Change in Physical Fitness due to the COVID-19 Pandemic Lockdown in French Adolescents: A comparison between two independent large samples from Diagnoform battery

Laurent Beghin, David Thivel, Jean-Benoit Baudelet, Thibault Deschamps, Hervé Ovigneur, Jeremy Vanhelst

Change in Physical Fitness due to the COVID-19 Pandemic Lockdown in French Adolescents: A comparison between two independent large samples from Diagnoform battery.

Laurent Béghin[1], David Thivel[2], Jean-Benoît Baudelet[3], Thibault Deschamps[4], Hervé Ovigneur[4], Jérémy Vanhelst[5]

[1] Univ. Lille, Inserm, CHU Lille, U1286 - INFINITE - Institute for Translational Research in Inflammation, F-59000 Lille, France

[2] Université Clermont Auvergne, CRNH, AME2P, F-63000, Clermont-Ferrand, France. "Health in Motion" International Research Chair, UCA foundation, France.

[3] Univ. Lille, CHU Lille, Congenital & Pediatric Heart Unit, Institut Cœur Poumon, F-59000 Lille, France

[4] IRFO, Diagnoform, F-59139 Wattignies, France

5 Sorbonne Paris Nord University, Inserm U1153, Inrae U1125, Cnam, Nutritional Epidemiology Research Team (EREN), Centre of Research in Epidemiology and Statistics - University of Paris Cité (CRESS), Bobigny, France.

Corresponding author information:

Jérémy Vanhelst

Sorbonne Paris Nord University

E-mail: jeremy.vanhelst@hotmail.fr

ABSTRACT

Background: Numerous studies reported a significant decline in physical activity level in adolescents as a result of the COVID-19 lockdown. Physical fitness is recognized as a powerful marker of health in youth. The aim of this study was to evaluate the impact of the COVID-19 Pandemic Lockdown on health-related physical fitness in French adolescents.

Methods: Two cross-sectional studies were performed comparing two different groups of French adolescents, before (sample 1) and after the first lockdown (sample 2). A total of 1231 adolescents (aged to 16.5 ± 1.5 years) participated in the two cross-sectional studies. Complete data for physical fitness and anthropometrics data were obtained.

Results: Adolescents from sample 2 showed lower physical fitness levels compared to adolescents from sample 1. Regarding physical fitness for boys and girls, physical fitness levels were significantly lower in both sex between adolescents from the sample 1 and adolescents from the sample 2, except for cardiorespiratory fitness and flexibility for boys and girls, respectively. The Physical fitness global score were also significantly lower between adolescents from the sample 1 and 2 for boys (-9.8%, $p < 0.01$) and girls (-16,2%; $p < 0.01$), respectively. Overall, the higher difference was found for performance in the speed body displacement test (-30%). A difference of 12,8% and 25% were observed for boys and girls, respectively.

Conclusions: COVID-19- Pandemic Lockdown had a negative impact on physical fitness in French youth. This study highlight the need to develop, in a near future, prevention programmes in order to improve the physical fitness in youth.

Keywords: Health crisis, youth, Health.

INTRODUCTION

Physical fitness is now widely recognized as a powerful marker of health in children and adolescents [1]. Health-related physical fitness refers to the ability of your body systems to work together efficiently to allow you to be healthy and perform activities of daily living [2]. Health-related physical fitness includes several components such as cardiorespiratory fitness (CRF), musculoskeletal fitness (including muscular strength and endurance, flexibility) and motor fitness [3]. In addition, body composition may be also included in health-related physical fitness components [3]. Health-related physical fitness is associated to multiple health benefits, such as a low risk to develop chronic diseases and premature death [1]. Recently, two systematic reviews and meta-analysis showed the evidence linking both CRF and muscular strength in children and adolescents with the health status later in life [4-5]. Authors showed that low muscular strength and CRF in adolescence are strongly associated with risk factors for major causes of death in adulthood [4-5]. As shown in these two systematic reviews, CRF is the most studied with strong evidence on health-related associations. A need to assess regularly this component in youth is well established and underlined by the American heart Association [6].

In December 2019, a beginning a global pandemic emerged following an abnormal increase of viral pneumonia in Wuhan. In March 2020, the World health Organization (WHO) announced a novel disease named Covid-19, which is caused by the SARS-CoV-2 virus and became a worldwide pandemic. Consequently, governments took several restrictions measures, including lockdown, who affected significantly daily physical activity behaviors. In France, the first lockdown began from March 17th 2020 until May 11th 2020, i.e 55 days. During this lockdown, all schools were closed while the school environment for children and adolescent is crucial to be more physically active and to achieve meet physical activity guidelines [7-9].

Physical inactivity and sedentary behaviors have adverse consequences on physical fitness levels [10]. Many research studies from different countries showed a worrying decrease of physical activity levels (PAL), associated to a dramatic increase of time spent in sedentary behaviors during and after lockdown [11-12]. Authors constated that social context, parental education level, environment and physical characteristics are factors having an impact on the percentage of decrease in PAL during lockdown [13-16]. While a substantial decline in physical fitness levels adolescents was already found since many decades, this public health crisis might therefore accentuate this worsening trend [17-18]. Many studies performed in European and American countries confirms this trend. Overall, authors showed school-aged boys and girls exhibited significant physical fitness performance losses after the successive lockdowns due to coronavirus disease period [19-27]. In France, data on health-related physical fitness during this period are scarce and limited to children population [24].

Authors showed a significant decrease on physical fitness and motor fitness performances [24]. Main limits of this study are the low sample size (n=106 and 100 before and after confinements, respectively), exclusively in young children. Consequently, these limits arouse a particular interest to examine the impact of public health crisis in a large sample including adolescent population.

In this context, we hypothesize that the first lockdown had a negative impact on health-related physical fitness in French adolescents. Using data from two independent large samples, the aim of this study was to examine the impact of COVID-19 Pandemic Lockdown on health-related physical fitness in French adolescents.

