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Social isolation during the covid-19 pandemic impaired vitamin d concentrations, motor performance and physical fitness in adolescents

El aislamiento social durante la pandemia de covid-19 perjudicó las concentraciones de vitamina d, el rendimiento motor y la aptitud física en adolescentes

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Abstract. This study aims to verify the effect of social isolation arising from the Coronavirus pandemic (COVID-19) severe acute respiratory syndrome (SARS-CoV-2) on vitamin D (25(OH)D) concentrations, motor performance, and cardiorespiratory fitness (CRF) in adolescents. This research method is Case-control study, which included 34 boys, aged 12-16 years. In the pre-pandemic period, 17 schoolchildren were evaluated in December 2019, classified according to body mass index Z-score (BMI-z) as: eutrophic (n=8) and overweight (n=9). The post-pandemic group was composed of 17 boys, evaluated in March 2022, matched with the same BMI-z characteristics. Stature, body mass, fat mass (FM), fat free mass (FFM), flexibility (FLEX), 25(OH)D, absolute CRF (CRF_{abs}) and relative (CRF_{rel}) were assessed. The Supine-to-Stand test (STS_{TIME}) execution time was used to assess motor performance and motor competence by the motor patterns used in execution (STS_{MC}). considering $p<0.05$ significant. The results showed that, post-pandemic, there were impairment on 25(OH)D, FLEX, STS_{TIME} e CRF ($p<0.05$). Both eutrophic and overweight groups reduced 25(OH)D concentrations ($p<0.001$) and increased STS_{TIME} ($p=0.02$) but did not modify STS_{MC}. Regarding CRF, eutrophic individuals showed lower CRF_{abs} and CRF_{rel} values ($p \leq 0.005$), however no changes in the overweight group. We conclude that social isolation impaired the 25(OH)D concentrations and motor performance of adolescents. However, it stands out that the eutrophic were the most impacted with social isolation, as they showed unfavorable effect also on CRF.
Keywords: adolescents, adiposity, physical fitness, motor competence, pandemic (COVID-19), social isolation.

Resumen. Este estudio tiene como objetivo evaluar el efecto del aislamiento social derivado de la pandemia de Coronavirus (COVID-19) síndrome respiratorio agudo severo (SARS-CoV-2) sobre las concentraciones de vitamina D (25(OH)D), el rendimiento motor y la aptitud cardiorrespiratoria (ACR) en adolescentes. Este método de investigación es un estudio de caso-control que incluyó a 34 niños, de 12 a 16 años. En el período prepandémico, 17 escolares fueron evaluados en diciembre de 2019, clasificados según el puntaje Z del índice de masa corporal (IMC-z) como: eutróficos (n=8) y con sobrepeso (n=9). El grupo pospandémico estuvo compuesto por 17 niños, evaluados en marzo de 2022, emparejados con las mismas características de IMC-z. Se evaluaron la estatura, la masa corporal, la masa grasa (MG), la masa libre de grasa (MLG), la flexibilidad (FLEX), 25(OH)D, la ACR absoluta (ACR_{abs}) y relativa (ACR_{rel}). Se utilizó el tiempo de ejecución de la prueba Supine-to-Stand (STS_{TIME}) para evaluar el rendimiento y la competencia motores mediante los patrones motores utilizados en la ejecución (STS_{MC}), considerando $p<0.05$ como significativo. Los resultados mostraron que, en el período pospandémico, se observaron afectaciones en 25(OH)D, FLEX, STS_{TIME} y ACR ($p<0.05$). Los eutróficos y con sobrepeso redujeron las concentraciones de 25(OH)D ($p<0.001$) y aumentaron el STS_{TIME} ($p=0.02$), pero no modificaron el STS_{MC}. En cuanto a la ACR, los eutróficos mostraron valores más bajos de ACR_{abs} y ACR_{rel} ($p \leq 0.005$), sin embargo, no hubo cambios en el grupo con sobrepeso. Concluimos que el aislamiento social afectó las concentraciones de 25(OH)D y el rendimiento motor de los adolescentes. Sin embargo, se destaca que los eutróficos fueron los más impactados con el aislamiento social, ya que también mostraron un efecto desfavorable en la ACR.
Palabras clave: adolescentes, adiposidad, aptitud física, competencia motora, pandemia (COVID-19), aislamiento social.

