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COVID-19 Restrictions' Effect on Physical Fitness – A Comparative Study of First-Year Students in Pre, During, and Post-Pandemic Eras

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Abstract

This study investigates the influence of COVID-19 restrictions on first-year university students' physical fitness over five years, analyzing data from the University of Defence. The findings reveal a significant decline in first-semester performances in 2020/21, primarily attributed to students who did not undergo physical entrance exams and experienced a partial lockdown along with distant schooling. The class of 2021/22, despite similar conditions, achieved comparatively better results, possibly due to increased control of students during distant schooling at the residence hall. Conversely, the period of 2019/20 saw the most substantial decline in physical performance, suggesting challenges in adapting to abrupt transitions to distant schooling. From these results, it is evident that factors such as physical entrance exams, in-person schooling, and supervision play crucial roles in improving physical performance among university students. These findings underscore the impact of pandemic-related disruptions on physical capabilities, offering insights for education and health policymakers aiming to support student well-being during unprecedented times.

KEY WORDS: *physical fitness, longitudinal study, distant schooling, COVID-19 restrictions, impact assessment, public health dynamics.*

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1. Introduction

Physical fitness plays a critical role in fostering effective and self-reliant behavior among individuals, impacting societal productivity, overall health, and resilience [1]. Despite global efforts to promote active lifestyles and reduce digital media use, the COVID-19 pandemic has introduced unprecedented challenges. Measures such as social distancing, remote work, and lockdowns have exacerbated unhealthy behaviors, leading to a decline in physical fitness [6], [7], [8], [9], [10].

Regular exercise and physical activity (PA) are well-documented for their comprehensive benefits on physical and mental health [11], [12]. Current guidelines recommend that healthy adults engage in at least 150 minutes of moderate to vigorous physical activity (MVPA) weekly to reduce risks associated with all-cause mortality, cardiovascular disease, diabetes, dementia, and mental health disorders [13], [14]. Despite these recommendations, global levels of physical inactivity remain high, with only half of healthy adults meeting the guidelines [15].

Access to recreational areas is pivotal for PA, and restrictions during the pandemic may promote sedentary behavior, contributing to chronic diseases and mental health issues [16], [17]. Large-scale epidemiological studies underscore the mortality benefits of regular PA, while also suggesting indirect benefits in mitigating COVID-19 risks through obesity management and immune enhancement [19], [20], [21].

On March 11, 2020, the Director-General of the World Health Organization declared coronavirus disease (COVID-19) a global pandemic, prompting significant movement restrictions worldwide and within nations, affecting adults' ability to meet recommended levels of physical activity (PA) and exercise. During the early stages of the COVID-19 pandemic, several international surveys revealed substantial declines in self-reported physical activity levels compared to pre-pandemic levels. Furthermore, reductions in physical activity and increases in sedentary behavior were associated with poorer mental health and increased anxiety [22], [23], [24].

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While the exact timeline of the COVID-19 pandemic remains undefined, the most severe countermeasures were implemented during the years 2020 and 2021. Scientific exploration and documentation of physical fitness changes have been conducted; however, many studies have predominantly focused on acute responses to lockdown without follow-up trend inquiries.

This study aims to investigate the impact of COVID-19 on the physical fitness of first-year university students over a five-year period, spanning pre-pandemic, pandemic, and post-pandemic phases. It seeks to understand how acceptance and study conditions before, during, or after COVID-19 restrictions influenced physical fitness trends among students.

2. Methods

The research sample comprised 1,996 male and 253 female soldiers from the Czech Republic Army, all first-year students at the University of Defence. All participants were in good health and possessed sufficient fitness levels to successfully complete the first two semesters' credit disciplines in physical education. Familiar with the tests, participants received training during distance schooling. Ethical approval was obtained from the University of Defence's Ethical Board, and participants were informed of the use of their results for analyses and research by the Centre of Physical Education and Sport.

Data analysis utilized results from the first two semesters of physical education credit disciplines over five consecutive school years (2018-2022). Participants had three attempts for each test during university exam periods, with the best results recorded for the study.