METHODS

Participants

This study is part of the French health Diagnoform® programme (https://irfo.fr/) assessing physical fitness levels in French population from the age of 5 years. A cross-sectional design was used in order to contrast health-related physical fitness data of two samples of adolescents, evaluated before and after the lockdown in France. For the present analysis, two cross-sectional studies were performed comparing two different groups of French adolescent students, who studied at the same school at two different school years (before and after the first lockdown, i.e september 2020 and September 2021).

A total of 1231 adolescents participated in the two independent large samples. Complete data for physical fitness and anthropometrics data were obtained for all participants. Before and after lockdown, 532 adolescents (318 boys, 214 girls) and 699 adolescents (325 boys, 374 girls) participated, respectively. Anthropometric characteristics and physical fitness were measured.

All data obtained from the organizer "Institut des Rencontres de la FOrme" of the event were anonymized, and declared and approved by the Commission Nationale de l'Informatique et des Libertés (National Commission on Informatics and Liberty). The assessment was explained to both adolescent and their parents, after which the children or their parents could accept or decline record anonymously their information technology data. Data were recorded by the organizer in an electronic data system. An audit of the complete dataset was performed, and aberrant data were excluded. As this research was not performed to improve biological or medical Human knowledge, this present study is not considered as clinical research according to French regulatory requirement ("Jardé" law). In this context, this study does not need any approval from an ethical committee [28].

Anthropometric characteristics

Body weight was measured with the participant wearing light clothes and without shoes to the nearest 0.1 kg using an electronic scale (Seca, Hamburg, Germany). Height was measured without shoes to the nearest 0.1 cm using a standard physician's scale (Seca, Hamburg, Germany). Body Mass Index was calculated as weight/height^2 (kg/m^2). Normal weight, overweight and obesity were assessed using specific thresholds according to WHO classification [29]. These international cut-offs are defined by values of BMI at age 18: BMI 18.5 normal weight, 25 (overweight) and 30 (obesity).

Physical fitness

Health-related physical fitness procedures have been described below and its reliability and validity indicated, as previously published [30-32].

Cardiorespiratory Fitness (CRF) was measured by a 20-meter shuttle run–walk test during 6 *min*. This test has been validated against the 20-m shuttle run reference test from Leger et al (1988) (r = 0.78; P =0 .001) and showed a good reliability (0.84) [30]. Adolescents were instructed to run and walk as far as possible between two lines located 20 m apart during 6 min. The adolescent ran as quickly as possible from the starting line to the other line and returned to the starting line at a fast walking pace, crossing each line with at least one foot throughout the complete test. The test began on the whistle and was concluded after 6 *min*. The distance covered by the adolescent was recorded and was expressed in meter (*m*).

Lower Explosive strength (LES) was assessed by the standing broad jump test. This test showed a good reliability (0.84) [30]. From a starting position immediately behind a line, standing with the feet approximately shoulder width apart, adolescent jumped as far as possible with their feet together. The result was recorded in *cm*. A nonslip hard surface, chalk and a tape measure were used to perform the test.

Speed/agility (SA) was assessed by the 4 × 10 m shuttle run test. An excellent reliability was found for the 4x10m shuttle run in adolescent (0.90) [30]. Two parallel lines were drawn on the floor 10 m apart. The adolescent was instructed to run as fast as possible from the starting line to the second line and return, crossing each line with at least one foot every time. The test covered a total distance of 40 m (4 x 10 m). Test time ended when the adolescent crossed (again, keep verb tenses consistent) the end line with one foot. Time was recorded using a standard stop watch.

Upper muscular strength and endurance (UMSE) was assessed by the pushup test with knees on the ground. A good reliability was found for this test (0.81) [30]. Before the beginning of this test, participants did some light warm-up of arms and shoulders. Participants were positioned prone with hands shoulder width apart with the trunk held in a rigid, straight position. Participants began in the "up" position with their elbows fully extended. When descending the body toward the ground adolescents flexed their elbows until the upper arm was parallel to the testing surface. They were instructed to limit head and trunk motion, and to perform as many push-ups as they can without break. No limit of time was defined. The result of the test was expressed in number of push'ups seconds (*n*).

Lower muscular strength and endurance (LMSE) was assessed by the five consecutive long jump. The reliability for this test was excellent (0.90) [30]. From a starting position immediately behind a line, standing with the feet approximately shoulder width apart, adolescent jumped five times consecutively (without break) as far as possible with their feet together. A nonslip hard surface, chalk and a tape measure were used to perform the test. The result was recorded in cm.

Speed Body Displacement (SBD) was assessed by a 30-m speed test. This test showed a good reliability (0.85) [30]. This test was performed by running as fast as possible for 20 *m*. The adolescent stood still in a comfortable position, feet behind the starting line, with no rocking movements. The test began on the whistle and was concluded when the adolescent crossed the finish line. Time was recorded using a standard stopwatch. The result of the test was expressed in seconds (*sec*).

Coordination was assessed by the five consecutive strides test. This test showed also an excellent reliability (0.90) [30]. The adolescent stood still in a comfortable position, feet behind the starting line, with no rocking movements. Adolescent performed five consecutive strides as far as possible. A nonslip hard surface, chalk and a tape measure were used to perform the test. The result was recorded in cm.

Flexibility was assessed by a test measuring leniency and the capability to reach down as far as possible. An excellent reliability was found (0.91) [30]. From a standing position, with both legs straight and feet together, the participant flexed their trunk and reached down as far as possible with their hands. Participant had to maintain

the position for 3 *sec*. Results of this test were indexed: a score of 5 for placing the hands flat on the ground; 4 for fingers touching the ground; 3 for fingers reaching the ankle; 2 for fingers reaching the tibia; and 1 for fingers/hands reaching the knees.