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Introduction

Social isolation was one of the main health measures used to contain the spread of the coronavirus pandemic (COVID-19), which consisted of withdrawal from face-to-face activities and reduced social interaction in every country in the world (WHO, 2021). Restrictions included closing schools and preventing outdoor and gym physical activity (PA). Meanwhile, social isolation has had a negative impact on people's daily activities, as they become less active in isolation, contributing to an increase in sedentary behavior and physical inactivity. Moreover, there were changes in eating and sleeping habits (Brito, Lima, Mascarenhas, Mota, & Leite, 2021; Silva et al., 2020), changes in routine that may lead to less body weight control and increased obesity, an important risk factor for COVID-19 severity (Adair, 2023; Lockhart & O'Rahilly, 2020). Isolation can lead to less sun exposure, which may potentiate the decrease in vitamin D (25(OH)D), a situation associated with impaired cardiometabolic health, as well as reduced immunity (Gibbons et al., 2022). Also, it can have long-term effects on both physical and mental health (Galán-Arroyo, Herreruela-Jara, Castillo-Paredes, & Rojo-Ramos, 2024).

Although the regular practice of PA represents an important habit for health and benefits for coping with the COVID-19 pandemic (Chen et al., 2020; Ferreira, Irigoyen, Consolim-Colombo, Saraiva, & Angelis, 2020; Sallis & Pratt, 2020), there was the curtailment of its practice and control by public agencies. Thus, during the pandemic, children and adolescents had the interruption of face-to-face education in the period of social isolation, as well as reduced participation in daily PA and increased screen time (Brito et al., 2020; López-Bueno et al., 2020). These drastic modifications in child and youth population lifestyle, especially with the prohibition and reduction of PA practice, probably compromise motor development, especially in the rapid growth or pubertal phase (Duncan et al., 2022). As well as the concentrations of 25(OH)D, which are associated with higher sun exposure (DeLuca, 2004) and regular PA practice of adolescents (Corazza, Tadiotto, Michel, Mota, & Leite, 2019), mainly in outdoor locations.

The reduced practice of PA decrease muscle mass and cardiorespiratory fitness (CRF), components of physical fitness can compromise motor competence, leading to lower mobility and agility of children and adolescents (Duncan et al., 2022). Lower flexibility (FLEX) also reduces motor functionality in all age groups (Brito, Araújo, & Araújo, 2013). In practical terms, young people's motor competence can be assessed by the Supine-to-Stand test (STS), whose early studies describe the different strategies and patterns for children (VanSant, 1988a), adolescents (VanSant, 1990), and young adults (VanSant, 1988b), to stay in the upright position from the lying position on the ground, a factor that varies with age. The STS test has been used to assess performance in preschool children (Nesbitt et al., 2017) and schoolchildren (Duncan, Lawson, Walker, Stodden, & Eyre, 2017), whose test time correlated inversely with age, however not with body mass index in children with adequate weight (Ng, Conaway, Rigby, Priestman, & Baxter, 2013). While obese adolescents showed lower motor performance by STS (Tadiotto et al., 2021), as well as lower CRF compared to eutrophic ones, due to body overload, requiring adjustments by allometry (Nevill et al., 2021).

There are some scientific articles evaluating the negative impact of social isolation on health of children and adolescents (Li, Taeihagh, & Tan, 2023; Saulle, Minozzi, Amato, & Davoli, 2021), however, no studies were found on the impairment in motor performance. Thus, as ease of performance on the STS test seems to be directly associated with higher performance on physical tests (Duncan et al., 2017), changes in STS may represent reduced motor performance due to less PA practice occasioned by isolation measures in the pandemic, as well as less sun exposure. Therefore, it is important to assess the impact of this isolation period on 25(OH)D concentrations, motor competence, and physical fitness components of adolescents upon their return to school activities. Thus, this study aims to verify the effect of social isolation resulting from the COVID-19 pandemic on lipid and 25(OH)D concentrations, as well as on motor performance and physical fitness in adolescents.

Materials and methods

Cross-sectional study with time comparison, which included 34 students with ages between 12 and 16 years. In the pre-pandemic period 17 boys were evaluated, who were classified according to body mass index score z (BMI-z) as: eutrophic (n=8), overweight (n=9). Whereas the post-pandemic COVID-19 group was composed of 17 boys, matched according to the characteristics of the pre-pandemic group. The pre-pandemic assessments were conducted in December 2019, at the evaluation of a control group of an ongoing study in the research group, while the post-pandemic assessments occurred in March 2022, with the return to face-to-face classes in public education. The decision to compare two different groups pre- and post-pandemic was due to the 24-month duration of social isolation and the logistical challenges of longitudinal data collection over such an extended period. This design allows for the comparison of physical and motor performance changes across different time points, although it limits direct cause-effect inference. Inclusion criteria were: (a) participation in all evaluations; (b) age range between 12 and 16 years and (c) similar levels of adiposity. Exclusion criteria were: (a) participants with muscle injury or any other contraindication for the test. The participants and their guardians received a detailed explanation and, after agreeing with the study procedures, signed the informed consent form, and their children signed the informed consent form, according to the project approved by the Ethics Committee of the UniDomBosco University Center (CAAE 62963916.0.0000.5223). A sample power analysis was conducted to determine the appropriate sample size. Using the G*Power software (v.3.1.9.2), we calculated the required sample size based on an expected medium effect size (d = 0.5), a significance level of 5% ($\alpha = 0.05$), and a statistical power of 80% ($1-\beta = 0.80$), and based on these criteria, the minimum sample size was 34 participants in total.

