



Change in physical fitness due to the COVID-19 pandemic lockdown in French adolescents: a comparison between two independent large samples from Diagnoform battery

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Abstract

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. 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. 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 was 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% was observed for boys and girls, respectively.

Conclusion: COVID-19 pandemic lockdown had a negative impact on physical fitness in French youth. This study highlights the need to develop, in a near future, prevention programmes in order to improve the physical fitness in youth.

What is Known:

- COVID-19 pandemic deeply impacted lifestyle habits. A worrying decrease of physical activity, associated to a dramatic increase of time spent in sedentary behaviors was found in many countries.

What is New:

- Our study bring first data on the health-related physical fitness consequences due to lockdown in French adolescents. Our study demonstrate the negative impact of COVID-19 pandemic lockdown on health-related physical fitness in French adolescents.

Keywords Health crisis · Youth · Health

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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]. The 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 of 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 and 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]. The authors stated 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 in 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 confirm this trend. Overall, the 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]. The authors showed a significant decrease on physical fitness and motor fitness performances [24]. The 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 a 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 $\text{weight}/\text{height}^2$ (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 their reliability and validity indicated, as previously published [30–32].

Cardiorespiratory Fitness (CRF) was measured by a 20-m shuttle run–walk test for 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 for 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 4×10 m 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 (4×10 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 s. 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 χ^2 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.

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

	Pre lockdown sample	Post lockdown sample	<i>P</i>
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 ($\text{kg}\cdot\text{m}^{-2}$)*	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 ($\text{kg}\cdot\text{m}^{-2}$)*	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 ($\text{kg}\cdot\text{m}^{-2}$)*	21.76 ± 3.38	21.86 ± 7.50	0.81

* BMI, body mass index

Physical fitness levels according to sex among pre and post lockdown samples are described in Table 2 and Fig. 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 with those from pre lockdown sample (579.9 ± 149.9 vs. 575.6 ± 98.0 ; $p < 0.01$). A similar trend was also found in adolescent 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. Adolescent girls have had a difference more important than 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% was observed for boys and girls, respectively. In contrast, the weaker change in overall was found in cardiorespiratory fitness results (-4.2%). The most slight 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, expected 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]. The authors showed that both muscular strength (upper

Table 2 Physical fitness levels (mean \pm SD) according to sex among two cohorts

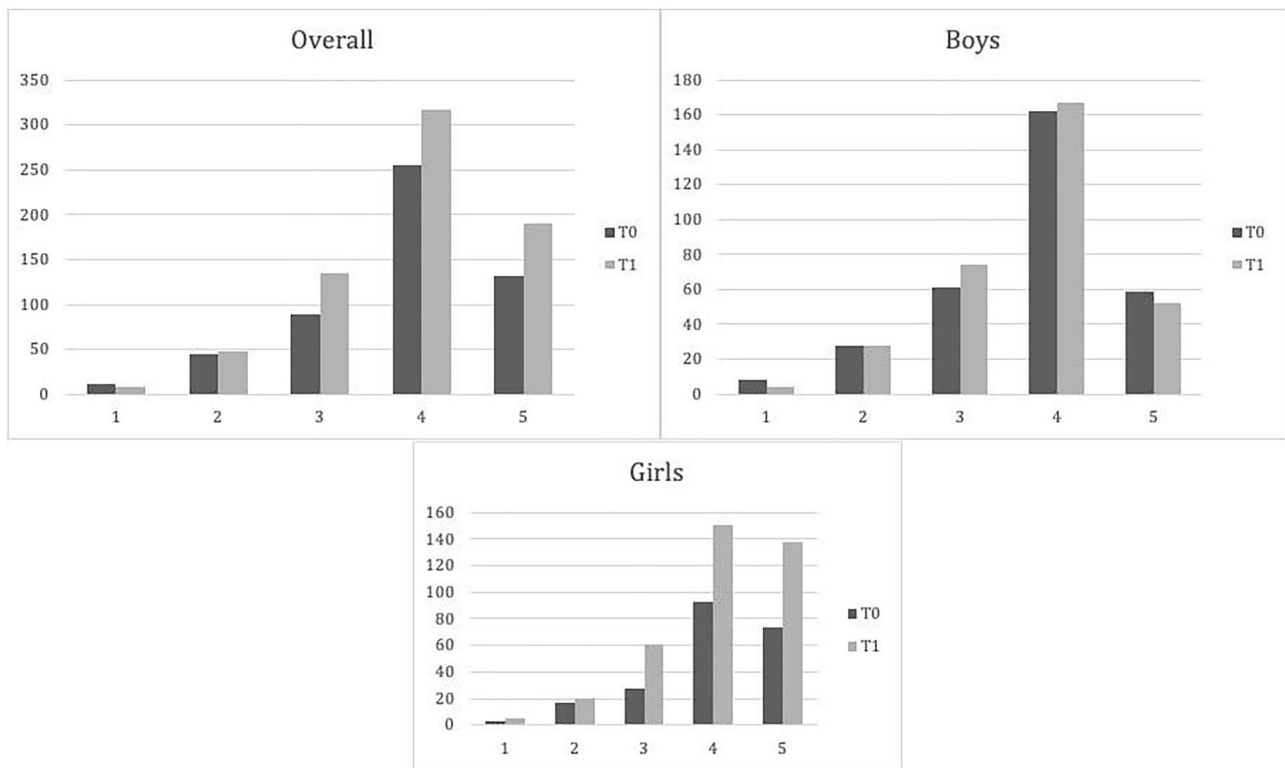
		Pre lockdown sample	Post lockdown sample	<i>P</i>
CRF* (<i>m</i>)	Total	538.9 \pm 101.2	516.3 \pm 159.5	0.002
	Boys	575.6 \pm 98.0	579.9 \pm 149.9	0.002
	Girls	484.4 \pm 78.9	461.0 \pm 146.6	0.002
LES* (<i>m</i>)	Total	184.4 \pm 39.4	161.1 \pm 36.3	<0.001
	Boys	203.1 \pm 34.1	184.2 \pm 30.9	<0.001
	Girls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