An individual global physical fitness score, called Quotient of Physical Fitness (QPF), was calculated. For this, absolute value obtained for each test was transformed to a normalized value from 1 (poor) to 20 (excellent). The mean of the normalized values for each test was computed to obtain the QPF expressed in "percentage".

Statistical analysis

Continuous variables were expressed as means (standard deviation, SD) and categorical variables were expressed as numbers (percentage). Physical fitness components were described according to gender and time of assessment (pre and post lockdown samples). We assessed the difference between physical fitness tests performed in pre lockdown and post lockdown samples 2 using an independent t-test for continuous data, and chi2 test for categorical data. Values of $p < 0.05$ were considered statistically significant. All analyses were computed using R software (version 4.2.0).

RESULTS

Table 1 shows the characteristics of the study population of adolescents from pre and post lockdown samples. No meaningful difference in anthropometrics characteristics was found between two samples.

Physical fitness levels according to sex among pre and post lockdown samples are described in Table 2 and Figure 1. In two independent samples, physical fitness was better in boys than in girls, except for the flexibility test. Overall, significant differences were found between two samples for each physical fitness components. Adolescents from sample 2 (after the first lockdown) showed lower physical fitness levels compared to adolescents from sample 1. Regarding physical fitness for boys and girls, physical fitness levels were significantly lower in both sex between adolescents from the pre lockdown sample and adolescents from the post lockdown sample, except for cardiorespiratory fitness and flexibility for boys and girls, respectively. In boys, the performance of the cardiorespiratory fitness test was found to be significantly better for adolescents from post lockdown sample compared those from pre lockdown sample (579.9 ± 149.9 vs. 575.6 ± 98.0; $p < 0.01$). A similar trend was also found in adolescents girls for the flexibility test. In addition, and naturally in front of previous results mentioned above, the physical fitness global score (expressed in percentage) was also

significantly lower between adolescents from the pre and post lockdown samples for boys (57.8 ± 12.6 vs 52.2 ± 14.5; -9.8%, p <0.01) and girls (34.9 ± 10.8 vs 29.1 ± 11.1; -16,2%; p <0.01), respectively. Adolescents' girls have had a difference more important of their global score physical fitness levels (-16.2%) compared to adolescents boys (-9.8%).

Figure 2 showed difference in performance for each physical fitness tests between pre and post lockdown samples. Only the percentage difference of cardiorespiratory fitness in boys is positive, but remains low (+0.7%). Overall, the higher difference was found for performance in the speed body displacement test (-30%). A difference of 12,8% and 25% were observed for boys and girls, respectively. In contrast, the weaker change in overall was found in cardiorespiratory fitness results (-4.2%). The most slighty difference for girls was to -4.8% in cardiorespiratory fitness level, and -3.9% for boys in performance for upper body muscular strength and endurance.

DISCUSSION

The aim of this study was to assess, for the first time, the impact of the lockdown on the physical fitness levels in French adolescents.

The first main result from our study showed that both boys and girls had lower performance to physical fitness tests after the first covid-19 lockdown, expect for CRF in boys adolescent. Therefore, our initial study hypothesis is accepted. Our results are in agreement with a precedent study performed in French younger children [24]. Authors showed both muscular strength (upper and lower) and cardiorespiratory fitness were significantly reduced among 3rd- and 4th-grade children after the COVID-19 lockdown period compared with pre-pandemic performances [24]. Similar results were also found in adolescence population across many countries [19,23,25-27]. Our result is definitely not surprising in light of major movement restrictions involved by the French government during the pandemic situation in France. The decline of health-related physical fitness may be attributed to change lifestyle behaviors, i.e a decrease of physical activity levels, a sedentariness rising and unhealthy dietary intake. As previously described, schools, sports clubs and associations have closed during the lockdown inducing a decrease of opportunity to be physically active. Studies showed that school environment (recess, physical education lessons, commuting home to school) was favorable to be active and meet the WHO recommended physical activity guidelines [8, 33-34]. In addition, leisure-time out-of-school hours is used

mainly for sedentary activities [8]. Several studies in Europe confirmed these facts reporting a reduced physical activity level and increased sedentary behaviors in adolescents during lockdown period [35-37].

Another outcome found from our study was to note more evident global difference between pre and post lockdown in girls compared to boys. Expect to lower muscular strength and endurance test, girls had greater difference between before and after first lockdown in physical fitness performance compared to boys adolescents. Our results are contradictory to those previous studies in European adolescents [23, 25]. Sunda et al (2022) showed a greater impairment in 600 m run and sit-up performance in Croatian boys than in girls after two months of lockdown [25]. Tsoukos et al (2022) reported also a greater reduction in performance in flexibility, 505 agility and 30 m sprint tests in Greek boys compared to girls after 5-month lockdown [23]. We have no clear explanation for this difference between our findings and those found in previous studies. Authors explained their difference found lower in girls by the possibly greater decrease in physical activity in boys than in girls. However, recent studies assessing changes in physical activity patterns due to lockdown showed that there was no difference in decrease between girls and boys adolescents [25,37]. A possible explanation in the sex difference in our study might be due the motivation to practice physical activity during the pandemic period. Lack of willpower is reported as a main barrier in girls to perform exercise [38]. However, since we did not assess physical activity patterns in the present study, we cannot speculate more about their roles in explaining a greater physical fitness levels impairment in girls compared to boys adolescents and should deserve further studies.

Lastly, our study revealed no consequences of the COVID-19 pandemic and imposed lockdown on the anthropometric data in French adolescents. Sunda et al (2022) found similar results in their Croatian cohorts [25]. To explain these results, authors have underlighted that adolescence is a life period very dynamic and characterized by rapid changes in body composition (weight, height) and the availability of food and nutritional habits, which are major determinants of growth, have not changed dramatically during the pandemic [25]. However, an Italian study showed that children and adolescents confined due to Covid-19 pandemic showed higher unhealthy foods, such as red meat, potato chip, and sugary drink consumption [39]. Our finding might be attributed rather to the duration of movement restriction and lockdowns, not long enough to see a change in anthropometric characteristics. Indeed, weight gain is caused by the combination of a less active lifestyle, including sedentary behaviors, and a failure to reduce energy intake to match the reduced total energy expenditure arising from reduced physical activity over a prolonged period of time. Our data concern only the

impact of the first lockdown, including 55 days. By consequent, this period seems too short to observe changes in body composition unlike to physical fitness where short term physical inactivity (less than 4 weeks) have already an impact [40].

