



Review Article

The Role of Physical Activity in Children with Type 1 Diabetes during Quarantine and COVID-19 Pandemic: Narrative Review

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ABSTRACT

Background: The rapid and unprecedented outbreak of the Coronavirus (COVID-19), which spread rapidly around the world in late 2019, prompted the World Health Organization to declare a public health emergency, which soon became an international public health concern. The concerns are especially more serious in people with certain diseases, such as diabetes. The need to quarantine and the preservation of social distances lead to further inactivity and, thus, more health consequences. It is necessary to maintain physical activity and regular exercise which, in addition to reducing the consequences of inactivity, can lead to better control of blood glucose in children with type 1 diabetes. This review article investigated the need for regular physical activity in children with type 1 diabetes who were quarantined during the COVID-19 outbreak.

Methods: For this purpose, the PubMed, Scopus, and Google Scholar databases were searched for relevant articles published up to September 2021, and articles identified based on the search keywords were reviewed.

Results: Online exercise programs may be helpful in counteracting the sedentary lifestyle associated with the pandemic. A short exercise session, which can be repeated frequently throughout the day, may represent an optimal intervention strategy to maintain the health and well-being of young people with type 1 diabetes

Conclusion: Exercise in a safe home environment and under the supervision and encouragement of parents while monitoring and controlling blood glucose has several physical and psychological benefits that should be considered during quarantine and the outbreak of COVID-19

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Background

In late 2019, Severe Acute Respiratory Syndrome-Coronavirus-2 (SARS-CoV-2), also known as coronavirus disease-2019 (COVID-19), spread rapidly worldwide and became pandemic [1]. The hypothesis that children are less likely to develop COVID-19 is deceptive, because it has been shown that infants,

toddlers, and children can also be infected with the virus. However, COVID-19 infection appears to be clinically lower in children than in adults, with children accounting for 1-5% of diagnosed cases with an average age of 6.7 years [2].

Type 1 diabetes, one of the most common chronic diseases in childhood, is an autoimmune disorder in which a person's T cells destroy the beta cells in the pancreas, which is responsible for producing insulin, and lead to disruption in its production [3]. Research has shown that the main reason for the increased risk of COVID-19 complications in diabetics may be poor

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glycemic control or hyperglycemia [4].

The role of regular exercise in the prevention, control, and treatment of various diseases has been proven. Significant results are available on the effects of exercise in life and disease management in children and adolescents with type 1 diabetes. A systematic review and meta-analysis conducted in 2018 showed that exercise improves some of the biomarkers of severity of type 1 diabetes in children and adults [5]. On the other hand, inactivity resulting from the outbreak of COVID-19 may have negative effects on blood glucose control in this population [6]. The present article aimed to review the need for regular physical activity in children with type 1 diabetes during quarantine the COVID-19 outbreak.

COVID-19

In December 2019, analyses of samples of the lower respiratory tract revealed a new type of coronavirus, called SARS-CoV-2, which causes a new disease named COVID-19 [7].

Angiotensin-converting enzyme 2 (ACE2) receptor is known to allow the entry of the virus of COVID-19 into the host cell [8]. ACE2 is widely expressed in the respiratory tract, kidneys, heart, brain neurons, intestines, immune cells, vascular endothelium, and pancreas [9]. The most well-known form of transmission of COVID-19 is through large respiratory droplets that are transmitted from one person to another by talking, sneezing, and coughing [10].

Clinical features of COVID-19 range from asymptomatic to flu-like symptoms such as fever, cough, respiratory problems, fatigue, and muscle aches. In more severe cases, acute respiratory distress syndrome and involvement or death of various organs in the body also occur [11]. Children with COVID-19 infection are generally asymptomatic, thus increasing the risk of spread of the outbreak. In fact, in more than 90% of children with the disease, the infection is clinically silent or characterized by mild to moderate symptoms, while 5.2% of cases are severe and 0.6% of affected children face a critical form of the disease [2]. A more active innate immune response, a healthy respiratory tract, as well as different distribution, maturation, and function of viral receptors may partly explain the relative resistance to COVID-19 infection in children [1].