In the present study, the selection of the variables analyzed was based on the importance already established in the literature on the impact of physical activity and vitamin D concentrations on health and motor performance in adolescents (Dong et al., 2010). Anthropometric measurements were performed as described in Lohman; Roche; Martorell (1988). BMI-z was calculated using the WHO Anthro Plus® program (Onis et al., 2007), from body mass (BM) (kg) measured on a Welmy® W200/50® digital scale and height (cm) on an Avanutri® portable stadiometer. Waist circumference (WC) was assessed with an anthropometric tape applied to the skin, in the area between the ribs and the iliac crest. The waist-to-height ratio (WHtR) was calculated by the quotient between waist circumference (cm) and height (cm). The trunk-brain height was measured with the participant seated on a 50 cm high stool under the stadiometer. To calculate lower limb length, the difference between trunk-brain height and height was used (Lohman et al., 1988).

Bioelectrical impedance (BIA) was used for body composition measurements. The procedure was performed in the morning, with the participants lying on their backs, after 12 hours fasting. Fat free mass (FFM) and percent fat mass (%FM) were calculated using the equation validated by Houtkooper et al. (Houtkooper, Going, Lohman, Roche, & Van Loan, 1992).

The evaluation of biological maturation was performed by the somatic maturation method, a mathematical model based on anthropometry, age, and sex, determined by equations predicting Peak Height Velocity (PHV) (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). In addition, the Age of Peak Height Velocity (APHV) was also calculated by subtracting the maturity shift from the chronological age.

Blood samples were collected in the morning after a 12-hour fast to perform the colorimetric enzymatic method for the determination of triglycerides (TG), high-density lipoprotein (HDL-c) and 25(OH)D by the electrochemiluminescence method.

The evaluation of motor performance and competence were determined by the STS_{TIME} and STS_{MC} based on the protocols suggested by Vansant (VanSant, 1988a). The test was performed on a flat surface in the supine position. Participants were instructed to get up as quickly as possible in the way they wanted and to maintain the standing position after an audible command. No demonstration was performed to avoid influencing participants movement patterns. Three attempts were performed, the first one was used as familiarization to the procedure, while the other two were filmed with a digital camera in the sagittal plane, for subsequent analysis using the Kinovea® program. The shortest execution time was considered to determine the performance in the STS_{TIME}, while the STS_{MC} was evaluated from the classification of the movement sequences proposed by Vansant (VanSant, 1988a).

The cardiorespiratory fitness (CRF) was evaluated using the Shuttle Run Test (Léger, Mercier, Gadoury, & Lambert, 1988), performed in the school gymnasium. The protocol consists of multiple progressive stages of running with increasing intensity in which the participant needs to move between two markers with 20 meters following the pace set by a beep. The initial speed was 8.5 km/h with increases of 0.5 km/h per stage. A heart monitoring belt (Polar® A300) was used to measure maximum heart rate, and the test was only interrupted at the participant's request or when the participant did not reach the line marked for the beep for two consecutive laps. The adolescents were previously familiarized with the test and later the CRF was estimated by specific equation for adolescents proposed by Menezes-Junior et al. (Menezes-Junior et al., 2020).

Handgrip strength (HGS) was measured by the handgrip method, using a hydraulic hand dynamometer (Saehan®). Participants were instructed to squeeze the equipment gradually and continuously until maximum strength was reached. Two executions were performed, with a 60 second interval between attempts, and the highest value reached was considered in kilograms (kg). In addition, abdominal endurance (ABDO) was measured from the maximum number of abdominal push-ups performed on the ground for one minute (Plowman & Meredith, 2013). The normality and homogeneity of the data were tested by the kolmogorov-smirnov and Levene tests respectively. Descriptive statistics were presented as mean and standard deviation, and the results of the pre-pandemic and post-pandemic groups were compared using independent t-test. For multiple comparisons between groups and variables, a Multivariate General Linear Model was performed with Time (pre-pandemic and post-pandemic) and adiposity (eutrophic and overweight) as factors. Comparisons between groups at time 1 and 2 were performed by one-way ANOVA (Field, 2018). Statistical analysis was performed using SPSS Program version 26.0 and the significance level was p≤0,05.