Five physical performance tests were conducted by physical education teachers with a minimum of 6 years of experience. The first-semester disciplines included the 10 x 10 m shuttle run, 1000 m run, and pull-ups for men, and pull-up hold for women:

1. *10 x 10 m Shuttle Run.* Participants perform a dynamic 10 x 10 meters shuttle run, ensuring at least one foot crosses the 10 m line each turn. The number of completed 10-meter segments is recorded by an examiner, with time measured to the tenth of a second.
2. *1000 m Run.* Participants engage in a 1000-meter run on a 300 m athletic track, starting collectively, with individual times recorded.
3. *12-Minute Run.* Starting collectively, participants run for 12 minutes, with remaining time visible. A signal sounds one minute before conclusion, and the distance covered is accurately documented. Personal watches were permitted for self-tracking.
4. *Pull-Ups.* Men perform pull-ups with strict form, starting from a dead-hang position with a straight body. Kipping motions are avoided, and the goal is to lift until the chin surpasses the bar. The number of successful pull-ups is documented.
5. *Pull-Up Hold.* For women, the pull-up hold test begins from the pull-up position, using assistance to reach the starting point. The focus is on maintaining the chin above the bar without contact for as long as possible, with duration measured.

Second-semester tests comprised the 12-minute run and pull-ups for men, and pull-up hold for women.

Data analysis. The following non-parametric methods were used to compare groups: the Kruskal-Wallis test, the Tukey-Kramer-Nemenyi all-pairs test and the Wilcoxon signed rank test (paired), see [25]. Statistical analyses were performed in software R, with the statistical significance level set at $\alpha = 0.05$.

3. Results

Data analysis in this study was categorized into three parts: the first semester, the second semester, and the crossover of the first and second semesters. Each part included two subgroups, one for males and one for females. The data for the first semester disciplines are presented in Tables 1 and 2, Figures 1 and 2. Tables 1 and 2 contain basic descriptive statistics, namely sample size – n, sample mean – Mean, sample standard deviation – St. dev., median (Median), minimum value – Min, maximum value – Max, lower quartile – $Q_{0.25}$, upper quartile – $Q_{0.75}$, skewness – Skewness and kurtosis – Kurtosis for the school years 2018/19 to 2022/23. Graphically, these data are shown in Figure 1 and 2 using boxplots. The school class of 2020/21 distinguished itself with generally the poorest results in all three disciplines – pull-ups, 10 x 10 m shuttle run, and 1000 m run, for both men and women. In the male subgroup, the class of 2018/19 achieved the most favorable results, demonstrating statistically significantly superior performance in pull-ups compared to all other classes, see Table 5 for the p-values of the multiple comparison test. For the purpose of statistical testing, we choose a significance level of 0.05 (a p-value less than 0.05 identifies a statistically significant difference).

Additionally, they showed superior 1000 m run results in all years except 2019/20 and better 10 x 10 m shuttle run results compared to 2020/21, while being statistically equivalent to other classes, see Table 5. For the female subgroup, the class of 2019/20 showcased the best results, with a pull-up hold performance superior to that of 2020/21 and 2021/22. Statistically insignificant differences were observed in the 1000 m run and 10 x 10 m shuttle run compared to other classes.

Table 1 shows the first-semester results over five years for male disciplines. The class of 2018/19 outperformed all other classes in every discipline, while the class of 2020/21 had the lowest scores.

Table 1.

1st semester – males

2018/19	**n**	**Mean**	**St. dev.**	**Median**	**Min**	**Max**	**$Q_{0.25}$**	**$Q_{0.75}$**	**Skewness**	**Kurtosis**
Number of pull-ups	214	11.92	3.57	11	4	23	9	14	0.68	0.03
10x10 m shuttle run	214	25.36	1.19	25.6	18	27	24.8	26.1	–1.93	7.77
1000 m run	214	207.66	11.73	207.5	172	230	200	216	–0.18	–0.29
2019/20										
Number of pull-ups	243	9.6	4.78	9	4	28	6	12	1.01	0.76
10x10 m shuttle run	243	25.58	0.87	25.6	23.1	27	24.99	26.3	–0.23	–0.76
1000 m run	243	210.21	12.18	210	176	230	203	220	–0.28	–0.57
2020/21										
Number of pull-ups	207	9.19	4.56	9	4	25	5.5	11	0.86	0.09
10x10 m shuttle run	207	26.31	0.93	26.4	23.7	30	25.7	27	0.59	2.29
1000 m run	207	216.12	11.52	217	176	230	208	227	–0.62	–0.21
2021/22										
Number of pull-ups	312	9.11	4.3	8.5	4	24	5	12	0.9	0.65
10x10 m shuttle run	312	25.64	0.9	25.7	20.2	27	25	26.32	–0.91	3.13
1000 m run	311	211.86	13.14	213	176	230	203.5	222	–0.54	–0.49
2022/23										
Number of pull-ups	220	10.02	4.92	9	4	22	5	14	0.46	–0.85
10x10 m shuttle run	220	25.65	0.91	25.7	23.3	27	25	26.4	–0.43	–0.67
1000 m run	220	211.55	12.3	212.5	174	230	203	221	–0.43	–0.42

