exercise for children

Flexibility, as a crucial factor of health-related physical fitness, refers to the ability to move joints smoothly and without restriction and pain-free range of motions. Flexibility also allows completing an action or a task effectively and without risk of physical injury, especially to joints, muscles, or ligaments, during eccentric exercise or training. Moreover, flexibility helps with muscle symmetry and postural control, particularly among children (Lee, et al., 2018). Stretching exercises have been also used for the prevention of low back pain in adults and children (Coledam, de Arruda, & de Oliveira, 2012; Faigenbaum, et al, 2005). Some recommendations (Table 2) are designed for exercise prescriptions for normal subjects (Knudson, 2008). The ACSM has further indicated that static stretching needs to be maintained for 10-30 sec with a repetition of 3-4 times per session, and it should be performed at least twice a week to enhance the flexibility level (Lee et al., 2018). The intensity of the stretching exercises should be minimal and the muscles and joints should be gently stretched and held before the pain point. Static stretching will additionally create a short-term increase in the range of motions and decrease passive tension in the muscles at a particular joint angle due to stress relaxation. The effect of stretching on muscle stiffness is not clear (Knudson, 2008; Knudson, Magnusson, & McHugh, 2000). Table 4 is an example of stretching training for children.

Balance exercises for children

Table 3. An example of a resistance training session for children

Session phase	Exercise	Volume (sets × reps)	Intensity (% 1 RM)	Phase time (min)
Warm up	Foam roller complex	2× 10 (each site)	N/A	20
	2 × 10 (each site)	2 × 8	BW	
	N/A			
	20			
	Goblet squat			
	Split squats	2 × 6 (each leg)	BW	
	Low box jump	2 × 6	BW	
	Scapula push-ups	2 × 8	BW	
	Monster band push press	2 × 8	Light band	
	Monster band pull-downs	2 × 8	Light band	
	Side plank	2 × 30 seconds	BW	
Main session	OH squat	3 × 6	Wooden dowel or junior barbell	20
	TRX supine row	3 × 8	BW	
Auxiliary exercise	Stretching complex	2 × 20 seconds	N/A	5

Source: Lloyd RS, Oliver JL. Strength and conditioning for young athletes: science and application. London: Routledge (2019) (Lloyd & Oliver, 2019).

Table 4. Example of a flexibility training session for children.

Exercise	Time	Type	Set	Repetitions
Warm Up	10 Minutes	March		
Main Session	20s	Wrist flexor and extensor stretches	3	Isometric Contraction
	20s	Standing pectoralis major stretches	4	Isometric Contraction
	20s	Shoulder internal rotation stretches	4	Isometric Contraction
	20s	Knees to chest low back stretches	4	Isometric Contraction
	20s	Butterfly hip internal rotators stretch	3	Isometric Contraction
	20s	Seated hamstring stretch	3	Isometric Contraction
	20s	Seated calf stretch	3	Isometric Contraction
	20s	Seated dorsiflexor stretch	3	Isometric Contraction
	20s	Curl-up	3	15 To 20
	20s	Curl-up oblique variation	3	15 To 20
	20s	Bridge	3	15 To 20
	20s	Birddog	3	15 To 20
	20s	Bridge from the knees	3	15 To 20
	20s	Back extension	3	15 To 20
	20s	Pine mobility by cat-camel	3	Isometric Contraction
	20s	Stretching exercises of hamstrings	3	15 To 20
Cooling Down		Stretching exercises		

Source: Knudson, Duane V (2008) (Knudson, 2008) and Moreira, R., et al (Moreira, Akagi, Wun, Moriguchi, & Sato, 2012).

Table 5. Example balance training program for children.