Table 1.
Sample characteristics and parameters of physical fitness pre-pandemic and post-pandemic in adolescents

Variables	Pre-pandemic (n=17)	Post-pandemic (n=17)		
	Mean±SD	Mean±SD	t	p
Age (Years)	14.9±1.21	14.6±0.95	0.647	0.522
PHV (Years)	1.12±1.04	1.02±0.85	0.301	0.766
APHV (Years)	13.8±0.46	13.6±0.31	1.065	0.295
Anthropometry and Body Composition				
BM (Kg)	67.8±14.1	66.94±14.4	0.187	0.853
Height (cm)	168.8±8.29	169.8±6.71	-0.397	0.694
BMI-z (z score)	1.02±1.32	0.87±1.49	0.318	0.753
TMI (kg m^{-3})	14.1±3.04	13.7±3.25	0.359	0.722
WC	78.5±10.4	77.2±11.8	0.333	0.741
WHtR	0.46±0.06	0.45±0.07	0.420	0.678
FM (kg)	18.3±9.41	16.4±9.00	0.611	0.546
%FM (%)	25.4±9.99	23.2±8.13	0.699	0.489
FFM (kg)	49.5±6.48	50.5±7.30	-0.388	0.701
%FFM (%)	74.8±10.5	76.7±8.13	-0.596	0.556
Metabolic Variables				
TG (mg/dL)	82.8±28.9	69.7±27.3	1.360	0.183
HDL-c (mg/dL)	50.9±6.07	47.8±8.82	1.224	0.231
25(OH)D (ng/mL)	33.3±4.73	21.8±6.08	6.111	<0.001
Physical and motor performance				
CRF_{rel}	46.5±11.7	39.4±8.38	2.011	0.003
CRF_{abs}	3.03±0.49	2.54±0.29	3.481	0.001
ABDO (rep)	29.4±10.9	26.5±7.88	0.879	0.386
FLEX (cm)	23.7±8.51	15.9±10.2	2.421	0.021
HGS-right (kg)	31.7±6.56	30.13±13	0.648	0.522
HGS-left (kg)	32.4±7.01	28.9±8.12	1.340	0.190
STS_{TIME} (s)	1.91±0.56	2.53±0.60	-3.095	0.004
STS_{MC} (points)	9.65±2.47	9.91±2.38	-0.353	0.726

PHV, peak height velocity; APHV, age of peak height velocity; BM, body mass; BMI-z, body mass index z score; TMI, tri-ponderal mass index; WC, waist circumference; WHtR, waist/height ratio; FM, fat mass; FFM, fat-free mass. TG, triglycerides; HDL, high-density lipoprotein; 25(OH)D, vitamin D; CRF_{rel}, relative cardiorespiratory fitness; CRF_{abs}, absolute cardiorespiratory fitness; ABDO, abdominal resistance; FLEX, flexibility; STS_{TIME}, supine-to-stand time; STS_{MC}, supine-to-stand motor competence.

Results

Participants in the pre-pandemic and post-pandemic groups were paired by age, anthropometric and body composition measures, and therefore presented similar means for these variables in the two evaluated phases ($p>0.05$). However, the post-pandemic group had lower means for 25(OH)D and physical fitness variables CRF_{abs}, CRF_{rel} and FLEX ($p<0.05$). In addition to longer time in the STS_{TIME} performance ($p=0.004$). Table 1 shows pre- and post-pandemic groups characteristics. The participants were allocated into eutrophic and overweight groups pre-pandemic and post-pandemic moments. As expected, the overweight group showed higher mean values for the variables BM, BMI-z, TMI, WC, WHtR, FM, %FM and lower mean for %FFM in both periods evaluated ($p<0.05$). However,

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there were no differences for Age, Maturational Development, Height, MLG, FLEX and HGS between groups ($p>0.05$). Moreover, at the first moment, eutrophic participants showed better performance in the variables CRF_{abs}, CRF_{rel}, ABDO, STS_{TIME} and STS_{MC} ($p<0.05$), which was repeated in the post-pandemic except for CRF_{abs} and ABDO ($p>0.05$).

The impact of isolation time on each group were examined separately at the two time points. The groups were similar in the means of the variables Age, Maturational Development, Anthropometry and Body Composition at both pre- and post-pandemic times ($p>0.05$). However, in the post-pandemic period, 25(OH)D concentrations significantly decreased in the eutrophic and overweight groups ($p<0.001$), as well as an increase in the time required to complete the STS_{TIME} ($p<0.05$) compared to their pre-pandemic counterparts. Although PA tests such as ABDO, FLEX, and HGS showed no difference ($p>0.05$) between pre- and post-pandemic in the eutrophic and overweight groups. Eutrophic individuals showed reduced CRF_{abs} and CRF_{rel} values ($p<0.05$) compared to pre-pandemic levels. The variables that showed significance are shown in Figure 01.