Type 1 Diabetes, Signs and Symptoms

Diabetes, one of the leading causes of death worldwide, is a chronic inflammatory disease characterized by metabolic and vascular abnormalities [12]. The two main types of this disease are type 1 diabetes and type 2 diabetes. In diabetes, high blood sugar levels are caused by insufficient production of the insulin hormone in the body (type 1 diabetes) or the body's resistance to the insulin hormone and its inability to perform its normal function (type 2 diabetes) [13]. In type 1 diabetes, the body's immune system attacks insulin-producing cells, and so, the body produces very little or no insulin. Therefore, the need for daily insulin control in these patients is inevitable [3]. Hyperglycemia is associated with multiple defects in the immune system and dysfunction of monocytes, macrophages, and neutrophils [12]. Type

1 diabetes accounts for about 5% of all diagnoses of diabetes, and its global incidence increases by about 3% each year [14]. Although type 1 diabetes is one of the most common childhood disorders, it can occur at any age [15]. However, the peak incidence occurs at the age of 5-7 years and at or near puberty [16].

The most important symptoms of type 1 diabetes in children and adolescents are polyphagia (overeating), polydipsia (increased thirst), and polyuria (frequent, excessive urination). However, weight loss, dry mouth, and fatigue are also common symptoms of type 1 diabetes [17]. These diagnostic symptoms are almost similar in adults and are somewhat less common [17]. Diabetic ketoacidosis (DKA) also occurs in approximately one-third of people with type 1 diabetes [18]. DKA is a complication of severe insulin deficiency that leads to hyperglycemia accompanied by glycosuria (excretion of glucose in the urine), dehydration, and ketogenesis [19].

The cause of type 1 diabetes is unknown; however, it seems that genetic factors cannot be the only cause, and a combination of environmental and genetic factors are thought to be involved in the susceptibility to type 1 diabetes. Environmental factors that may be involved in type 1 diabetes include poor diet, insufficient vitamin D intake, exposure to viruses associated with Langerhans's inflammation, and decreased intestinal microbiome diversity [20]. Obesity can also be associated with an increased risk of developing type 1 diabetes through β -cell stress, which is potentially associated with mechanical underpinning [20]. People with type 1 diabetes need daily insulin therapy, regular blood glucose monitoring, and a healthy lifestyle, which can be achieved through proper diet and regular exercise.

COVID-19 and Type 1 Diabetes

There is currently evidence that people with diabetes are not more susceptible to SARS-CoV-2 infection; this means that the prevalence of COVID-19 among people with diabetes is almost the same as the general population, and these people are not at higher risk for developing COVID-19. However, it has been reported that people with diabetes develop serious complications from COVID-19 [21]. Research has also shown that the main reason for the increased risk of COVID-19 complications in diabetics may be poor glycemic control or hyperglycemia [4]. SARS-CoV-2 infection through the release of more hormones that affect blood glucose, such as glucocorticoids and catecholamines, leads to a further increase in blood glucose levels and abnormal glucose variability in people with diabetes, thus creating more stressful conditions [22]. The severe consequences of COVID-19 in people with diabetes can occur for two reasons. First, due to the weak immune system and its insufficient function, the fight against the virus becomes more difficult, and the recovery period takes longer. Second, the virus may have more growth and development in the context of high blood glucose [23]. Reports from China and Italy also confirm this finding in patients with type 1 diabetes [21]. Possible reasons for this are the younger age of patients with type 1 diabetes, the lower prevalence of type 1 diabetes, and the overexpression of

CD8 + T lymphocytes in type 1 diabetes [24]. However, more studies are needed to reach a definite conclusion.

One of the problems that individuals with diabetes may face during COVID-19 is DKA, which can control fluid intake and electrolyte levels, an important factor in the control and management of sepsis [25]. Sepsis and septic shock are other serious complications that some people with COVID-19 have experienced [26].

The Positive Effect of Physical Activity on Type 1 Diabetes

As mentioned, type 1 diabetes is the most common endocrine disorder in childhood, affecting a large number of children every year, and this rate is increasing day by day [15]. As there is no definitive cure for type 1 diabetes, managing and controlling the disease through a variety of methods, such as healthy diets and regular exercise, can improve the quality of life for patients. Children are generally less affected by COVID-19 problems than adults; however, children with certain conditions, such as type 1 diabetes and related diseases, if left untreated, can be at high risk for serious complications from COVID-19 infection. Therefore, proper disease management is necessary in this population. Management of type 1 diabetes in children strengthens and promotes healthy functions in them and prevents or delays negative health-related outcomes such as cardiovascular disease, DKA, nephropathy, and neuropathy [27].