Table 2 shows the first-semester results over five years for female disciplines. Differences between classes are subtler than in males. Generally, better results were achieved by the classes of 2018/19, 2019/20, and 2022/23, while the classes of 2020/21 and 2021/22 performed poorly.

Table 2.

1st semester – females

2018/19	**n**	**Mean**	**St. dev.**	**Median**	**Min**	**Max**	**$Q_{0.25}$**	**$Q_{0.75}$**	**Skewness**	**Kurtosis**
Pull-up hold	43	28.27	11.33	26	15	60	20	33.5	1.16	1.1
10x10 m shuttle run	43	28.26	1.09	28.3	25.7	30	27.65	28.9	–0.33	–0.54
1000 m run	43	248.3	13.89	253	211	267	241.5	258	–0.97	0.17
2019/20										
Pull-up hold	39	30.44	14.03	29	9	64	20.7	38.85	0.62	–0.22
10x10 m shuttle run	39	28.04	1.13	28.1	26	30	26.97	28.84	0.04	–1.04
1000 m run	39	246.05	13.96	247	213	265	236	258.5	–0.22	–0.82
2020/21										
Pull-up hold	59	18.08	9.88	15	8	45	11	23	1.14	0.48
10x10 m shuttle run	59	28.76	0.91	29	26.7	30	28.3	29.3	–0.71	–0.28
1000 m run	59	253.8	10.69	257	225	265	250	262	–1.06	0.17
2021/22										
Pull-up hold	56	18.77	9.33	16.5	8	42	11	25	0.79	–0.28
10x10 m shuttle run	57	28.21	0.94	28.3	25.59	29.9	27.7	29	–0.51	–0.02
1000 m run	57	251.25	13.53	254	203	265	244	263	–1.14	1.26
2022/23										
Pull-up hold	56	26	13.35	23	9	62	16.5	33.25	0.9	0.2
10x10 m shuttle run	56	28.45	0.95	28.5	25.8	30	27.98	29.13	–0.6	–0.13
1000 m run	56	246.61	14.67	249.5	215	264	232.75	260	–0.47	–1.07

The second-semester male results presented in Table 3 show similar performances among the classes, except for 2019/20, which had markedly worse results.

Table 3.

2nd semester – males

2018/19	**n**	**Mean**	**St. dev.**	**Median**	**Min**	**Max**	**$Q_{0.25}$**	**$Q_{0.75}$**	**Skewness**	**Kurtosis**
12-minute run	200	2818.7	147.95	2800	2600	3400	2700	2900	0.81	0.49
Number of pull-ups	200	11.82	3.5	11	8	24	9	14	0.86	0.21
2019/20										
12-minute run	221	2720.88	193.72	2700	2000	3390	2620	2800	0.53	2.83
Number of pull-ups	221	9.49	3.94	8	5	23	6	11	1.26	1.13
2020/21										
12-minute run	183	2798.96	166.43	2800	2600	3315	2650	2910	0.63	–0.3
Number of pull-ups	183	11.13	4.8	10	6	27	7	13.5	0.86	0.06
2021/22										
12-minute run	268	2836.96	171.65	2840	2600	3300	2700	2950	0.49	–0.48
Number of pull-ups	268	10.92	4.04	11	6	25	7	13.25	0.71	0.01
2022/23										
12-minute run	192	2828.54	176.8	2800	2600	3330	2700	2922.5	0.7	–0.02
Number of pull-ups	192	11.71	4.89	11	6	25	7	15.25	0.54	–0.8

The second-semester results for females in Table 4 show the dominance of the class of 2018/19 in the 12-minute run and the class of 2022/23 in the pull-up hold, while other classes did not markedly distinguish themselves from the others.

