

Article

Impact of COVID-19-Related Sports Activity Disruptions on the Physical Fitness of Japanese Adolescent Athletes

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Abstract: We assessed whether the coronavirus disease 2019 (COVID-19) pandemic-related disruptions impacted the physical fitness of adolescent athletes. We reviewed the age-, sex-, and sports category-matched data of 78 adolescent athletes (divided into two groups: 2019 group = 37; 2020 group = 41) from the clinical database and investigated their height, weight, body composition, flexibility muscle strength, and jump height. We also provided questionnaires to the teams' coaches to collect data on the duration of practice suspension due to the COVID-19 pandemic; the practice hours per week in August 2019, immediately after the suspension ended, and in August 2020; and the guidelines for the players after resuming their practice. For data analyses, we considered $p \leq 0.05$ as statistically significant. The strength of knee flexion and extension was significantly lower in the 2020 group than in the 2019 group; there was no difference in the other physical fitness parameters. The practice duration in August 2019 and August 2020 was the same. COVID-19-related interruptions did not alter the athletes' jump height, upper-limb strength, and flexibility but reduced lower-limb muscle strength. We recommend that basic strength training protocols be followed to prevent sports-related injuries after such unexpected practice interruptions.

Keywords: coronavirus disease-19; social forced interruption; physical check-up; youth athletes

1. Introduction

The coronavirus disease 2019 (COVID-19) is an infectious viral disease caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that began to spread in December 2019 [1]. The disease rapidly spread worldwide throughout 2020 and was declared a pandemic by the World Health Organization (WHO) on 11 March 2020 [2]. In Japan, more than 3 million people have had positive test results as of February 2022, and about 20,000 deaths have been reported [3]. Following the WHO recommendations, countries across the globe have implemented safety measures to reduce human-to-human virus transmission, and governments have imposed restrictions on most public activities, which has impacted the lifestyles and routines of adolescents and adults alike. Currently, COVID-19 is associated with a low risk of serious illness in healthy adolescents [4]; however, they were still required to restrict their out-of-home activities to prevent the spread of the disease to chronically ill and older individuals.

In a variety of individuals, physical activity has been reduced due to the limitation of activities associated with COVID-19. In healthy Italian adults, city-wide lockdown

associated with COVID-19 has been reported to predominantly reduce daily steps and mean heart rate [5]. In Spanish young adults, the walking time and number of steps measured using a smartphone accelerometer were reported to be predominantly low during lockdown [6]. In patients with heart failure, the average number of steps taken during lockdown was also measured using a wrist accelerometer, and the number of steps taken was reduced compared to normal conditions [7]. The same reports are available for children and adolescents. Moore et al. [8] reported that the COVID-19 pandemic resulted in less time spent out of the house and increased sedentary lifestyles, screen time, and sleep time. In Australian adolescents, the walking distance measured using smartphone sensors was also reported to have decreased significantly during the COVID-19 pandemic [9].

The decrease in physical activity in the months following the pandemic may further impact the physical fitness of adolescents. Tsokos et al. [10] reported that a five-month lockdown due to COVID-19 negatively influenced the strength, power, and flexibility of adolescent students, and notably, more in males than in females. Sunda et al. [11] suggested that the COVID-19 lockdown negatively influenced muscular fitness status in adolescents, especially in boys. Due to concerns regarding such adverse effects, when trying to prevent COVID-19 infection or any other epidemic in the short term, it is recommended not to neglect its effects on the quality of life and healthy lifestyle behaviors of the general population in the long term [12].

Several sporting events, including the 2020 Tokyo Olympics and Paralympics, were canceled or postponed to follow physical distancing guidelines; most athletes have been forced to stop training due to restrictions on public gatherings. We hypothesized that the amount of physical activity in adolescent athletes has drastically reduced due to school closures, self-restraint, and suspension of practice. In elite athletes, significant total training volume and performance decreased during the lockdown [13]. Some experts have noted the decline in physical activity among young athletes in a socially distanced world [14] and have reported that prolonged restrictions may result in widespread attrition of youth from sport [15]. Unexpected and forced suspension of sports-related activities leads to increased sports injuries once athletes resume sports activities [16], which causes further deterioration in their general physical fitness due to the periods of inactivity that are subsequently required for recovery. Therefore, the fitness status of adolescent athletes should be assessed before they resume sports to prevent such injuries [17]. However, to date, no studies have described the association between COVID-19-related inactivity and physical fitness in adolescent athletes.