Previous studies shows that the COVID-19 is associated with direct adverse health consequences in short and long term [41]. Results from our study shows also an indirect impact on the health. Indeed, lockdown periods have decreased in performances of physical fitness tests in youth whereas a poor physical fitness level in adolescence is strongly associated with all-cause mortality and cardiovascular- and cancer-specific mortality in later life [4-5]. Recently, data from a large prospective register have also showed linking physical fitness at a young age is associated with severity of COVID-19 many years later [42]. In order to counteract the detrimental effects of the COVID-19 disease, his multiples lockdown and social distancing imposed on physical fitness levels among adolescents, there is a need to develop preventive strategies. Developing online intervention programs of physical activity might be also a relevant strategy whether further mitigation would be taken. Indeed, many studies showed that a remote physical education intervention maintained or even increased physical fitness levels in children and adolescents [43-45].

Findings from our study brings first data on the health-related physical fitness consequences due to lockdown in French adolescents. However, some limitations have to be considered. The main limitation is the design of this study (cross-sectional design). Indeed, since the lockdown was unexpected, a longitudinal study was not possible. However, we were able to assess physical fitness across two cross-sectional studies in adolescents studying in the same school (i.e, same region and city in North of France). In light of this first limitation, our two studies cohort are not representative of the French adolescent populations. Lastly, we did not collect several qualitative and quantitative data, such as parents' education level, socioeconomic status or daily physical activity, which have effects on health-related physical fitness in adolescents.

Findings of this present study demonstrate the negative impact of COVID-19- Pandemic Lockdown on health-related physical fitness in French adolescents. After this public health crisis, still current, public health policies must continue to promote a healthy lifestyle (dietary intake and physical activity) in youth in order to counterpart adverse health consequences of these consecutives lockdown. Moreover, teachers and school policies should include specific and adequate PA programs adapted to the age to reduce the risk of decrease of physical fitness level when possible movement restrictions periods could occur. Further studies on the effects of the second and third lockdown in France are warranted and expected. In addition, future studies should be performed across

several years in order to assess the impact of this health crisis on physical fitness among adolescents in a long-term.

REFERENCES

1. Ortega FB, Ruiz JR, Castillo MJ, Sjöström M (2008) Physical fitness in childhood and adolescence: a powerful marker of health. Int J Obes (Lond) 32:1-11. doi: 10.1038/sj.ijo.0803774.

2. Caspersen CJ, Powell KE, Christenson GM (1985) Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep 100:126-31.

3. Ruiz JR, Castro-Piñero J, Artero EG, Ortega FB, Sjöström M, Suni J, Castillo MJ (2009) Predictive validity of health-related fitness in youth: a systematic review. Br J Sports Med 43:909-23. doi: 10.1136/bjsm.2008.056499.

4. García-Hermoso A, Ramírez-Vélez R, García-Alonso Y, Alonso-Martínez AM, Izquierdo M (2020) Association of Cardiorespiratory Fitness Levels During Youth With Health Risk Later in Life: A Systematic Review and Meta-analysis. JAMA Pediatr 174:952-960. doi: 10.1001/jamapediatrics.2020.2400.

5. García-Hermoso A, Ramírez-Campillo R, Izquierdo M (2019) Is Muscular Fitness Associated with Future Health Benefits in Children and Adolescents? A Systematic Review and Meta-Analysis of Longitudinal Studies. Sports Med 49:1079-1094. doi: 10.1007/s40279-019-01098-6.

6. Raghuveer G, Hartz J, Lubans DR, Takken T, Wiltz JL, Mietus-Snyder M, Perak AM, Baker-Smith C, Pietris N, Edwards NM; American Heart Association Young Hearts Athero, Hypertension and Obesity in the Young Committee of the Council on Lifelong Congenital Heart Disease and Heart Health in the Young (2020) Cardiorespiratory Fitness in Youth: An Important Marker of Health: A Scientific Statement From the American Heart Association. Circulation. 2020 Aug 18;142(7):e101-e118. doi: 10.1161/CIR.0000000000000866.

7. Ridgers ND, Salmon J, Parrish AM, Stanley RM, Okely AD (2012) Physical activity during school recess: a systematic review. Am J Prev Med 43:320-8. doi: 10.1016/j.amepre.2012.05.019.

8. Vanhelst J, Béghin L, Duhamel A, De Henauw S, Molnar D, Vicente-Rodriguez G, Manios Y, Widhalm K, Kersting M, Polito A, Ruiz JR, Moreno LA, Gottrand F (2017) Relationship between school rhythm and physical

activity in adolescents: the HELENA study. J Sports Sci. 2017 Aug;35(16):1666-1673. doi: 10.1080/02640414.2016.1229013.

9. Loureiro N, Marques A, Loureiro V, de Matos MG (2021) Active Transportation to School. Utopia or a Strategy for a Healthy Life in Adolescence. Int J Environ Res Public Health 18:4503. doi: 10.3390/ijerph18094503.

10. Mateo-Orcajada A, González-Gálvez N, Abenza-Cano L, Vaquero-Cristóbal (2022) Differences in Physical Fitness and Body Composition Between Active and Sedentary Adolescents: A Systematic Review and Meta-Analysis. J Youth Adolesc 51:177-192. doi: 10.1007/s10964-021-01552-7.