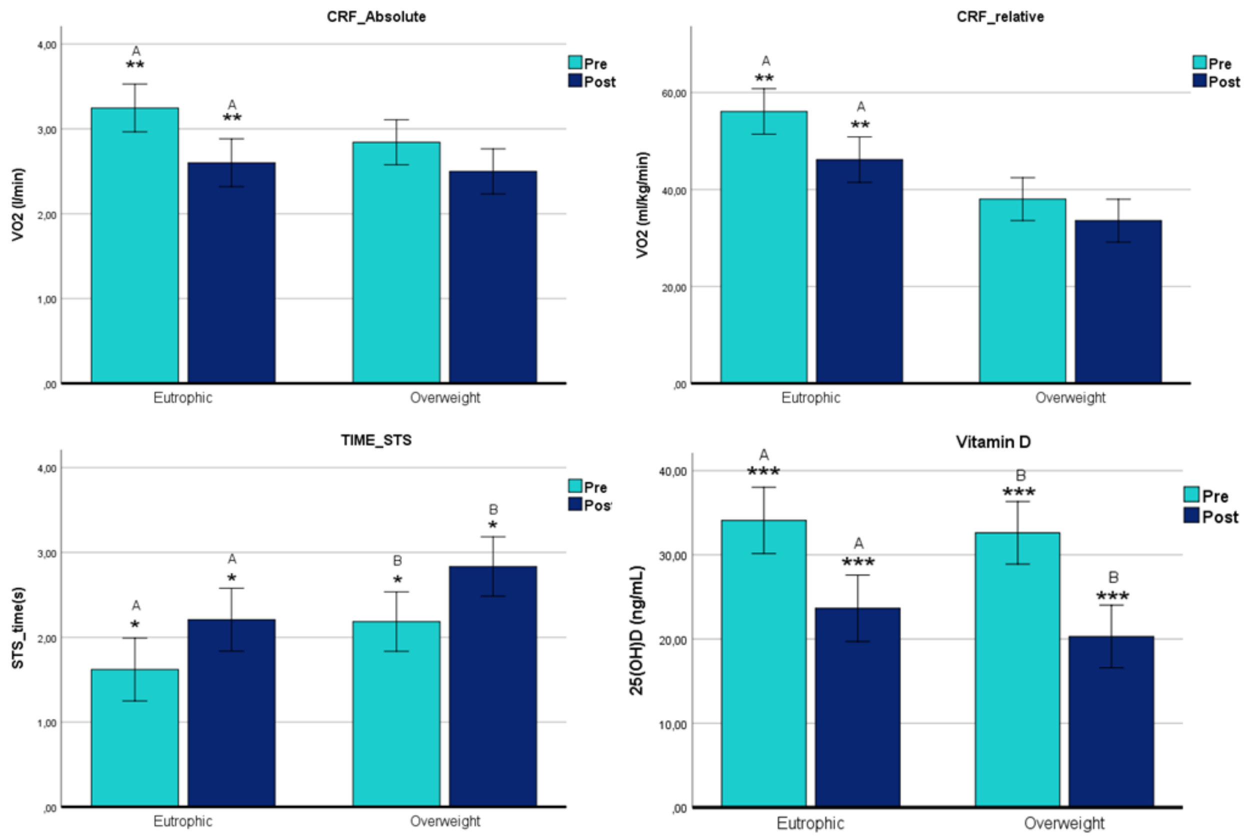

Figure 1. Physical fitness, motor competence and vitamin D pre- and post-pandemic moment (n=34). 25(OH)D, vitamin D; $CRF_{relative}$, relative cardiorespiratory fitness; VO2, Maximal oxygen uptake; $CRF_{absolute}$, absolute cardiorespiratory fitness; STS_{TIME}, supine-to-stand time; A - Eutrophic vs. Eutrophic; B – Overweight vs. Overweight; *p<0,05; ***p*<0,01; ****p*≤0,001.

Discussion

The present research revealed that adolescents exhibited impaired 25(OH)D concentrations and motor performance, which were associated with the social isolation measures adopted during the COVID-19 pandemic. We also observed that eutrophic adolescents were more impacted by these measures, which reduced their daily practice of physical activities, as they also showed a reduction in CRF and FLEX, important components of physical fitness and health. Our results collaborate with studies that showed how COVID-19 pandemic has affected people's lives around the world. In addition to the consequences of the disease, the period of social withdrawal produced social, economic, political, and cultural impacts (Li et al., 2023). As well as the closing of schools entailed damage to the health, physical and psychological well-being of school-age children and adolescents (Saulle et al., 2021).