Table 4.

2nd semester – females

2018/19	**n**	**Mean**	**St. dev.**	**Median**	**Min**	**Max**	**$Q_{0.25}$**	**$Q_{0.75}$**	**Skewness**	**Kurtosis**
12-minute run	42	2484.29	172.84	2435	2300	2920	2350	2561.25	0.97	-0.12
Pull-up hold	42	24.65	9.23	23	15	49	17.25	28.75	1.01	0.23
2019/20										
12-minute run	34	2445.91	129.63	2400	2281	2870	2365	2495	1.31	1.65
Pull-up hold	34	27.94	14.81	25	11	78	18.25	31.5	1.56	2.43
2020/21										
12-minute run	60	2414.42	119.61	2365	2300	2800	2307.5	2485	1.03	0.32
Pull-up hold	60	24.58	12.23	19	14	59	15	31.25	1.19	0.35
2021/22										
12-minute run	53	2446.23	145.33	2400	2300	2830	2300	2530	0.85	–0.14
Pull-up hold	53	24.36	10.93	22	12	61	15	30	1.02	0.87
2022/23										
12-minute run	48	2464.9	156.58	2410	2300	2850	2340	2565	0.77	–0.64
Pull-up hold	48	30.65	14.15	28	12	73	20	35.25	1.1	0.7

Table 5 shows statistical analysis of performance differences for each discipline.

Table 5.

Multiple comparisons – Tukey-Kramer-Nemenyi all-pairs test (p-values)

Number of pull-ups					**Pull-up hold**				
Males	*2018/19*	*2019/20*	*2020/21*	*2021/22*	**Females**	*2018/19*	*2019/20*	*2020/21*	*2021/22*
2019/20	<0.001	–	–	–	*2019/20*	0.997	–	–	–
2020/21	<0.001	0.900	–	–	*2020/21*	<0.001	<0.001	–	–
2021/22	<0.001	0.910	1.000	–	*2021/22*	<0.001	<0.001	0.985	–
2022/23	<0.001	0.820	0.320	0.280	*2022/23*	0.699	0.492	0.003	0.019
100 m run					**100 m run**				
Males	*2018/19*	*2019/20*	*2020/21*	*2021/22*	**Females**	*2018/19*	*2019/20*	*2020/21*	*2021/22*
2019/20	0.155	–	–	–	*2019/20*	0.990	–	–	–
2020/21	<0.001	<0.001	–	–	*2020/21*	0.240	0.080	–	–
2021/22	<0.001	0.313	0.003	–	*2021/22*	0.640	0.320	0.950	–
2022/23	0.005	0.706	0.001	0.987	*2022/23*	0.990	1.000	0.060	0.300
Shuttle 10 x 10 m run					**Shuttle 10 x 10 m run**				
Males	*2018/19*	*2019/20*	*2020/21*	*2021/22*	**Females**	*2018/19*	*2019/20*	*2020/21*	*2021/22*
2019/20	0.730	–	–	–	*2019/20*	0.891	–	–	–
2020/21	<0.001	<0.001	–	–	*2020/21*	0.075	0.005	–	–
2021/22	0.190	0.900	<0.001	–	*2021/22*	0.995	0.977	0.012	–
2022/23	0.170	0.840	<0.001	1.000	*2022/23*	0.890	0.336	0.390	0.618

Data for the second-semester disciplines are presented in Tables 3 and 4 and in Figures 1 and 2. The second semester exhibited more diversity than the first semester, with the class of 2019/20 showcasing the lowest results for men in both disciplines. Conversely, for women, the class with the poorest performance was 2020/21. The best results for men in the 12-minute run were observed in the class of 2021/22, and for pull-ups, in the class of 2018/19. Among women, despite the higher scores in the 12-minute run for the classes of 2018/19 and 2022/23, the differences were not statistically significant, indicating equivalent performances across all classes. For pull-up hold, the class of 2022/23 demonstrated the best performances, although statistically significant only when compared to the class of 2020/21, see Table 5.