Exercise	Type	Description
Warm-up	Stretching exercises (Zolghadr, Sedaghati, & Daneshmandi, 2019)	These exercises could perform on the floor and on balance pads, with eyes open and close and at different elevation
	Walking on a line (Dehghani & Gunay, 2015)	
	Side walking (Dehghani & Gunay, 2015)	
	Reverse walking (Dehghani & Gunay, 2015)	
	Zig–Zag walking (Dehghani & Gunay, 2015)	
	Longer strides (Dehghani & Gunay, 2015)	
	Tandem standing (Dehghani & Gunay, 2015)	
	Double-leg stance with feet apart and together and one-leg stance (Dehghani & Gunay, 2015)	
	Standing on one foot (Zolghadr et al., 2019)	
	Weight transfer (Zolghadr et al., 2019) Weight transfer (Zolghadr et al., 2019)	
	Swinging the arms back and forth together rhythmically (Moradi, Jalali, & Bucci, 2020)	
	Bending and straightening the knees (Moradi, Jalali, & Bucci, 2020)	
	Walking along curves and then with abrupt changes of direction (Moradi, Jalali, & Bucci, 2020)	
	Walking through the space made by two facing benches (Moradi, Jalali, & Bucci, 2020)	
	Walking on the rope (Moradi, Jalali, & Bucci, 2020)	
	Walking on the balance beam with open hands (Moradi, Jalali, & Bucci, 2020)	
	Standing on the balance board (Moradi, Jalali, & Bucci, 2020)	
	Jumping on the hula hoop rings with one leg and two legs (Moradi, Jalali, & Bucci, 2020)	
	Training with a Swiss ball (Moradi, Jalali, & Bucci, 2020)	Example: sitting on the Swiss ball, single leg supine bridge, abdominal crunch and so on
	Rolling (Moradi, Jalali, & Bucci, 2020)	
	Hopping (Moradi, Jalali, & Bucci, 2020)	
	Skipping (Moradi, Jalali, & Bucci, 2020)	
	Galloping (Moradi, Jalali, & Bucci, 2020)	
	Jumping (Moradi, Jalali, & Bucci, 2020)	
Cooling Down	Stretching exercises (Zolghadr et al., 2019)	

Balance, as one of the factors of motor-related fitness, is defined as the ability to maintain equilibrium. Dynamic balance is thus the ability to maintain balance while changing posture, such as walking and running, and static balance refers to the ability to maintain a static center of gravity when standing and sitting (Jazi, Purrajabi, Movahedi, & Jalali, 2012). Sensory input, central nervous system processing, and neuromuscular responses also control body balance (Houghton & Guzman, 2013). The basic prerequisite for motor development in children depends on on postural control, especially postural stability (Emara, 2015). Accordingly, factors that influence postural control and balance are sensory information obtained from the somatosensory, visual, and vestibular systems and motor responses that affect coordination, joint range of motions, and strength (Mohammadi, Alizadeh, & Gaieni, 2012). Balance ability, a strategic component of coordination capacities, is also subject to several factors (Dehghani & Gunay, 2015). Table 5 provides examples of balance training for children.

Table 6. Examples of the plyometric training program for children.

Session phase	Exercise	Volume (sets × reps)	Rest	Phase time (min)
Warm-up	Glute bridge	2 × 8	N/A	20
	Crab walks	2 × 8	N/A	20
	Superman	2 × 6 (each side)	N/A	20
	Bear crawls	2 × 6	N/A	20
	Spiderman	2 × 6 (each leg)	N/A	20
	Monster band walks	2 × 8 (each leg)	N/A	20
	Goblet squats	2 × 6	N/A	20
Main session	Bodyweight clock – work (single leg balance)	3 × 6	30 s	
	High 5 – single leg balance	3 × 20 s (each leg)	30 s	
	Box jumps	3 × 8	60 s	
	Drop lands	3 × 6	60 s	30
	Broad jump + stick	3 × 6	60 s	
	Cross-work hop + sticks	3 × 5 (each leg)	60 s	

Source: Lloyd RS, Oliver JL. Strength and conditioning for young athletes: science application. London: Routledge (2019) (Lloyd & Oliver, 2019).