In this study, probably the reduced sun exposure because of social isolation measures led to decreased 25(OH)D concentrations in both eutrophic and obese participants, reductions evidenced in the post-pandemic period. This result is like that found in the literature, which showed lower 25(OH)D concentrations of healthy children and adolescents in the first year of the pandemic due to the restrictions imposed by the isolation measures (Beyazgül et al., 2022). Importantly, adolescents are at a crucial stage of human growth and development, and the isolation period directly impacted daily activities, leading to reduced outdoor activities. Therefore, there was reduced exposure to sunlight, which is the main source of vitamin D, whose cutaneous synthesis corresponds to approximately 90% of the blood concentrations of vitamin D (Peters & Martini, 2014).

Although this study focused on the influence of social isolation on 25(OH)D levels, we recognize that factors such as sun exposure and diet could have contributed to the variation in vitamin D concentrations. Social isolation likely reduced sun exposure; however, we were unable to directly measure the participants' dietary intake, including vitamin D-rich foods or supplements. Vitamin D is essential for strong bones, healthy immune system and more favorable cardiometabolic profile (Corazza, Tadiotto, Menezes Junior, et al., 2019), as well as has been considered as a protective and/or preventive factor against COVID-19 (Panfili et al., 2021; Yılmaz & Şen, 2020). In the pediatric population, studies associate vitamin D deficiency with the most severe cases of COVID-19 (Bayramoğlu et al., 2021), showing the importance of maintaining 25(OH)D concentrations within a threshold classified as sufficient. The findings of this study also raise concerns about the uneven recovery of physical fitness and vitamin D levels among adolescents. While interventions such as vitamin D supplementation and increased physical activity could mitigate some effects, long-term surveillance is needed to assess whether the physical and motor deficits observed during the pandemic persist (Antonucci et al., 2023). This is particularly important given the associations between low vitamin D levels and long-term health conditions, such as those observed in COVID-19 survivors (di Filippo et al., 2023).

In addition, in this study, the motor performance showed a decline in adolescents assessed in the post-pandemic, compared to the sample assessed before the pandemic. We used the STS_{TIME} test, which incorporates the main components of physical fitness, fundamental for healthy development in youth, which may lead to overall negative impacts on the motor health of this individual throughout life (Duncan et al., 2022). Thus, in the isolation period, another factor that we highlight is the reduction of motor experiences experienced by these adolescents in different environments, which were restricted during the pandemic, which can compromise the development of motor skills and abilities, which is the ability to control and coordinate movements appropriately (Goodway, Ozmun, & Gallahue, 2019). The differences observed between the eutrophic and overweight groups may be explained by related to body composition and physical fitness levels. Eutrophic adolescents, with lower fat mass, may have a greater capacity for physical activity, positively impacting motor performance and cardiorespiratory fitness. Overweight adolescents, on the other hand, may experience mechanical challenges during physical activities due to excess body mass (Marco et al., 2023), which could explain their lower performance in tests such as the STS and their diminished CRF response.

Regarding physical fitness, this research found reduced CRF and FLEX in the general post-pandemic group. The CRF is a measure of the capacity of the cardiovascular and respiratory system to supply oxygen to the muscles during physical activity (Menezes-Junior et al., 2020). It is considered an important component of physical fitness and is related to overall health and well-being (Menezes Júnior, Jesus, & Leite, 2019). In addition, a low level of CRF in adolescence may increase the risk of cardiovascular disease and other health conditions throughout adulthood (Castro-Piñero et al., 2017). As well, flexibility is the ability to perform joint movements in the greatest possible amplitude all decreased, probably associated with the reduction of broad body movements, due to staying in closed places and excessive use of technologies during the pandemic period (Brito et al., 2020). Also, the lower FLEX found in the post-pandemic period may result in lower motor competence and be associated with longer STS_{TIME}.

Adolescents in the post-pandemic group in this study had on average 15% lower CRF than pre-pandemic adolescents, suggesting that adolescents were less physically active and were more sedentary after the pandemic. Kidokoro et al. (Kidokoro, Tomkinson, Lang, & Suzuki, 2023) also found a trend in reduced fitness levels in children and adolescents before (2013-2019) and during (2019-2021) the COVID-19 pandemic. These results are concerning because physical activity is important for overall health and well-being, especially during adolescence, which is a critical period for physical and mental development (Adelantado-Renau et al., 2023; Menezes-Junior, Jesus, Brand, Mota, & Leite, 2022). Mental health is an important factor that can influence the practice of physical activities, especially during periods of social isolation. Studies suggest that anxiety and stress significantly increased in young people during the pandemic, which may have contributed to a decrease in physical activity (Galán-Arroyo et al., 2024; Tuñón, Laíño, & Weisstaub, 2024). Additionally, isolation may have exacerbated feelings of loneliness and depression, which are associated with a more sedentary lifestyle, potentially impacting the physical and mental health of the study participants.