11. Ganzar LA, Salvo D, Burford K, Zhang Y, Kohl HW 3rd, Hoelscher DM (2022) Longitudinal changes in objectively-measured physical activity and sedentary time among school-age children in Central Texas, US during the COVID-19 pandemic. Int J Behav Nutr Phys Act 19: 56. doi: 10.1186/s12966-022-01299-9.

12. Neville RD, Lakes KD, Hopkins WG, Tarantino G, Draper CE, Beck R, Madigan S (2022) Global Changes in Child and Adolescent Physical Activity During the COVID-19 Pandemic: A Systematic Review and Meta-analysis. JAMA Pediatr 11:e222313. doi: 10.1001/jamapediatrics.2022.2313.

13. Ng K, Cooper J, McHale F, Clifford J, Woods C (2020) Barriers and facilitators to changes in adolescent physical activity during COVID-19. BMJ Open Sport Exerc Med 6: e000919. doi: 10.1136/bmjsem-2020-000919.

14. Moore SA, Faulkner G, Rhodes RE, Brussoni M, Chulak-Bozzer T, Ferguson LJ, Mitra R, O'Reilly N, Spence JC, Vanderloo LM, Tremblay MS (2020) Impact of the COVID-19 virus outbreak on movement and play behaviours of Canadian children and youth: a national survey. Int J Behav Nutr Phys Act 17:85. doi: 10.1186/s12966-020-00987-8.

15. Zhang X, Zhu W, Kang S, Qiu L, Lu Z, Sun Y (2020) Association between Physical Activity and Mood States of Children and Adolescents in Social Isolation during the COVID-19 Epidemic. Int J Environ Res Public Health 17: 7666. doi: 10.3390/ijerph17207666.

16. Guerrero MD, Vanderloo LM, Rhodes RE, Faulkner G, Moore SA, Tremblay MS (2020) Canadian children's and youth's adherence to the 24-h movement guidelines during the COVID-19 pandemic: A decision tree analysis. J Sport Health Sci 9: 313-321. doi: 10.1016/j.jshs.2020.06.005.

17. Tomkinson GR, Lang JJ, Tremblay MS (2019) Temporal trends in the cardiorespiratory fitness of children and adolescents representing 19 high-income and upper middle-income countries between 1981 and 2014. Br J Sports Med 53:478-486. doi: 10.1136/bjsports-2017-097982.

18. Tomkinson GR, Kaster T, Dooley FL, Fitzgerald JS, Annandale M, Ferrar K, Lang JJ, Smith JJ (2021) Temporal Trends in the Standing Broad Jump Performance of 10,940,801 Children and Adolescents Between 1960 and 2017. Sports Med 51:531-548. doi: 10.1007/s40279-020-01394-6.

19. Rúa-Alonso M, Rial-Vázquez J, Nine I, Lete-Lasa JR, Clavel I, Giráldez-García MA, Rodríguez-Corral M, Dopico-Calvo X, Iglesias-Soler E (2022) Comparison of Physical Fitness Profiles Obtained before and during COVID-19 Pandemic in Two Independent Large Samples of Children and Adolescents: DAFIS Project. Int J Environ Res Public Health 19:3963. doi: 10.3390/ijerph19073963.

20. Jarnig G, Kerbl R, van Poppel MNM (2022) The Impact of COVID-19-Related Mitigation Measures on the Health and Fitness Status of Primary School Children in Austria: A Longitudinal Study with Data from 708 Children Measured before and during the Ongoing COVID-19 Pandemic. Sports (Basel) 11;10(3):43. doi: 10.3390/sports10030043.

21. Chen S, Wang B, Imagbe S, Gu X, Androzzi J, Liu Y, Yli-Piipari SR, Hu G, Staiano AE (2022) Adolescents Behaviors, Fitness, and Knowledge Related to Active Living before and during the COVID-19 Pandemic: A Repeated Cross-Sectional Analysis. Int J Environ Res Public Health 19:2560. doi: 10.3390/ijerph19052560.

22. Zhou T, Zhai X, Wu N, Koriyama S, Wang D, Jin Y, Li W, Sawada SS, Fan X (2022) Changes in Physical Fitness during COVID-19 Pandemic Lockdown among Adolescents: A Longitudinal Study. Healthcare (Basel) 10: 351. doi: 10.3390/healthcare10020351.

23. Tsoukos A, Bogdanis GC (2021) The Effects of a Five-Month Lockdown Due to COVID-19 on Physical Fitness Parameters in Adolescent Students: A Comparison between Cohorts. Int J Environ Res Public Health 19:326. doi: 10.3390/ijerph19010326.

24. Chambonnière C, Fearnbach N, Pelissier L, Genin P, Fillon A, Boscaro A, Bonjean L, Bailly M, Siroux J, Guirado T, Pereira B, Thivel D, Duclos M (2021). Adverse Collateral Effects of COVID-19 Public Health Restrictions on Physical Fitness and Cognitive Performance in Primary School Children. Int J Environ Res Public Health 18:11099. doi: 10.3390/ijerph182111099

25. Sunda M, Gilic B, Peric I, Jurcev Savicevic A, Sekulic D (2021). Evidencing the Influence of the COVID-19 Pandemic and Imposed Lockdown Measures on Fitness Status in Adolescents: A Preliminary Report. Healthcare (Basel) 9:681. doi: 10.3390/healthcare9060681.

26. Wahl-Alexander Z, Camic CL (2021) Impact of COVID-19 on School-Aged Male and Female Health-Related Fitness Markers. Pediatr Exerc 33:61-64. doi: 10.1123/pes.2020-0208.

27. López-Bueno R, Calatayud J, Andersen LL, Casaña J, Ezzatvar Y, Casajús JA, López-Sánchez GF, Smith L (2021) Cardiorespiratory fitness in adolescents before and after the COVID-19 confinement: a prospective cohort study. Eur J Pediatr 180: 2287-2293. doi: 10.1007/s00431-021-04029-8.