Insulin injection and a healthy lifestyle through a balanced diet and regular exercise are the most important ways to control blood glucose in children and adolescents with type 1 diabetes [28]. Physical activity has different effects on blood glucose control according to various factors, such as the number of exercise sessions per week and the length of the intervention period (12 weeks or more) [29-32]. Regardless of the type of exercise (aerobic versus resistance), exercise in children and adolescents with type 1 diabetes has a positive effect on blood glucose control [29-31].

The researchers also reported a positive correlation between glycemic control and level of physical activity in children and adolescents with type 1 diabetes. The higher the level of physical activity and the more active children were, the better blood glucose was controlled [27]. Other studies have shown that depending on the frequency and regularity of exercise, high levels of exercise in children and adolescents with type 1 diabetes are involved in more effective control of their blood glucose [29, 30].

Therefore, children and adolescents with type 1 diabetes can improve their quality of life by incorporating exercise into their daily lives along with leading an active lifestyle and following a proper diet.

In addition to physical benefits and maintaining physical fitness, improving blood glucose control, and preventing the serious consequences of diabetes and related diseases such as cardiovascular disease, regular physical activity in children with type 1 diabetes has psychological benefits [32] which, especially for children and adolescents with type 1 diabetes, are very important as there is a significant relationship between depression and stress and poor control of blood glucose and its complications [33].

Despite the importance of this issue, very few studies have addressed it, and more studies are needed in this field. The researchers showed that physical activity is strongly associated with the psychological well-being of children and adolescents with type 1 diabetes [32].

Restrictions in social relationships during quarantine have caused children and adolescents to suddenly lose many of their daily activities, opportunities to play, and relationships with peers. Over a long period of time, these factors can cause symptoms of depression, hopelessness, tediousness, stress, and anxiety in children and adolescents [34]. Because stress has negative effects on blood glucose control, managing and controlling stress, anxiety, and depression during this period will be important [35]. A positive relationship has been found between physical activity and mental health indicators in children with type 1 diabetes. More physical activity results in higher mental health, fewer psychological symptoms, less anxiety, greater perception of health, and improved quality of life in such children. A positive message for children and adolescents with type 1 diabetes is that they should engage in physical activity like their healthy peers to support their quality of life and improve their mental health [32]. Therefore, maintaining physical activity and game playing among children and adolescents during the outbreak of COVID-19 is very important.

The involvement of children with type 1 diabetes in physical activities is inevitable due to their physical and psychological benefits; however, these children need to be taught how to prevent hypoglycemia. In general, achieving daily nutrient requirements to control blood glucose in children with type 1 diabetes, especially those involved in exercise, is complex. The researchers showed nocturnal hypoglycemia in children with type 1 diabetes and introduced physical activity during the day as one of the main important factors [36]. For children and adolescents with type 1 diabetes who engage in physical activities, achieving a good balance between controlling blood glucose and consuming nutrients and carbohydrates for proper functioning of the energy supply is very important. The consumption of carbohydrate snacks, adjustment of insulin dose, and continuous control of blood glucose levels, especially after physical activity, should be considered [36]. Macronutrient intake guidelines for children and adolescents with type 1 diabetes include receiving 45-50% energy from carbohydrates, less than 35% energy from fat (saturated fats less than 10%), and 15-20% energy from protein. This distribution may vary depending on the individual characteristics of children [37]. In general, carbohydrate intake in children and adolescents with type 1 diabetes should not be overly restricted, as it may lead to adverse effects on growth and increase the risk of cardiovascular dysfunction and malnutrition [38].

Methods

For this purpose, the PubMed, Scopus, and Google Scholar databases were searched for relevant articles published up to September 2021, and articles identified based on the search keywords were reviewed.

Results

The widespread prevalence of COVID-19 and government recommendations for maintaining social distance, quarantining, and staying at home have had major impacts on physical activity behaviors worldwide. Physical inactivity during quarantine has negative effects on physical and mental health. Obesity, cardiovascular vulnerability, muscle atrophy, bone loss, and decreased aerobic capacity are among the negative effects of inactivity on the body [39]. Prolonged isolation also has negative effects on psychological responses and exacerbates post-traumatic stress symptoms, depression, and anxiety [40]. Studies have described the positive role played by physical activity in improving general health, mental health, heart health, blood circulation, and respiration, reducing stress and anxiety, and improving immune function [32, 41, 42].