Importantly, the CRF decreases rapidly during periods of sedentary lifestyle and inactivity, while recovery of the CRF is generally slow. For example, Leite et al. (2022) showed that overweight adolescents needed to exercise three times a week for approximately 60 min at moderate to vigorous intensity for 12 weeks to increase VO2max by 8.5%.

Thus, in the analysis of the differences between individuals with the same age, pubertal characteristics, and body composition in the pre- and post-pandemic periods, we found that the eutrophic boys showed the greatest reduction in performance in the STS_{TIME}. The greater loss in this group is justified by the lower movement and greater daily limitation to body movements due to social isolation, since the eutrophic boys had better performances in the pre-pandemic compared to the overweight group. Therefore, they presented greater losses in the execution time of the STS than individuals with lower performances in the pre-pandemic, who tend to present lower CRF due to their body shape (Nevill et al., 2021). Noteworthy is that in this study it was observed that only the group of eutrophic adolescents showed a reduction in the absolute and relative CRF in the post-pandemic compared to their eutrophic peers in the pre-pandemic. This reduction was not observed between the pre- and post-pandemic overweight groups, probably the lack of CRF modification may be related to sedentary habits, which are generally part of the routine of overweight adolescents (Corazza, Tadiotto, Menezes Junior, et al., 2019; Tadiotto et al., 2021, 2018).

Furthermore, in this study, the pre- and post-pandemic overweight groups showed lower performance and agility than the eutrophic groups in both parameters of the STS test, results that corroborate with the current literature, which highlights that getting up as fast as possible is not only a result of functional and motor abilities, but also of the morphology and physical conditioning of everyone (Tadiotto et al., 2021).

Along these lines, the pandemic may have contributed to a reduction in physical activity due to movement restrictions and closure of sports facilities, and these effects may have a lasting impact on the health and well-being of adolescents (Musa, Dergaa, Bachiller, & Saad, 2023; Raine et al., 2023). Children may be particularly susceptible to long-term harms associated with low CRF, as, physical fitness during childhood and adolescence is related to adult CRF and physical activity levels (Kidokoro et al., 2023). Efforts have been made to adapt and incorporate daily activities into the home environment, but like remote school teaching methods, these adjustments have not proven effective (Rundle, Park, Herbstman, Kinsey, & Wang, 2020), physical activities have also been neglected, even with the recognition that better conditioning could be a protective factor for more severe cases of COVID-19. This highlights the importance of continued monitoring and intervention strategies to mitigate the consequences of prolonged physical inactivity (Jastrzębska et al., 2023).

The limitations of this study are related to the comparison of two groups composed of different individuals in the pre- and post-pandemic periods, using data collected for the pre-pandemic group and new data collection for the post-pandemic group. This decision was influenced by the long period of social isolation imposed, which lasted 24 months and affected age and maturation stages in the analyzed variables, preventing us from using the same individuals. Additionally, we were unable to directly measure sun exposure and dietary intake, both of which could have influenced the 25(OH)D concentrations observed. Sun exposure likely decreased due to social isolation, but we did not collect data on outdoor activity or vitamin D-rich dietary intake, which may have contributed to the variation in vitamin D levels.

Despite these limitations, we highlight as a positive aspect the cross-sectional study design with time comparison, where post-pandemic participants were properly matched for age, maturation, and body composition characteristics of the initial groups. This allowed us to isolate the effects of body composition on fitness variables, which could independently influence the results of CRF, muscle strength, and STS performance. Given the cross-sectional study design with time comparison, we are cautious in making causal claims regarding the effects of social isolation on physical fitness and 25(OH)D levels. However, the observed differences between the pre-pandemic and post-pandemic groups provide valuable insights into the potential impacts of prolonged inactivity and reduced sun exposure to adolescent health. Future studies employing longitudinal designs or controlled trials are needed to confirm these associations and explore long-term effects.

The results of this study, though conducted during a specific period of global isolation, provide valuable insights into the potential long-term health risks posed by reduced physical activity and vitamin D deficiency in adolescents. These findings can inform future research on strategies to prevent the development of health issues related to inactivity, such as obesity, decreased motor skills, and poor cardiorespiratory fitness, which could have lasting effects beyond the pandemic (di Filippo et al., 2023).