Table 6.
Wilcoxon test (p-values): comparison of performances in the disciplines pull-ups (males) and pull-up hold (females), 1st and 2nd semester

Males		**Females**	
Year	p-value	Year	p-value
2018/19	0.423	*2018/19*	0.009
2019/20	0.883	*2019/20*	0.006
2020/21	<0.001	*2020/21*	<0.001
2021/22	<0.001	*2021/22*	<0.001
2022/23	<0.001	*2022/23*	<0.001

In the comparison of males in pull-ups between the first and second semesters of the same classes, identical performances were revealed for 2018/19 and 2019/20, while an increase was observed in the second semesters for 2020/21, 2021/22, and 2022/23, see Table 6 and Figure 1. For females, differences between semesters in pull-up hold were statistically significant in all years. Decreased performances were observed in the second semester for 2018/19 and 2019/20, while increased performances were noted in 2020/21, 2021/22, and 2022/23, see Table 6 and Figure 2.

4. Discussion

The primary focus of this study was to investigate how COVID-19-related restrictions influenced the physical fitness of university freshmen during their first year of study. The most severe restrictions occurred in 2020, with a complete lockdown not being an extraordinary measure applied, and 2021, where distant learning was still in use. Our findings of very poor physical performances in the class of 2020/21 during the first semester align with the physical inactivity outcomes reported by Pinho [26]. It is important to note that the low physical fitness of the 2020/21 class might not be solely due to COVID-19 restrictions but also the result of the selection process. This class did not undergo physical entrance exams, and therefore, the fitness baseline itself might be lower than that of classes who did go through the selection process. This fact, in conjunction with the era's difficulties, might be the determining factor, as the class of 2021/22 shared similar characteristics with the exception of a higher level of supervision by their teachers and supervisors during distant schooling at the residence hall, displaying higher physical capabilities.

Entrance exams and no restrictions are characteristics of the 2018/19 class, where the physical fitness level of men was superior to others, and the same goes for the first semester of women in the 2019/2020 class. Silva [27], in their longitudinal study, reported decrements in body composition and cardiovascular fitness after lockdown, and improvements after two months of the reintroduction of in-person classes. Our study supports these findings. Lockdown and distant schooling promoted individual training, often supported by smart apps and other multimedia facilities, which helped mitigate the impact of physical inactivity [28], as evidenced by the improved performances in pull-ups for the 2020/2021 class.

The importance of in-person classes stands out from the overall superior performance of the 2018/19 and 2022/2023 classes, where no distant schooling was applied. The adaptation to the new situation challenged individuals' flexibility, and their reaction was not immediate, resulting in a drop in fitness levels even in normally above-average active individuals during the beginning of new conditions [29], as visible in the second semester of the 2019/20 men's class, where lockdown and individual training during distant schooling were applied.

For the physical education program at the University of Defence, it can be said to display positive results in both normal and distant schooling regimes. Comparing pull-ups and pull-up hold between the first and second semesters showed statistically significant increases in the majority of classes, namely men in 2020/21, 2021/22, 2022/23, and women in 2020/2021, 2021/22, 2023. Stability was observed in men in 2018/19, 2019/20, and decline only in women in 2018/19 and 2019/20, despite the challenging conditions, whereas the general trend of physical fitness among college students is declining [30].

Figure 1 displays boxplots of performances in each individual discipline of the male subgroup in this study. On the left side is a scale representing the number of repetitions in pull-ups, distance covered in meters in the 12-minute run, and time achieved in seconds in the 10x10 m shuttle run, and 1000 m run. Higher values represent better performance in pull-ups and the 12-minute run, while lower values indicate better performance in the 10x10 m shuttle run and the 1000 m run.