The implementation of quarantine has led to the implementation of preventive measures in sports-related activities such as the closure of sports clubs and swimming pools and has prevented walking, running and playing outdoors. Therefore, home exercise is the only way to stay active during the COVID-19 epidemic. The researchers provided specific recommendations for home-based exercise [43]. They stated practical tips for staying active at home, such as performing aerobic exercise training on a bike or rowing ergometer, bodyweight training, dancing, and active video games, all of which can be used to counteract the harmful side effects of physical inactivity and its psychological consequences in the COVID-19 time [43].

The WHO also has provided specific guidelines for the level of physical activity in children and adolescents. According to these guidelines, children under the age of 5 years old should spend at least 180 minutes a day on physical activity. Children 3 to 4 years old should also have moderate to vigorous activities for 60 minutes a day. According to these guidelines, all children and adolescents 5 to 17 years old should be involved at least 60 minutes a day in moderate to vigorous physical activity. Moreover, activities to strengthen muscles and bones should be done at least three days a week [44].

The prevalence of the modern lifestyle in recent decades has led to a decrease in physical activity and an increase in sedentary behaviors in children and adolescents. Researchers have found that children with chronic diseases, including children with type 1 diabetes, are sedentary for more than 10 hours a day [45]. The widespread outbreak of COVID-19 in late 2019 led to the implementation of quarantine and the closure of leisure and play centers, parks, gyms, and sports clubs, which is a very important factor in reducing physical activity, especially in children, who are forced to stay at home for long hours during the day. The researchers stated that the level of physical activity of children and adolescents during the COVID-19 epidemic decreased sharply from 540 minutes per week (before the epidemic) to 105 minutes per week (during the epidemic) [46]. Such a large decline in physical activity brings with it countless physical and psychological consequences for children and adolescents. Limitations during the outbreak of

COVID-19 and quarantine may have a negative effect on blood glucose control in people with type 1 diabetes because physical activity outside the home, which is usually helpful in controlling blood glucose, is severely restricted. Therefore, reductions in physical activity and exercise due to sedentary behaviors can have harmful effects on glycemic control [47]. In a cross-sectional study, researchers compared the levels of physical activity of adolescents aged 11–18 years with type 1 diabetes and healthy controls. Overall, the results showed that physical activity levels during lockdown were below recommended levels, but physical activity levels did not differ between children with type 1 diabetes and control participants, nor between genders. In general, young people were insufficiently active during the lockdown, and some sub-groups were more affected than others by the restrictions [48]. In another study, the level of physical activity and glycemic values of children with type 1 diabetes were examined, and the results showed a decrease in the level of physical activity and worsening glycemic during quarantine [49]. Because physical activity is an important part of lifestyle management for adolescents with type 1 diabetes, physical activity through online platforms or home-based exercise can be effective for these children. Therefore, the implementation of physical activities as a hobby and a valuable way during the quarantine period should definitely be considered.

The researchers explored the physical activity level and variations in glycemic control in children with type 1 diabetes before and during the lockdown and proposed an online training program. Anthropometric characteristics, PA, play, sports, and sedentary time and the medical-related outcomes were recorded by parents of children with type 1 diabetes who completed an online survey. Two different approaches to exercise were suggested. Full-Training (FT) entailed 50-minute-long sessions with a combination of aerobic and resistance exercises adapted to the young age of the participants. It was suggested that children perform training for eight weeks with a frequency of at least 5 days/week. Active Breaks (AB) consisted of short bouts of exercises that lasted 3–5 min with a combination of mobility, coordination, balance, and yoga movements. Specialists recommended to perform AB at least 3 times/day for eight weeks. The results showed a significant lowering in exercise participation and time spent in outdoor play and a significant increase in time spent engaged in sedentary behavior. However, the researchers said that online exercise programs may be helpful in counteracting the sedentary lifestyle associated with the pandemic. A short exercise session, which can be repeated frequently throughout the day, may represent an optimal intervention strategy to maintain the health and well-being of young people with type 1 diabetes [50].

Discussion

Exercise at home is a good activity for children with type 1 diabetes. The researchers examined the role of physical activity at home during quarantine and the prevalence of COVID-19 on glycemic control in children with type 1 diabetes and showed that children who engaged in physical

activity and performed regular exercise during quarantine had further improvements in blood glucose control. Authors confirmed that maintaining regular physical activity in a safe home environment is a fundamental strategy for controlling blood glucose and reaping the benefits of physical activity in children and adolescents with type 1 diabetes during the COVID-19 pandemic [51].