We concluded in this study that the isolation period during the COVID-19 pandemic negatively affected the adolescents' physical and motor performance, with greatest effects were on CRF and FLEX. It also impaired 25(OH)D concentrations, probably for reduction of solar exposition. Overall, the impacts of social isolation occurred in eutrophic adolescents, who had better physical performance and motor performance overweight adolescents in the pre-pandemic. In this sense, our research is essential for parents and Physical Education professionals to plan measures that support the physical and motor health of adolescents, stimulate and provide opportunities for outdoor activities, with exposure to sunlight, as well as promote healthy eating habits to mitigate the health consequences of social isolation.

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APPENDICE

Table 2.
Comparisons of physical fitness and motor performance parameters in pre- and post-pandemic periods in eutrophic and overweight Adolescents

	Eutrophic			Overweight		
Variables	Pre-pandemic (n=8)	Post-pandemic (n=8)		Pre-pandemic (n=9)	Post-pandemic (n=9)	
	Mean±SD	Mean±SD	p	Mean±SD	Mean±SD	p
Age (Years)	15.1±1.3	15.2±1.0	0.804	14.7±1.1	14.1±0.5	0.180
PHV (Years)	1.00±1.3	1.42±0.9	0.494	0.96±1.0	0.89±0.8	0.872
APHV (Years)	14.1±0.5	13.8±0.3	0.287	13.7±0.6	13.2±0.4	0.063
Anthropometry and Body Composition						
BM (Kg)	58.8±11.8	56.9±8.9	0.725	75.8±11.1	75.7±12.7	0.993
Height (cm)	170.5±8.9	172.6±6.0	0.599	167.3±7.8	167.4±6.5	0.975
BMI-z (z score)	-0.04±0.9	-0.48±0.8	0.349	1.98±0.7	2.08±0.6	0.756
TMI ($kg\ m^{-3}$)	11.7±1.0	10.9±0.9	0.172	16.2±2.5	16.1±2.5	0.935
WC	71.0±7.0	67.8±4.5	0.306	85.25±8.1	85.64±9.7	0.929
WHtR	0.41±0.03	0.39±0.01	0.297	0.51±0.05	0.51±0.05	0.949
FM (kg)	11.2±6.0	9.76±2.4	0.526	24.6±7.0	22.3±8.5	0.540
%FM (%)	17.9±7.9	17.0±3.0	0.754	32.0±6.2	28.7±7.1	0.317
FFM (kg)	47.8±6.8	47.2±7.2	0.871	51.1±6.1	53.4±6.3	0.455
%FFM (%)	82.9±3.0	82.9±3.0	0.903	67.9±6.2	71.2±7.1	0.317
Metabolic Variables						
TG (mg/dL)	81.4±10.1	75.4±10.4	0.682	84.1±9.5	64.6±9.5	0.160
HDL-c (mg/dL)	49.6±2.7	48.2±2.7	0.714	52.1±2.5	47.4±2.5	0.206
25(OH)D (ng/mL)	34.0±1.9 [a]	23.6±1.9	0.001	32.6±1.8 [b]	20.3±1.8	<0.001
Physical and motor performance						
CRF_{rel}	56.1±7.7[a]	46.1±5.0	0.005	38.0±7.0	33.5±5.8	0.157
CRF_{abs}	3.24±0.5[a]	2.60±0.2	0.002	2.84±0.4	2.49±0.3	0.071
ABDO (rep)	36.3±7.5	30.3±6.2	0.104	23.3±10.9	23.2±7.9	0.980
FLEX (cm)	25.5±9.3	18.0±10.9	0.165	22.1±7.8	14.0±9.76	0.071
HGS-right (kg)	32.8±7.7	30.9±8.6	0.642	30.7±5.5	29.4±7.8	0.683
HGS-left (kg)	32.6±8.1	30.2±8.3	0.567	32.2±6.3	27.7±8.2	0.219
STS_{TIME} (s)	1.62 ±0.2[a]	2.20±0.3	0.029	2.18±0.6[b]	2.83±0.6	0.012
STS_{MC} (points)	11.3±1.0	12.0±0.5	0.159	8.11±2.3	8.11±2.0	1.000

[a]Pre vs. Post eutrophic; [b]Pre vs. Post overweight; PHV, peak height velocity; APHV, age of peak height velocity; BM, body mass; BMI-z, body mass index z score; TMI, tri-ponderal mass index; WC, waist circumference; WHtR, waist/height ratio; FM, fat mass; FFM, fat-free mass. CRF_{rel}, relative cardiorespiratory fitness; CRF_{abs}, absolute cardiorespiratory fitness; ABDO, abdominal resistance; FLEX, flexibility; STS_{TIME}, supine-to-stand time; STS_{MC}, supine-to-stand motor competence; 25(OH)D, vitamin D.