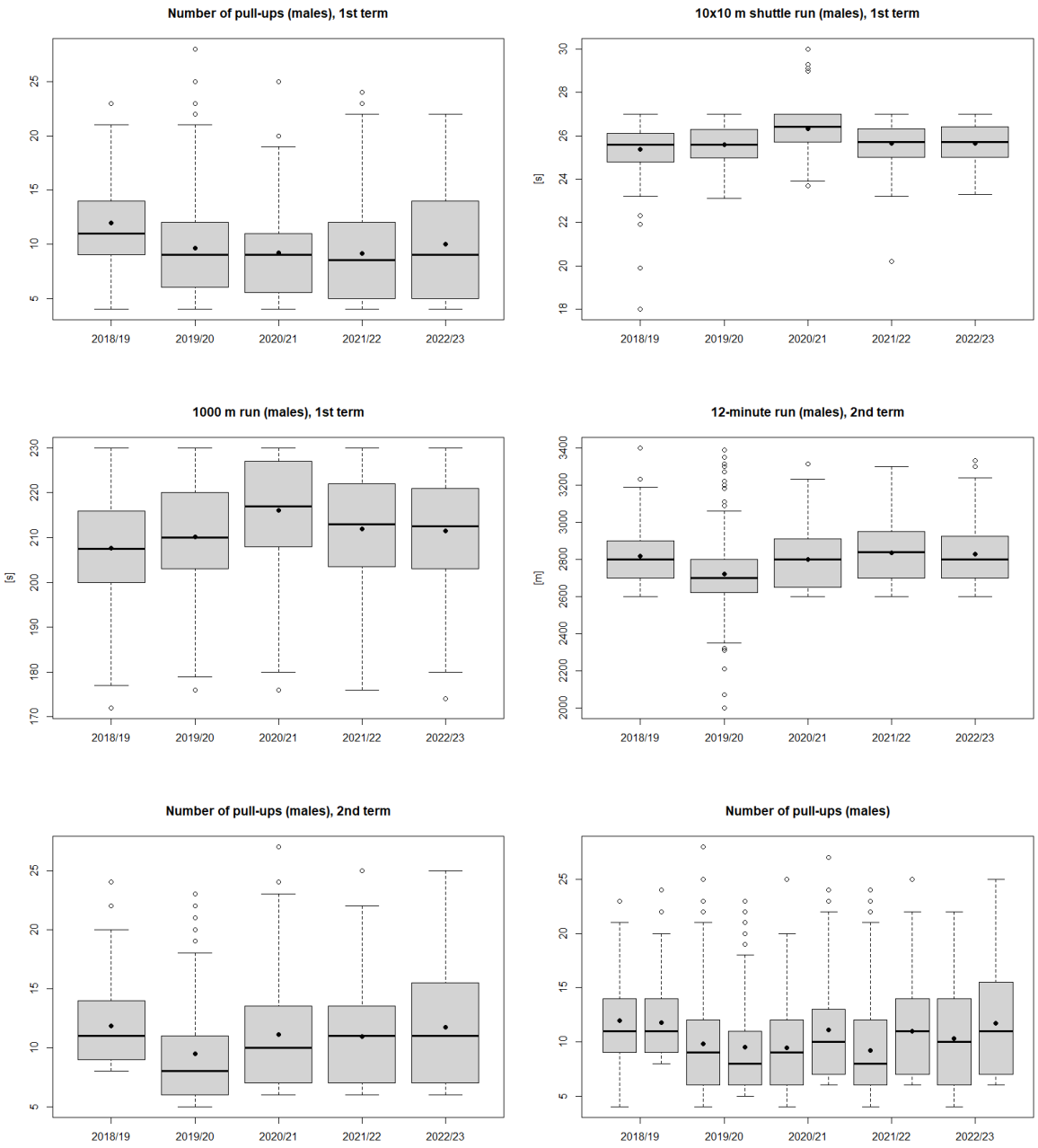

Fig. 1. Boxplots of performances in individual disciplines – males.

Figure 2 displays boxplots of performances in each individual discipline of the female subgroup in this study. On the left side is a scale representing distance covered in meters in the 12-minute run and time achieved in seconds in the 10x10 m shuttle run, pull-up hold, and 1000 m run. Higher values represent better performance in pull-up hold and the 12-minute run, while lower values indicate better performance in the 10x10 m shuttle run and the 1000 m run.