Physical activities at home can be easily done using various applicable exercises and simple equipment and tools. Resistance training, rope training, stretching exercises, push-ups (on the wall or floor), sit-ups, stair climbing, balance exercises, throwing exercises (such as throwing a ball), jumping exercises (such as vertical jumping), squats, crunches, planks, and online exercise classes (such as yoga and Pilates classes) are examples of exercises that children and teens with type 1 diabetes can perform easily at home and without the need for special equipment. Furthermore, performing exercises using a treadmill and stationary bike (if they have equipment at home) will be very effective [52, 53]. It is also very important to pay attention to the level of fitness of the individual performing physical activities. It is better to start the exercises slowly and gradually increase their intensity. A physical activity program that lasts at least 60 minutes a day is preferred for children and adolescents [44]. The researchers reported that regular physical activity (at least 4 hours per week) with glycemic control is a good way to manage hypoglycemia [54].

The role of parents in the physical activities of children and adolescents during quarantine is essential for children with type 1 diabetes. Parents of children and adolescents with type 1 diabetes may be concerned that increased physical activity may lead to further hypoglycemia and may prevent their children from engaging in adequate physical activity or limit the duration or intensity of their children's exercise level [55]. However, encouraging and supporting parents provides a significant incentive for physical activity in children with type 1 diabetes [56]. Parents can encourage children to play and exercise during quarantine, participate in physical activities with other children, and design a variety of physical activities for children (such as games, stair climbing, and circular exercises).

An important point about children and adolescents with type 1 diabetes performing physical activities is the constant monitoring of their blood glucose levels. Exercise guidelines require direct monitoring of blood glucose before, during, and after exercise to detect delayed low blood glucose levels. Moderate-intensity exercise (such as fast walking) gradually lowers blood glucose levels. During the post-exercise period, blood glucose levels may decrease in people with type 1 diabetes due to lower levels of the adrenaline hormone and more glucose intake by the liver and muscles to replenish glycogen stores. Therefore, continuous control of blood glucose is essential [53]. A previous study has shown that during quarantine and the outbreak of COVID-19, no deterioration in blood glucose control was observed in children and adolescents with type 1 diabetes who exercised regularly and were well controlled [51]. Researchers have mentioned that one possible reason can be related to the continued presence of children with

type 1 diabetes and their parents at home and the careful monitoring and appropriate instructions for nutrition and physical activity. Another reason could be the reduction of stress and anxiety following the closure of schools and the elimination of some after-school activities, as it has been proven that increased stress and anxiety can have negative effects on the control of blood glucose [51].

COVID-19 is a rapidly growing disease with the rise of new variants that cause new issues and different symptoms, upend assumptions about the coronavirus, and make it difficult to reach a clear conclusion about how exercise can help children and adolescents with type 1 diabetes. Additionally, the number of studies that have examined the effectiveness of training methods with different intensities and frequencies in children with type 1 diabetes during the pandemic is very limited. Furthermore, COVID-19 vaccine protection on children with type 1 diabetes and how exercise may affect this impact still remain unclear and need more investigation in future studies.

Another major challenge associated with type 1 diabetes is the relationship between Covid-19 and glycemic control. People with type 1 diabetes, especially those who perform physical activity, need to monitor their blood glucose levels regularly so as to minimize adverse outcomes of COVID-19. Therefore, it is suggested that future studies monitor physical activity, nutrition, and blood glucose monitoring of people with type 1 diabetes.

Conclusion

The management of type 1 diabetes involves the interaction of factors, such as continuous monitoring of blood glucose, dietary considerations, and physical activity. Restrictions caused by COVID-19 do not necessarily require the complete elimination of physical activity for individuals. It is necessary to perform physical activities in various forms, such as home-based exercises and games, to maintain an appropriate level of physical fitness in individuals. In children and adolescents with type 1 diabetes, regular physical activity leads to proper control of blood glucose and improves their mental health. Regardless of the type of exercise (aerobic or resistance), higher repetition and longer duration of physical activity and reduction of sedentary behavior during quarantine and the outbreak of COVID-19 have many benefits for children and adolescents with type 1 diabetes. Nonetheless, it is necessary to pay attention to blood glucose levels and monitor its constant control. Exercise in a safe home environment and under the supervision and encouragement of parents while monitoring and controlling blood glucose has several physical and psychological benefits that should be considered during quarantine and the outbreak of COVID-19.