Plyometric and power exercises for children

Plyometric exercises are a method of training performed by rapid muscle stretching, followed by rapid shortening. Thanks to plyometric training, the nervous system prepares to react to the stretch-shortening cycle faster. These exercises improve the speed and the power of children and strengthen their bones. It has been shown that plyometric training can also improve running speed, jumping, and strength in adults and young children (Johnson, Salzberg, & Stevenson, 2011). It has been approved that such exercises are safe and effective for enhancing muscle strength in children (Chaouachi et al., 2014). Moreover, it has been proven that jumping exercises in children and adolescents have beneficial effects on bone density and mineral content, with no side effects. Plyometric training should be therefore implemented, when possible, to increase bone mass at the early stages of life, which may have a direct preventive effect on bone diseases, like osteoporosis, later in life (Gómez-Bruton, et al., 2017). The plyometric exercise program must be designed individually. The following is a summary of the instructions for doing these exercises in child and youth athletes:

Training intensity: It should be based on eccentric loading, and at all times, so children should progress from low- to high-intensity exercises.

Training volume: Children should use performance thresholds (e.g., ground contact time or reactive strength index) to determine training volume; however, single sets of 6-10 repetitions, progressing to multiple sets of 6-10 repetitions, as a general guideline is supported.

Training frequency: It includes two sessions each week on non-consecutive days.

Repetition velocity: It refers to using performance thresholds (as above) to maximize motivation and performance quality.

Recovery: It encompasses 60-180 sec of inter-set rest period for low-level plyometric exercise; however, this may need to be increased when performing multiple plyometric of a high eccentric loading nature (Lloyd, Meyers, & Oliver, 2011).

The first stage of plyometric training for children and adolescents includes potential exercises, which are largely restricted to the imagination of the coach; however, such movement skills can include free-standing bodyweight squats and in-line lunges, and the next progression involves a range of jumping exercises, and the subsequent stage is hopping, where an element of horizontal distance is introduced to the plyometric task (Lloyd et al., 2011). Once children demonstrate competence at stages 1-3 and enter adolescence, they can move onto low-intensity box jumps (jumping onto and stepping down from a box), have “obstacle” drills such as the use of hurdles, and do multiple jumps (Lloyd et al., 2011). Table 6 provides an example of plyometric training for children.

Discussion

The sharp rise in physical inactivity in the 21st century has created major problems such as childhood obesity because children are naturally the most active age group. Additionally, the COVID-19 pandemic and related restrictions are drastically increasing inactivity and obesity in children and adolescents. Childhood obesity can also lead to many related diseases, including DM, CVDs, psychosomatic disorders, lung diseases, and other metabolic problems in childhood and old age. In return, physical activity/exercise at home during and after the COVID-19 pandemic can well improve obesity and other related diseases. Accordingly, a wide range of resistance, aerobic, balance, flexibility, and another type of exercises can be easily performed at home as a preventive intervention to improve obesity and related diseases during the pandemic.

Conclusion

In the current research, although it tried to include the latest and maximum clinical trial articles and focus on the different dimensions of the impact of exercise on children's health during the Covid-19 era, which was neglected in previous studies, there were also limitations. Among them, the sports exercises used were very diverse and the method of performing these exercises was different, which made us unable to examine all the exercises. Future research should examine the effect of exercise training over a longer period. It is suggested that the effect of various exercises on the health of sick children and adolescents should be investigated in future research and its effectiveness should be determined.

What is already known on this subject?

Implementing social distancing policy measures, such as the stay-at-home order, to control the spread of coronavirus disease 2019 (COVID-19) not only has affected lifestyles and weights in children but has also created an obesity-inducing environment, leading to modifications in the patterns of interactions between this age group and their surrounding environment.

What this study adds?

A wide range of resistance, aerobic, balance, flexibility and other types of exercises have been accordingly shown to protect against the negative effects of the pandemic on child health. Hence, efforts to facilitate such exercises are suggested to continue and be scaled up to prevent childhood obesity and relevant diseases during and after this unusual period.

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Compliance with ethical standards

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