28. Deplanque D, Sénéchal-Cohen S, Lemaire F; participants of Giens XXXII, round table n(o) 5 (2017) French Jardé's law and European regulation on drug trials: Harmonization and implementation of new rules. Therapie 72:73-80. doi: 10.1016/j.therap.2016.12.006.

29. Cole TJ, Lobstein T (2012). Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes 7:284-94. doi: 10.1111/j.2047-6310.2012.00064.x.

30. Mouraby R, Tafflet M, Nassif H, Toussaint JF, Desgorces FD (2012) Fiabilité et validation de la batterie de tests physiques Diagnoform. Sci sports 27 :50-53. doi : 10.1016/ j.scispo.2011.01.011

31. Duclos M, Lacomme P, Lambert C, Pereira B, Ren L, Fleury G, Ovigneur H, Deschamps T, Fearnbach N, Vanhelst J, Toussaint JF, Thivel D (2022) Is physical fitness associated with the type of attended school? A cross-sectional analysis among adolescents. J Sports Med Phys Fitness 62: 404-411. doi: 10.23736/S0022-4707.21.12203-0.

32. Vanhelst J, Ternynck C, Ovigneur H, Deschamps T (2019) Normative health-related fitness values for French children: The Diagnoform Programme. Scand J Med Sci Sports 30: 690-699. doi: 10.1111/sms.13607.

33. DeWeese RS, Acciai F, Tulloch D, Lloyd K, Yedidia MJ, Ohri-Vachaspati P (2022) Active commuting to school: A longitudinal analysis examining persistence of behavior over time in four New Jersey cities. Prev Med Rep 26:101718. doi: 10.1016/j.pmedr.2022.101718.

34. Frömel K, Svozil Z, Chmelík F, Jakubec L, Groffik D (2016) The Role of Physical Education Lessons and Recesses in School Lifestyle of Adolescents. J Sch Health 86:143-51. doi: 10.1111/josh.12362.

35. Schmidt SCE, Anedda B, Burchartz A, Eichsteller A, Kolb S, Nigg C, Niessner C, Oriwol D, Worth A, Woll A (2020) Physical activity and screen time of children and adolescents before and during the COVID-19 lockdown in Germany: a natural experiment. Sci Rep 10:21780. doi: 10.1038/s41598-020-78438-4.

36. Gilic B, Zenic N, Separovic V, Jurcev Savicevic A, Sekulic D (2021) Evidencing the influence of pre-pandemic sports participation and substance misuse on physical activity during the COVID-19 lockdown: a prospective analysis among older adolescents. Int J Occup Med Environ Health 34:151-163. doi: 10.13075/ijomeh.1896.01733.

37. López-Bueno R, López-Sánchez GF, Casajús JA, Calatayud J, Gil-Salmerón A, Grabovac I, Tully MA, Smith L (2020) Health-Related Behaviors Among School-Aged Children and Adolescents During the Spanish Covid-19 Confinement. Front Pediatr 8:573. doi: 10.3389/fped.2020.00573.

38. Rosselli M, Ermini E, Tosi B, Boddi M, Stefani L, Toncelli L, Modesti PA (2020) Gender differences in barriers to physical activity among adolescents. Nutr Metab Cardiovasc Dis 30:1582-1589. doi: 10.1016/j.numecd.2020.05.005.

39. Pietrobelli A, Pecoraro L, Ferruzzi A, Heo M, Faith M, Zoller T, Antoniazzi F, Piacentini G, Fearnbach SN, Heymsfield SB (2020) Effects of COVID-19 Lockdown on Lifestyle Behaviors in Children with Obesity Living in Verona, Italy: A Longitudinal Study. Obesity (Silver Spring) 28:1382-1385. doi: 10.1002/oby.22861.

40. Mujika I, Padilla S (2000) Detraining: loss of training-induced physiological and performance adaptations. Part I: short term insufficient training stimulus. Sports Med 30:79-87. doi: 10.2165/00007256-200030020-00002.

41. Ma Y, Deng J, Liu Q, Du M, Liu M, Liu J (2022) Long-Term Consequences of COVID-19 at 6 Months and Above: A Systematic Review and Meta-Analysis. Int J Environ Res Public Health 19:6865. doi: 10.3390/ijerph19116865.

42. Af Geijerstam A, Mehlig K, Börjesson M, Robertson J, Nyberg J, Adiels M, Rosengren A, Åberg M, Lissner L (2021) Fitness, strength and severity of COVID-19: a prospective register study of 1 559 187 Swedish conscripts. BMJ Open 11:e051316. doi: 10.1136/bmjopen-2021-051316.

43. Jeong HC, Lee EJ, Youn HS, So WY (2020) Development and Implementation of a "Music Beeps" Program to Promote Physical Fitness in Adolescents. Int J Environ Res Public Health 17:6148. doi: 10.3390/ijerph17176148.

44. Lemes VB, Fochesatto CF, Brand C, Gaya ACA, Cristi-Montero C, Gaya AR (2022) Changes in children's self-perceived physical fitness: results from a Physical Education internet-based intervention in COVID-19 school lockdown. Sport Sci Health 30:1-9. doi: 10.1007/s11332-022-00897-1.

45. Yang Y, Koenigstorfer J (2020) Determinants of physical activity maintenance during the Covid-19 pandemic: a focus on fitness apps. Transl Behav Med 10:835-842. doi: 10.1093/tbm/ibaa086.

Statements and Declarations

Conflict of interest

The remaining authors state no conflict of interest.

Funding

There is not support for this research.

Authors contributions

Jérémy Vanhelst, Laurent Béghin and David Thivel conducted the initial analyses and drafted the initial manuscript.

Jean-Benoît Baudelet conducted statistical analysis and drafted the initial manuscript.

Hervé Ovigneur, Thibault Deschamps designed data collection instruments, coordinated and supervised data collection and reviewed the manuscript.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Ethics approval

As this research was not performed to improve biological or medical Human knowledge, this present study is not consider as a clinical research according to French regulatory requirement ("Jardé" law). In this context, this study do not need any approval from an ethical committee.