Conflicts of interest: No conflicts

References

1. Lu R, Zhao X, Li J, Niu P, Yang B, Wu H, et al. Genomic characterisation and epidemiology of 2019 novel coronavirus:

- implications for virus origins and receptor binding. *Lancet*. 2020;395(10224):565-74.
2. Ludvigsson JF. Systematic review of COVID-19 in children shows milder cases and a better prognosis than adults. *Acta Paediatr*. 2020;109(6):1088-95.
 3. Katsarou A, Gudbjörnsdóttir S, Rawshani A, Dabelea D, Bonifacio E, Anderson BJ, et al. Type 1 diabetes mellitus. *Nat Rev Dis Primers*. 2017;3(1):1-17.
 4. Zhu L, She Z-G, Cheng X, Qin J-J, Zhang X-J, Cai J, et al. Association of blood glucose control and outcomes in patients with COVID-19 and pre-existing type 2 diabetes. *Cell metab*. 2020;31(6):1068-77.
 5. Ostman C, Jewiss D, King N, Smart N. Clinical outcomes to exercise training in type 1 diabetes: a systematic review and meta-analysis. *Diabetes Res Clin Pract*. 2018;139:380-91.
 6. Hall G, Laddu DR, Phillips SA, Lavie CJ, Arena R. A tale of two pandemics: How will COVID-19 and global trends in physical inactivity and sedentary behavior affect one another? *Prog Cardiovasc Dis*. 2021;64:108-10.
 7. Organization WH. WHO Director-General's opening remarks at the media briefing on COVID-19 - 23 October 2020 2020 [Available from: <https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---23-october-2020>].
 8. Letko M, Marzi A, Munster V. Functional assessment of cell entry and receptor usage for SARS-CoV-2 and other lineage B betacoronaviruses. *Nat Microbiol*. 2020;5(4):562-9.
 9. Guo Y, Korteweg C, McNutt MA, Gu J. Pathogenetic mechanisms of severe acute respiratory syndrome. *Virus Res*. 2008;133(1):4-12.
 10. Del Rio C, Malani PN. COVID-19—new insights on a rapidly changing epidemic. *JAMA*. 2020;323(14):1339-40.
 11. Wu C, Chen X, Cai Y, Zhou X, Xu S, Huang H, et al. Risk factors associated with acute respiratory distress syndrome and death in patients with coronavirus disease 2019 pneumonia in Wuhan, China. *JAMA Intern Med*. 2020;180(7):934-43.
 12. Knapp S. Diabetes and infection: Is there a link?—A mini-review. *Gerontology*. 2013;59(2):99-104.
 13. Zimmet P, Cowie C, Ekoe JM, Shaw J. Classification of diabetes mellitus and other categories of glucose intolerance. *Intern Tex Diabet Mellit*. 2015;1:16.
 14. Group DP. Incidence and trends of childhood type 1 diabetes worldwide 1990–1999. *Diabe Med*. 2006;23(8):857-66.
 15. Gale E. Type 1 diabetes in the young: the harvest of sorrow goes on. *Diabetologia*. 2005;48(8):1435-8.
 16. Harjutsalo V, Sjöberg L, Tuomilehto J. Time trends in the incidence of type 1 diabetes in Finnish children: a cohort study. *Lancet*. 2008;371(9626):1777-82.
 17. Atkinson MA, Eisenbarth GS, Michels AW. Type 1 diabetes. *Lancet*. 2014;383(9911):69-82.
 18. Dabelea D, Rewers A, Stafford JM, Standiford DA, Lawrence JM, Saydah S, et al. Trends in the prevalence of ketoacidosis at diabetes diagnosis: the SEARCH for diabetes in youth study. *Pediatrics*. 2014;133(4):938-45.
 19. Jefferies CA, Nakhla M, Derraik JG, Gunn AJ, Daneman D, Cutfield WS. Preventing diabetic ketoacidosis. *Pediatr Clin North Am*. 2015;62(4):857-71.
 20. Rewers M, Ludvigsson J. Environmental risk factors for type 1 diabetes. *Lancet*. 2016;387(10035):2340-8.
 21. Fadini G, Morieri M, Longato E, Avogaro A. Prevalence and impact of diabetes among people infected with SARS-CoV-2. *J Endocrinol Invest*. 2020;43(6):867-69.
 22. Wang A, Zhao W, Xu Z, Gu J. Timely blood glucose management for the outbreak of 2019 novel coronavirus disease (COVID-19) is urgently needed. *Diabetes Res Clin Pract*. 2020;162.
 23. Federation ID. COVID-19 and diabetes 2020 [Available from: <https://www.idf.org/aboutdiabetes/what-is-diabetes/covid-19-and-diabetes/1-covid-19-and-diabetes.html>].
 24. Pitocco D, Tartaglione L, Viti L, Di Leo M, Manto A, Caputo S, et al. Lack of type 1 diabetes involvement in SARS-COV-2 population: Only a particular coincidence? *Diabetes Res Clin Pract*. 2020;164.
 25. Cherubini V, Gohil A, Addala A, Zanfardino A, Iafusco D, Hannon T, et al. Unintended Consequences of COVID-19: Remember General Pediatrics. *J Pediatr*. 2020;223:197-98.
 26. Association AD. How COVID-19 Impacts People with Diabetes 2020 [Available from: <https://www.diabetes.org/coronavirus-covid-19/how-coronavirus-impacts-people-with-diabetes>].
 27. Miculis CP, De Campos W, da Silva Boguszewski MC. Correlation between glycaemic control and physical activity level in adolescents and children with type 1 diabetes. *J Phys Act Health*. 2015;12(2):232-7.