To address this knowledge gap, we aimed to investigate the influence of COVID-19-related interruptions in sports training on the physical fitness of adolescent athletes. Our report provides basic data on the fitness status of adolescents after a period of inactivity due to pandemic-related restrictions on public gatherings.

2. Materials and Methods

2.1. Experimental Approach to the Problem

In this retrospective study, to examine the effects of physical inactivity associated with COVID-19 on physical fitness, we extracted the following data on adolescent athletes between 2019 and 2020 from our physical examination database: body type and composition, muscle strength, flexibility, and jump height. We also measured the data according to the prescribed procedures. Furthermore, we provided an internet questionnaire to the coaches to obtain additional data on the length of the suspension and the amount of time and content of practice before and after the suspension.

2.2. Participants

This study was approved by the Ethics Committee of Hiroshima university hospital (file number: E-941, approval period 1 February 2017, to 31 December 2023). Written informed consent was obtained from the athletes' parents/guardians, as per the Declaration of Helsinki and the guidelines in the American Psychological Association's Publications

Manual, after both athletes and their parents/guardians received a thorough explanation of the benefits and risks of the investigation.

Adolescent athletes routinely undergo medical and physical check-ups at Hiroshima university hospital sports medicine center in August every year, and we retrospectively reviewed these data for our analysis. We investigated 41 adolescents who participated in 2020 (2020 group) and 37 athletes in 2019 (2019 group) and matched them according to their age, sex, and sports category. All the athletes played at the same competitive level (top-level in the prefecture) and in the same teams. The characteristics of both groups are shown in Table 1.

Table 1. Profile of participants.

		2019	2020	<i>p</i> Value
Sex	Male	28	26	0.31
	Female	9	14	
Age (years)		13.6	13.8	0.41
Sports	Rugby	7	15	
	Hockey	9	7	
	Handball	7	4	
	Table tennis	6	4	
	Kendo	8	3	

We excluded participants with a body temperature of >37 °C at the time of their medical check-up and those who had sustained a musculoskeletal injury 1 week before the check-up. Moreover, we encouraged the 2020 group to wear masks except when playing and requested a written confirmation indicating that they had no common cold symptoms or body temperature >37 °C during the week before the experiment to prevent the spread of COVID-19. In the 2020 group, no history of COVID-19 infection before the measurement was observed. Vaccination had not been initiated in Japan at the time of the medical check-up [18], and all participants were unvaccinated.

2.3. Procedures

We extracted the following data from the participants: body type and composition (height, weight, body fat amount, lean body weight, and muscle mass), muscle strength (isokinetic muscle strength during knee extension and flexion, and grip power), flexibility (straight-leg raising angle and heel-buttock distance), and jump height (squat jump height and counter-movement jump height).

2.3.1. Body Type and Composition

We used an InBody S10 Body Water Analyzer (InBody Co., Seoul, Korea), a direct segmental multifrequency bioimpedance analysis (DSM-BIA) device, for our analysis. In this DSM-BIA method, we used an 8-point tactile electrode system that recorded 30 impedance measurements at six frequencies (1, 5, 50, 250, 500, and 1000 kHz) of five body segments (right upper limb, left upper limb, trunk, right lower limb, and left lower limb). We also ensured that the measurements in children were accurate [19]. From the measured data, we derived the body fat amount, lean body weight, and muscle mass and included these values in our analyses.

After waking up, the participants were asked to remain in a fasting state until their measurements were taken at 9:00 AM. All participants fasted for at least 9 h, and drinking water was prohibited 30 min before the test. The participants' height and weight were measured and entered into the device before starting BIA. The measurements were taken with the participants in the supine position with no limbs in contact with each other. Electrically conductive accessories, such as glasses, necklaces, watches, and bracelets, were removed. After pre-treating the skin with electrolytic tissues (InBody tissue, InBody Co.,

Seoul, Korea), the electrodes were placed on the first and third fingers and both ankles. The participants were instructed to lie still while the measurements were being recorded.

2.3.2. Muscle Strength Measurements

The Biodex System 4 Dynamometer (Biodex Medical Systems, New York, NY, USA) was used to measure the isometric muscle strength of the knee. The participants flexed and extended their knees five times while they were in the sitting position at an angular velocity of 60° per second. We noted the peak torque during each repetition and evaluated the highest peak torque in the five repetitions (we did not consider the average peak value). The weight ratio of the measured peak torque was used as the measured value in this study.