Consent to participate

NA

Consent for publication

NA

479

Table 1. Characteristics of the study population of adolescents for two cohorts.

	Pre lockdown sample	Post lockdown sample	P
Total			
N	532	699	
Age (*y*)	16.5 ± 2.0	16.6 ± 1.1	0.17
Height (*cm*)	168.3 ± 8.9	168.4 ± 10.3	0.80
Body mass (*kg)*	62.1 ± 12.7	61.2 ± 12.2	0.19
BMI ($kg.m^{-2}$)*	21.9 ± 3.7	21.8 ±7.8	0.81
Boys			
N	318	325	
Age (*y*)	16.5 ± 2.2	16.7 ± 1.1	0.17
Height (*cm*)	172.7 ± 7.6	174.7 ± 9.2	0.79
Body mass (*kg)*	65.6 ± 13.4	65.5 ± 13.2	0.19
BMI ($kg.m^{-2}$)*	21.95 ± 3.98	21.71 ± 8.25	0.81
Girls			
N	214	374	
Age (*y*)	16.5 ± 1.6	16.6 ± 1.1	0.17
Height (*cm*)	161.8 ± 6.4	163.0 ± 7.9	0.80
Body mass (*kg)*	57.0 ± 9.6	57.4 ± 9.7	0.19
BMI ($kg.m^{-2}$)*	21.76 ± 3.38	21.86 ± 7.50	0.81

480 * BMI : Body Mass Index
481
482
483

484
485
486

Table 2. Physical fitness levels (mean ± SD) according to sex among two cohorts

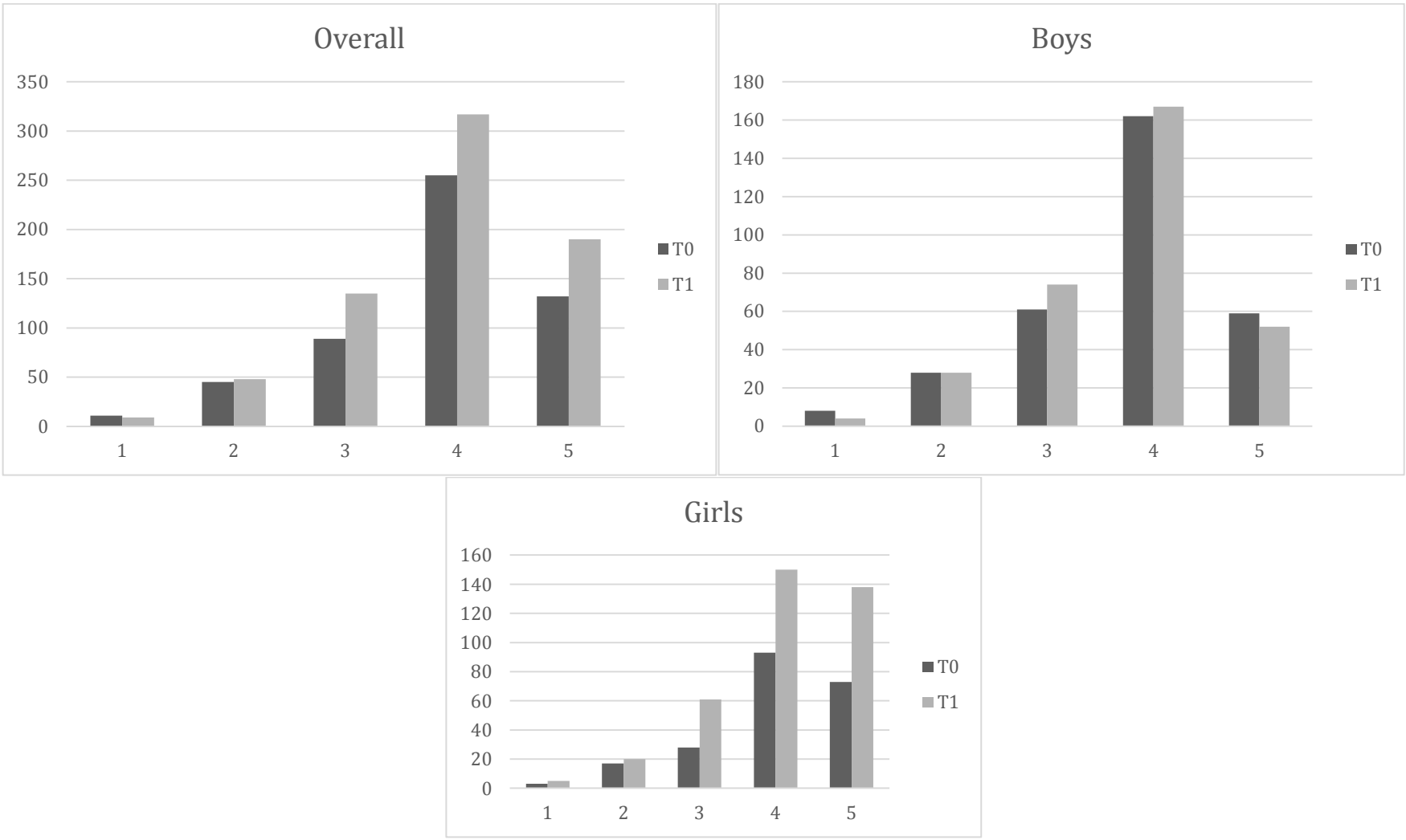
		Pre lockdown sample	Post lockdown sample	P
CRF* (*m*)				
	Total	538.9 ± 101.2	516.3 ± 159.5	0.002
	Boys	575.6 ± 98.0	579.9 ± 149.9	0.002
	Girls	484.4 ± 78.9	461.0 ± 146.6	0.002
LES* (*m*)				
	Total	184.4 ± 39.4	161.1 ± 36.3	< 0.001
	Boys	203.1 ± 34.1	184.2 ± 30.9	< 0.001
	Girls	156.5 ± 28.9	141.1 ± 27.7	< 0.001
Speed/agility (*s*)				
	Total	10.8 ± 1.52	12.1 ± 2.6	0.003
	Boys	10.2 ± 1.2	11.1 ± 2.2	< 0.001
	Girls	11.8 ± 1.5	13.0 ± 2.6	< 0.001
UMSE* (*n*)				
	Total	32.5 ± 21.0	28.0 ± 19.1	< 0.001
	Boys	40.8 ± 20.7	39.2 ± 19.2	< 0.001
	Girls	20.4 ± 14.7	18.2 ± 12.5	< 0.001
LMSE* (*cm*)				
	Total	931.6 ± 209.2	835.5 ± 216.1	< 0.001
	Boys	1036.3 ± 170.1	957.1 ± 198.7	< 0.001
	Girls	776.1 ± 159.5	729.8 ± 170.3	< 0.001
SBD* (*sec*)				
	Total	5.0 ± 0.9	6.5 ± 2.0	< 0.001
	Boys	4.7 ± 0.7	5.3 ± 1.4	< 0.001
	Girls	5.6 ± 0.9	7.0 ± 1.9	< 0.001
Coordination (*cm*)				
	Total	1012.8 ± 167.6	875.2 ± 195.4	< 0.001
	Boys	1096.2 ± 139.8	989.3 ±166.9	< 0.001
	Girls	888.7 ± 122.9	776.1 ± 161.5	< 0.001
Global score (*/20*)				
	Total	48.6 ± 16.4	39.9 ± 17.2	0.004
	Boys	57.8 ± 12.6	52.2 ± 14.5	0.004
	Girls	34.9 ± 10.8	29.1 ± 11.1	0.004