 28. Teles SAS, Fornés NS. Food consumption and metabolic control in children and adolescents with type 1 diabetes mellitus. *Rev Paul Pediatr*. 2011;29(3):378-84.
 29. Sideravičiūtė S, Gailiūnienė A, Visagurskienė K, Vizbaraitė D. The effect of long-term swimming program on glycemia control in 14–19-year aged healthy girls and girls with type 1 diabetes mellitus. *Medicina (Kaunas)*. 2006;42(6):513-8.
 30. Mosher PE, Nash MS, Perry AC, LaPerriere AR, Goldberg RB. Aerobic circuit exercise training: effect on adolescents with well-controlled insulin-dependent diabetes mellitus. *Arch Phys Med Rehabil*. 1998;79(6):652-7.
 31. Wang YCA, Stewart S, Tuli E, White P. Improved glycemic control in adolescents with type 1 diabetes mellitus who attend diabetes camp. *Pediatr Diabetes*. 2008;9(1):29-34.
 32. Aman J, Skinner T, De Beaufort C, Swift PG, Aanstoot HJ, Cameron F, et al. Associations between physical activity, sedentary behavior, and glycemic control in a large cohort of adolescents with type 1 diabetes: the Hvidoere Study Group on Childhood Diabetes. *Pediatr Diabetes*. 2009;10(4):234-9.
 33. Hood KK, Huestis S, Maher A, Butler D, Volkening L, Laffel LM. Depressive symptoms in children and adolescents with type 1 diabetes: association with diabetes-specific characteristics. *Diabetes care*. 2006;29(6):1389-91.
 34. Courtney D, Watson P, Battaglia M, Mulsant BH, Szatmari P. COVID-19 impacts on child and youth anxiety and depression: challenges and opportunities. *Can J Psychiatry*. 2020;65(10):688-91.
 35. Katulanda P, Dissanayake HA, Ranathunga I, Ratnasamy V, Wijewickrama PS, Yogendranathan N, et al. Prevention and management of COVID-19 among patients with diabetes: an appraisal of the literature. *Diabetologia*. 2020;63(8):1440-52.
 36. Bachmann S, Hess M, Martin-Diener E, Denhaerynck K, Zumsteg U. Nocturnal hypoglycemia and physical activity in children with diabetes: new insights by continuous glucose monitoring and accelerometry. *Diabetes Care*. 2016;39(7):95-6.
 37. Smart CE, Annan F, Higgins LA, Jellery E, Lopez M, Acerini CL. ISPAD Clinical Practice Consensus Guidelines 2018: Nutritional management in children and adolescents with diabetes. *Pediatr Diabetes*. 2018;27:136-54.
 38. de Bock M, Lobley K, Anderson D, Davis E, Donaghue K, Pappas M, et al. Endocrine and metabolic consequences due to restrictive carbohydrate diets in children with type 1 diabetes: An illustrative case series. *Pediatr Diabetes*. 2018;19(1):129-37.
 39. Bortz II WM. The disuse syndrome. *West J Med*. 1984;141(5):691-4.
 40. Brooks SK, Webster RK, Smith LE, Woodland L, Wessely S, Greenberg N, et al. The psychological impact of quarantine and how to reduce it: rapid review of the evidence. *Lancet*. 2020;395(10227):912-20.
 41. Romeo J, Wärnberg J, Pozo T, Marcos A. Physical activity, immunity and infection. *Proc Nutr Soc*. 2010;69(3):390-9.
 42. Wu N, Bredin SS, Guan Y, Dickinson K, Kim DD, Chua Z, et al. Cardiovascular health benefits of exercise training in persons living with type 1 diabetes: a systematic review and meta-analysis. *J Clin Med*. 2019;8(2):253.
 43. Hammami A, Harrabi B, Mohr M, Krstrup P. Physical activity and coronavirus disease 2019 (COVID-19): specific recommendations for home-based physical training. *Manag Spor Leis*. 2020:1-6.
 44. Organization WH. HealthyAtHome - Physical Activity 2020 [Available from: <https://www.who.int/news-room/campaigns/connecting-the-world-to-combat-coronavirus/healthyathome/healthyathome---physical-activity#>].
 45. Walker RG, Obeid J, Nguyen T, Ploeger H, Proudfoot NA, Bos C, et al. Sedentary time and screen-based sedentary behaviors of children with a chronic disease. *Pediatr Exerc Sci*. 2015;27(2):219-25.
 46. Xiang M, Zhang Z, Kuwahara K. Impact of COVID-19 pandemic on children and adolescents' lifestyle behavior larger than expected. *Prog Cardiovasc Dis*. 2020;63(4):531-32.
 47. MacMillan F, Kirk A, Mutrie N, Matthews L, Robertson K, Saunders DH. A systematic review of physical activity and sedentary behavior intervention studies in youth with type 1 diabetes: study characteristics, intervention design, and efficacy. *Pediatr Diabetes*. 2014;15(3):175-89.
 48. Telford DM, Signal DM, Hofman PL, Gusso SJIJoER, Health P. Physical Activity in Adolescents with and without Type 1 Diabetes during the New Zealand COVID-19 Pandemic Lockdown of 2020. *Int J Environ Res Public Health*. 2021;18(9):4475.
 49. Assaloni R, Pellino VC, Puci MV, Ferraro OE, Lovecchio N,