We used a Smedley-style digital grip dynamometer (Grip-D, Takei Scientific Instruments Co. Ltd., Nigata, Japan) to assess grip power. The participants made a maximal gripping effort twice in the standing position, and we recorded the peak value from the two measurements as the grip power.

2.3.3. Flexibility Measurements

The flexibility measurements were obtained by two physical therapists. For the straight-leg raising angle (SLR), the athlete was placed in a supine position. One physiotherapist grasped the distal lower leg, raised it passively with the knee in full extension, and stopped the elevation as soon as some resistance was noted. At this position, the other physiotherapist measured the angle between the midline of the trunk and the long axis of the thigh in 5° increments using a goniometer.

For the heel-buttock distance (HBD), the athlete was placed in the prone position. One physiotherapist grasped the distal lower leg and flexed the knee passively, stopping the flexion on encountering resistance. At this position, the other physiotherapist applied a scale vertically from the heel to the buttock and measured the distance between the two points.

2.3.4. Jump Height Measurements

We used Opto Jump Next (Microgate co., Bozen, Italy) to measure two jump motions: the counter-movement jump (CMJ) and squat jump (SJ). The reliability of the jump height measurement with this device has been previously established [20].

For the CMJ, we instructed the participants to stand upright with their hands on their hips, bend their knees, and jump straight up. For the SJ, we instructed them to follow the same steps, except that they had to stand still for a moment after bending the knees and before jumping up. We asked them not to use rebounding motions, such as swinging their head or squatting down further, after standing still.

The participants performed maximal-effort CMJs and SJs three times. We recorded the highest jump heights of the three trials (we did not consider the average peak value of the three trials).

2.4. Internet Questionnaire

As an additional survey, from September 2020 to October 2020, we sent an internet questionnaire to the coaches of the teams to which the athletes belonged. The questionnaire was administered using Google Forms. A questionnaire survey was conducted from the coaches who gave an explanation of the study on a Google form and gave their consent. The content of the questionnaire was as follows: (1) the start date of team practice suspension; (2) the end date of team practice suspension; (3) team practice time per day on weekdays and holidays in August 2019; (4) team practice time per day on weekdays and holidays immediately after suspension of practice; (5) team practice time per day on weekdays and holidays in August 2020; and (6) points to remember when practicing after the suspension (free description). The number of days of suspension was calculated from the answers to questions (1) and (2).

2.5. Statistical Data Analysis

All statistical analyses were performed using R v2.8.1 for Windows (R Foundation for Statistical Computing, Vienna, Austria). Each parameter is presented as the mean \pm standard deviation (SDs). All data were tested for normality using the Shapiro–Wilk normality test. Physical fitness data were compared between the 2019 and 2020 groups using Welch’s *t*-test or Mann–Whitney U test. *p*-values < 0.05 were considered significant. We compared the practice times in August 2019, immediately after the suspension, and in August 2020 according to the internet questionnaire using a one-way analysis of variance or the Kruskal–Wallis rank-sum test. We carried out post hoc tests, Tukey–Kramer test, or Steel–Dwass test if the above analyses were significant.

3. Results

3.1. Physical Fitness Data

The muscle strength during isokinetic knee flexion and extension was significantly lower in the 2020 group than in the 2019 group. In contrast, there was no significant difference in the body type and composition, flexibility data, jump parameter data, and grip power (Table 2) between the two groups.

Table 2. Comparison of the physical fitness data between 2019 group and 2020 group.