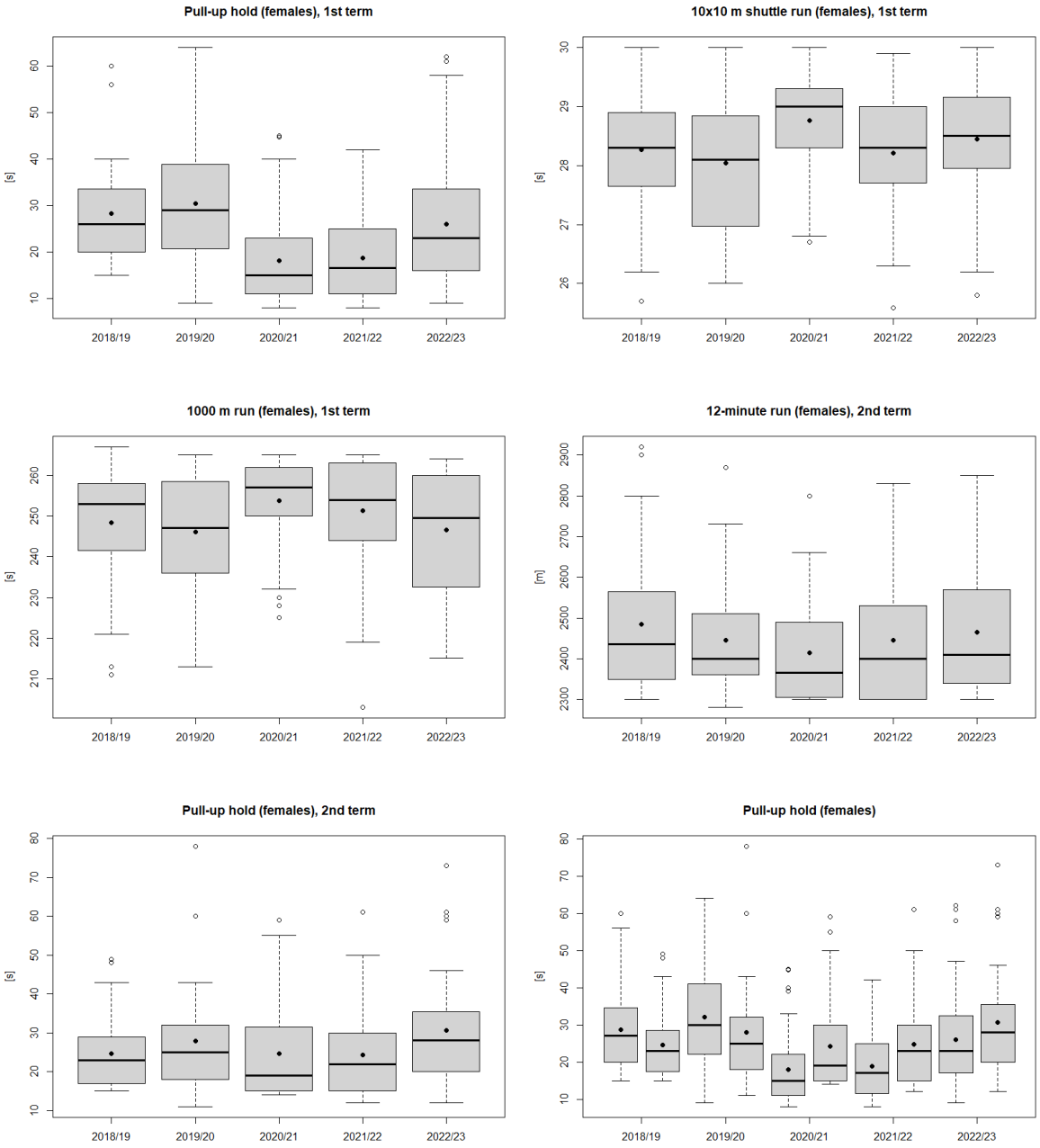

Fig. 2. Boxplots of performances in individual disciplines – females

5. Conclusion

This study analyzes the physical performance of university students in their first year of study before, during, and after COVID-19 pandemic-related restrictions, providing insightful observations on how physical capabilities varied during this period. The notably poor first-semester performances in 2020/21, characterized by students who did not undergo physical entrance exams and experienced a partial lockdown along with a distant-schooling system throughout the semester, suggest a significant impact of COVID-19 restrictions on physical performance. Interestingly, the class of 2021/22, which also did not undergo physical entrance exams but achieved better results, seems to have benefited from higher control of students due to the requirement to be present at the residence hall during distant schooling. The most substantial decline in physical performance in the second semester was observed in the period of 2019/20, suggesting that in-person schooling may be more effective. This highlights the importance of physical entrance exams, present schooling, and supervision as critical factors influencing physical capabilities among university students. The abrupt transition to distant schooling appeared challenging, indicating that students and the system may not have been fully prepared for such a sudden change. The observed decrements in physical performance during lockdown and distant-schooling align with findings from previous research.

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