- Girelli A, et al. Coronavirus disease (Covid-19): how does the exercise practice in active people with type 1 diabetes change? A preliminary survey. *Diabetes Res Clin Pract* 2020;166:108297.
50. Calcaterra V, Iafusco D, Pellino VC, Mameli C, Tornese G, Chianese A, et al. "CoVidentary": An online exercise training program to reduce sedentary behaviours in children with type 1 diabetes during the COVID-19 pandemic. *J Clin Transl Endocrinol*. 2021;25:100261.
 51. Tornese G, Ceconi V, Monasta L, Carletti C, Faleschini E, Barbi E. Glycemic control in type 1 diabetes mellitus during COVID-19 quarantine and the role of in-home physical activity. *Diabetes Technol Ther*. 2020;22(6):462-67.
 52. Federation ID. Home-based exercise for people with diabetes 2020 [Available from: <https://www.idf.org/aboutdiabetes/what-is-diabetes/covid-19-and-diabetes/home-based-exercise.html>].
 53. Hospital C-aCwDMCs. Physical Activity 2020 [Available from: <https://covid19childhooddiabetes.com/physical-activity-2/>].
 54. Aljawarneh YM, Wardell DW, Wood GL, Rozmus CL, JoNS. A systematic review of physical activity and exercise on physiological and biochemical outcomes in children and adolescents with type 1 diabetes. *J Nurs Scholarsh*. 2019;51(3):337-45.
 55. Beraki Å, Magnuson A, Särnblad S, Åman J, Samuelsson U. Increase in physical activity is associated with lower HbA1c levels in children and adolescents with type 1 diabetes: results from a cross-sectional study based on the Swedish pediatric diabetes quality registry (SWEDIABKIDS). *Diabetes Res Clin Pract*. 2014;105(1):119-25.
 56. Ryninks K, Sutton E, Thomas E, Jago R, Shield JP, Burren CP. Attitudes to exercise and diabetes in young people with type 1 diabetes mellitus: a qualitative analysis. *PLoS One*. 2015;10(10):0137562.