*CRF cardiorespiratory fitness, LES lower explosive strength, UMSE upper muscular strength and endurance, LMSE lower muscular strength and endurance, SBD speed body displacement

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 in 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 adolescent boys. Our results are contradictory to those previous studies in European adolescents [23, 25]. Sunda et al. showed a greater impairment in 600 m run



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

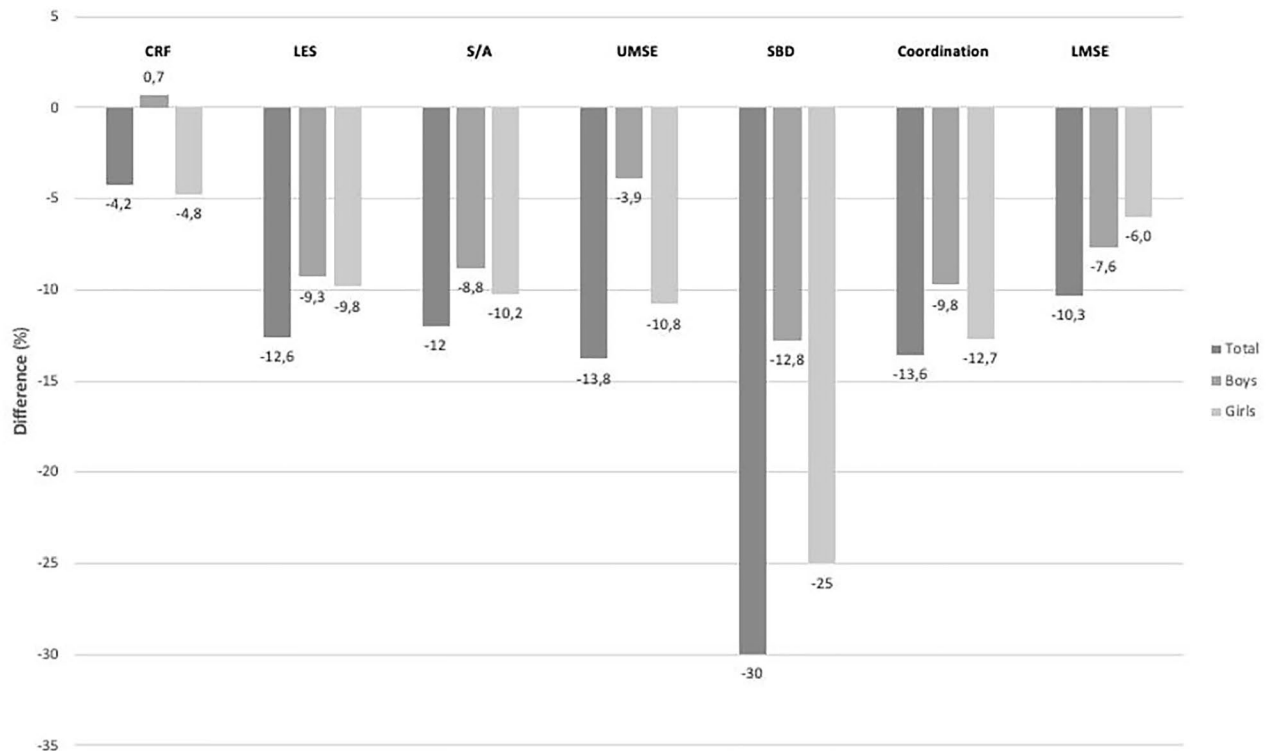
Fig. 1 Flexibility levels (n) according to sex between pre (T0) and post (T1) lockdown samples

and sit-up performance in Croatian boys than in girls after 2 months of lockdown [25]. Tsoukos and Bogdanis 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. The 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 adolescent girls and boys [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 adolescent girls compared to boys 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. found similar results in their Croatian cohorts [25]. To

explain these results, the authors have underlined 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. Consequently, this period seems too short to observe changes in body composition unlike the physical fitness where short-term physical inactivity (less than 4 weeks) has already an impact [40].

Previous studies shows that the COVID-19 is associated with direct adverse health consequences in short and



All difference were statistically significant ($P < 0.01$).

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

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, multiple lockdowns 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 bring 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 cohorts 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 consecutive lockdowns. 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 restriction periods could occur. Further studies on the effects of the second and third lockdowns 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.

Authors' contributions Jérémy Vanhelst, Laurent Béghin and David Thivel conducted the initial analyses and drafted the initial manuscript. Jean-Benoît Baudalet 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.

Declarations

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.

Competing interests The authors declare no competing interests.

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