487 * CRF: Cardiorespiratory fitness; LES: Lower explosive strength; UMSE: Upper muscular strength and endurance; LMSE: Lower
488 muscular strength and endurance; SBD: Speed body displacement.
489
490

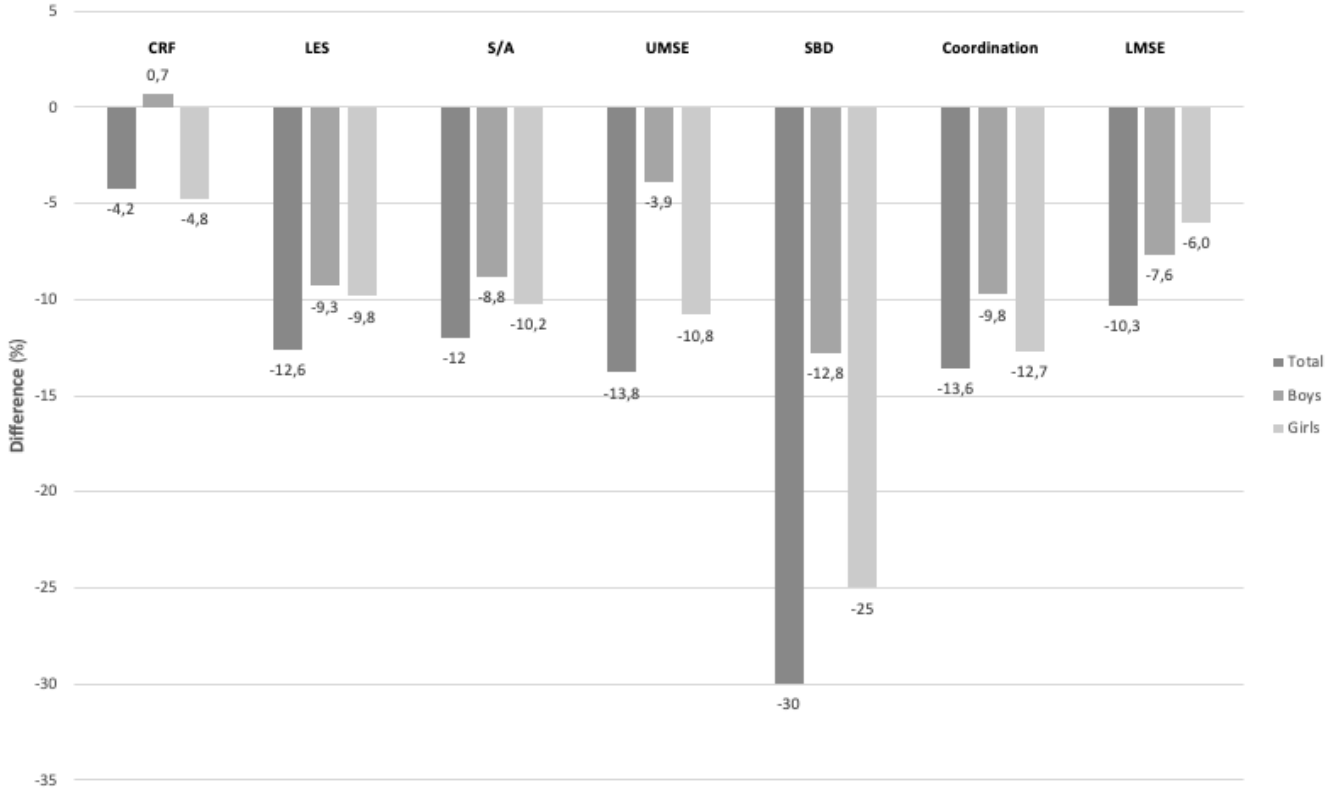
Legends

Figure 1. Flexibility levels (n) according to sex between pre (T0) and post (T1) lockdown samples.

Figure 2. Difference (%) in physical fitness levels between pre (T0) and post (T1) lockdown samples**.**



Significant difference were found overall and according to sex (P<0.01).



All difference were statistically significant (P<0.01).