		2019	2020	<i>p</i> Value
Body type composition	Height (cm)	160.8 \pm 10.2 (161.6)	162.5 \pm 7.7 (163.1)	0.40
	weight (kg)	51.4 \pm 13.3 (58.5)	55.4 \pm 12.6 (59.7)	0.12
	body fat amount (kg)	8.7 \pm 5.2 (7.5)	10.4 \pm 6.6 (8.3)	0.32
	lean body weight (kg)	42.9 \pm 9.6 (41.3)	44.9 \pm 8.5 (44.6)	0.28
	muscle mass (kg)	40.3 \pm 9.2 (39.0)	42.4 \pm 8.1 (42.2)	0.30
Muscle strength	Rt KEM (Nm/Kg)	223.4 \pm 42.7 (221.4)	197.2 \pm 34.7 (221)	<0.01 *
	Lt KEM (Nm/Kg)	218.7 \pm 41.5 (219.7)	193.1 \pm 34.3 (192.6)	<0.01 *
	Rt KFM (Nm/Kg)	110.4 \pm 24.5 (111.2)	98.7 \pm 26.5 (99.8)	0.04 *
	Lr KFM (Nm/Kg)	107.1 \pm 25.7 (105.2)	93 \pm 25.4 (94.8)	0.02 *
	Rt GP (kg)	31.2 \pm 8.8 (29.7)	30 \pm 7.7 (28.6)	0.51
	Lt GP (kg)	26.6 \pm 7.1 (26.7)	27.1 \pm 5.6 (26.8)	0.82
Flexibility	Rt SLR (degree)	55.4 \pm 8.7 (55.0)	54.4 \pm 10.4 (51.0)	0.53
	Lt SLR (degree)	55 \pm 9.1 (55.0)	51.1 \pm 10.5 (50.0)	0.21
	Rt HBD (cm)	7.1 \pm 5.1 (8.0)	5.9 \pm 4.7 (5.7)	0.25
	Lt HBD (cm)	7.3 \pm 5.4 (8.0)	5.4 \pm 4.1 (5.0)	0.12
Jump	SJ (cm)	24.4 \pm 6.5 (23.9)	24.4 \pm 5.4 (24.5)	0.96
	CMJ (cm)	26.6 \pm 7.1 (26.7)	27.1 \pm 5.6 (26.8)	0.82

Each parameter is shown as mean \pm standard deviation (median). * *p* < 0.05 . Abbreviations: KEM, knee extension muscle; KFM, knee flexion muscle; GP, grip power; SLR, straight leg raise; HBD, heel-buttock distance; SJ, squat jump; CMJ, counter movement jump; Rt, right; and Lt, left.

3.2. Internet Questionnaire

The 10 coaches of all the participants’ teams responded to our survey with a 100% response rate. The average duration of suspension of practice was 82.5 days and varied widely from a maximum of 168 days to a minimum of 14 days, depending on the team. The coaches guided the training as per the new social distancing guidelines and the athletes’ decreased physical fitness following the period of inactivity (Table 3). There was no significant difference in the practice duration between August 2019, immediately after the suspension period, and in August 2020 (Table 4).

Table 3. Results of the internet questionnaire for coaches.

Responses	10 Coaches 3 (Table Tennis), 2 (Rugby, Kendo), 1 (Hockey, Handball)
Suspension periods (days)	Mean (SD) 82.5 (44.6) Maximum 168 (24 February to 10 August) Minimum 14 (1 April to 15 April)
Cautionary points after resuming practice Adjusting to the “New Normal”	Practice with mask-wearing Ventilation Body temperature and symptom check Use hand sanitizer Avoiding the Three Cs
Consideration for physical weakness	Stepwise load increase Guideline released by national federation

Table 4. Comparison of team practice time.

	2019.8	Immediately after Suspension	2020.8	<i>p</i> Value
Weekday (hour)	1.8 ± 1.0 (2.0)	1.3 ± 0.8 (1.3)	1.5 ± 0.8 (2.0)	0.33
Holyday (hour)	3.4 ± 2.4 (3.0)	2.5 ± 2.2 (2.3)	3.1 ± 2.4 (3.0)	0.68

Each parameter is shown as mean ± standard deviation (median).

4. Discussion

In this study, lower-limb muscle strength was significantly lower in the 2020 group than in the 2019 group. In contrast, there were no differences between the two groups regarding height, weight, body composition, flexibility, upper-limb muscle strength, and jumping ability, which indicate the performance of total body movement. To date, the influence of COVID-19-related sports disruptions on fitness has been reported only in elite adult athletes [13,21]. To the best of our knowledge, the current study is the first one to be conducted on adolescent athletes. The link between social isolation and lower physical activity levels and physical fitness in children was identified decades ago [22], and now, the COVID-19 lockdown has been observed to reduce exercise time by 20–30 h per week among children and adolescents [23]. A survey by Japan Sports Agency reported a decrease in children’s physical fitness test scores when a comparison was made between pre- and post-pandemic periods [24]. Although our study participants were athletes with a regular exercise routine, it was assumed that the muscle weakness in the lower limbs was also triggered by the decrease in physical activity associated with the COVID-19 pandemic.

The influence of decreased training on muscle strength in adolescent athletes is controversial. Adolescents can maintain their grip strength even after 4 weeks of not training [25]; however, not training for 5 weeks is known to cause muscle weakness in the lower limbs [26]. In our study, grip strength (which indicates upper-limb strength) was not different between the 2019 and 2020 groups; nevertheless, we observed a significant difference in the athletes’ ability to perform knee flexion and extension (which indicates lower-limb strength) between the groups. The participants’ training was suspended for approximately 12 weeks, during which they spent most of their time at home due to school closure, refrained from going out, and generally engaged in more sedentary lifestyles, which may have significantly impacted their lower-limb strength. In contrast, we did not find any between-group differences in muscle mass when evaluating the body composition. Moreover, apart from muscle mass, the neuromuscular function is known to contribute to muscle strength [27]. Little or no hypertrophy has been observed after various forms of training in adolescents [28]. Therefore, the training-induced enhancement in maximal strength has been attributed solely to neuromuscular adaptations [29–31]. Thus, a decline in the neuromuscular function (and not muscle atrophy) due to a decreased muscular activity may have contributed to the deterioration of the participants’ muscle strength.

Our results also demonstrated that the knee muscle strength per body weight had deteriorated, even though there were no between-group differences in body weight and jump height, which constitute an index of the total body movement. In this study, the individuals' capacity to generate strength during knee isokinetic dynamometry assessments correlated with their jump performance [31]. Since jump height is related to muscle morphology [32] and the muscle-tendon complex [33], the suspension of practice likely had little influence on these two factors. The knee muscle strength correlated with the knee flexion angle at landing [34], which indicates that the mechanical stress on the joints while landing after the jump remained comparable between the two groups; however, the lower limbs muscle strength, which serves as a shock absorber, had deteriorated. This condition may put adolescents at an increased risk of lower-extremity injuries. A previous study had reported an increased risk of sports injuries after the pandemic in adults [35] and young athletes [36].

The internet-based questionnaire completed by the adolescent athletes' coaches revealed that there were no differences in the practice time before and after suspension, infection prevention methods were followed during training, and the intensity of exercise gradually increased. Despite the lower muscle strength and a potential higher risk of injury for the adolescents resuming sports after suspension, the practice time of the 2020 group remained similar to that of the 2019 group. When adolescent athletes resume training after an unexpected and forced suspension of practice, even those whose basic abilities are unlikely to decrease should undergo basic strength training to compensate for their interim decline in physical function before moving on to specialized training. This is the recommended protocol for return to play after COVID-19-associated lockdown in various sports and athletes [37–41]. Our study findings are a confirmation of that protocol. Furthermore, the physical fitness level of different adolescent athletes within a team may vary depending on their activity during the suspended period and their growth stage [42,43]; therefore, we recommend that all athletes should receive training only after undergoing an individualized check-up. In addition, the COVID-19-related suspension of sports activities associated in adolescent athletes lead to increased mental health symptoms [44]. It is necessary to pay attention to the mental health as well as the physical health.

This study has some limitations. First, there was no data regarding the participants' neuromuscular function. Although there was no difference in our participants' muscle mass, the knee muscle strength was lower in the 2020 group; we assumed that this was due to problems with neuromuscular function. However, we do not have clear evidence of this phenomenon. The effect of unexpected, forced suspension on the neuromuscular function should be investigated in the future. Second, this was a single-center study. Body size and growth differ significantly and individually during adolescence; therefore, a larger number of participants of different ages, sexes, and communities are required to obtain generalizable reference values. Furthermore, this study is a cross-sectional study of different individuals. The results of this study could be further strengthened by conducting a longitudinal study on the same individuals. However, we believe that our sample participants were appropriate for this analysis because their physiques and sport-playing levels were similar, indicating that our results are consistent and can provide insights on this particular target group.

5. Conclusions

COVID-19-related training interruptions did not change the athletes' jump height, upper-limbs strength, and flexibility, but negatively impacted their lower-limb muscle strength. We recommend that basic strength training protocols be followed to prevent sports-related injuries after such unexpected practice interruptions. Our findings will provide coaches and sports institutes with relevant information to develop proper schedules for their athletes before they resume playing.

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