

# Performance analysis in top handball matches in the seasons before, during, and after the COVID-19 pandemic

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**Abstract.** The aim of the study was to determine whether there are differences in performance analysis in handball between Pre-COVID-19, during COVID-19, and Post-COVID-19 seasons. The study material was obtained from the official match statistics of PGNiG Super league Ltd. Matches were played in the 2019/2020 season before COVID-19, 2020/2021 during COVID-19, and 2021/2022 Post-COVID-19. The Mann-Whitney U test was used for comparisons between two groups, for three groups using the Kruskal-Wallis test. In Pre-COVID-19 season, players made an average of 1.3 more 9 meter throws the Post-COVID-19. Post-COVID-19 season is characterized by a higher 6 meter goals and 6 meter throw count with respect to the Pre-COVID-19. The results show a higher goalkeeper 7 meter throw effectiveness in Pre-COVID-19 season than in COVID-19. The increasing number of throws and goals from the 6th meter along with a decrease in the number of throws from the 9th meter indicates the latest trends in handball. A reduction in the number of offensive fouls and an increase in the number of fast attacks and the effectiveness of goalkeepers' interventions from 7 meters in the second round of the COVID-19 season indicates the adaptation of players to the new conditions created by the pandemic.

Keywords: Man, statistic, tactic, round, actions

## 1. Introduction

The literature indicates that during home activity during the COVID-19 pandemic in a group of basketball players, RPE levels, number of days (professional players maintained their training days) and hours of training decreased, and they experienced a decrease in sleep quality (Lorenzo Calvo et al., 2021). Similar effects were observed in handball players as well (Hermassi et al., 2021; Mon-López et al., 2020).

Previous studies involving physiological measurements among handball players after a period of home

training (strength and endurance) indicate a decrease in endurance capacity, however, VO<sub>2</sub>max and power levels remained unchanged (Fikenzer et al., 2021), or increased by 5.9% after 70–95% HR training (Paludo et al., 2022). After the period of home training, an increase in HR during the shuttle run test in zones 5, 6, and 7 was observed, along with elevated lactic acid LA levels (Font et al., 2021). Studies have also highlighted lower VO<sub>2</sub>max, cardiac stroke volume, and maximum power levels among SARS-CoV-2-infected athletes compared to uninfected ones, particularly among handball players (Lässing et al., 2022). Similar findings of decreased VO<sub>2</sub>max and HR were noted in endurance athletes as well (Śliż et al., 2022). A decrease in equilibrium performance was also shown in handball players undergoing COVID-19, while no such decrease

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occurred in players without infection (Jaszczur-Nowicki et al., 2022). The demonstrated reduction in selected physiological values associated with training during lockdown is cognitively valuable given the nature of exertion during a handball match (García-Sánchez et al., 2023). The disruption of the training process associated with the COVID-19 pandemic has created a rationale for undertaking targeted training modifications aimed at optimizing training following lockdown periods. In soccer, the main emphasis of such training has been on aerobic training, resistance training, speed and explosive strength training, flexibility, prevention of muscle injuries, prevention of tender injuries, and neuromuscular prevention (Bisciotti et al., 2020).

Studies related to COVID-19 among athletes have also focused on psychological factors. Higher levels of fatigue, friendship, emotional appraisal of others, and resilience were found in basketball players, relative to basketball players, and players' mental states were predictors of differences in variables related to training and recovery (Lorenzo Calvo et al., 2021). Among handball players, psychological factors (mood, emotional intelligence, and resilience) influenced rated training parameters during home workouts (Mon-López et al., 2020). Analyses related to psychological factors during the COVID-19 pandemic in a group of soccer, ice hockey, and handball players at the highest level of competition in Sweden indicate several changes. Deterioration in well-being proved to be a common phenomenon. It was also shown that the players met the criteria for depression (19% female, 3% male) and anxiety (20% female, 5% male). In the male group (10%), gambling tendencies (moderate risk and problem gambling) were additionally observed. Distress associated with the COVID-19 pandemic was common among elite athletes (Håkansson et al., 2020).

Previous research related to quantitative and qualitative analysis in team games has focused on finding differences between games played during the COVID-19 pandemic and other seasons. The seasons played during COVID-19 were characterized by a unique organization, in which games were played without fans (empty arenas and stadiums). This created natural conditions for the study of the Home Advantage (HA) phenomenon, which is related to fan (supporter) participation, and minimizing the impact of travel during away matches (especially across time zones) (Bustamante-Sánchez et al., 2022; McHill and Chinoy, 2020). Fan attendance at home matches was

considered a significant contributor to HA, although disparities among fans, players, activists, and referees' perceptions existed (Gershgoren et al., 2022). Interestingly, basketball and ice hockey exhibited higher HA and Home Win Percentage (HW%) before the pandemic compared to during it (Alonso et al., 2022; Higgs and Stavness, 2021; Paulauskas et al., 2022). Statistical comparisons of performance analysis in basketball (NBA) indicate an increase in the efficiency of free throws and field goals during COVID-19 and the highest differences are in free throw accuracy (Markwell et al., 2022). In basketball (Euroleague), differences were shown in the number and efficiency of free throws, number of interceptions, the efficiency of three-point attempts, fouls, points, and ball possession during the seasons before and during the pandemic (Paulauskas et al., 2022).

The advantage in home games (HA) is indicated by soccer studies, in which higher scores occur in matches with fans than with empty stands, which translates into more home defeats than wins (Link and Anzer, 2022; Tilp and Thaller, 2020). The literature also indicates that during games in empty stadiums, players showed increased high-intensity running activity and total distance runs. Contact with the opponent (distance < 2 m) decreased by 11.2% (Link and Anzer, 2022). The absence of fans in matches played in their own stadium resulted in fewer shots and target shots (Wunderlich et al., 2021). A decrease in the punishment of away teams by referees in the context of the number of fouls, and yellow and red cards were also observed (Link and Anzer, 2022; Wunderlich et al., 2021). According to the authors, the differences shown may be because home teams lack social support from the home crowd (Link and Anzer, 2022; Tilp and Thaller, 2020).

The presented review of research related to the occurrence of the pandemic COVID-19 indicates the changes that occurred in the training process (volume, content, methods), physiological and psychological indicators, as well as quantitative, and qualitative analysis of sports combat in team games. All the presented aspects can be translated into the actions of handball players during matches during the start season during the COVID-19 pandemic and related restrictions. The reviewed literature related to COVID-19 indicates a substantive need for research on performance analysis in handball at a high sport level.

The aim of the study was to determine whether there are differences in performance analysis in hand-

ball at a high sport level between Pre-COVID-19, during COVID-19, and Post-COVID-19 seasons.

For the presented research objective, hypotheses were set:

$H_0$ : There are no differences in performance analysis in handball matches between Pre-COVID-19, COVID-19, and Post-COVID-19 seasons.

$H_1$ : There are differences in performance analysis in handball matches between Pre-COVID-19, COVID-19, and Post-COVID-19 seasons.

## 2. Material and methods

### 2.1. Material

The study material was obtained from the official match statistics of PGNiG Superleague Ltd. which is responsible for organizing the top-level games in Poland. The data was collected from the official website of PGNiG Superleague Ltd. [https://statystyki.pgnig-superliga.pl/pl/handball/pgnig-superliga,2042/45960/matches/all?round\\_id=1](https://statystyki.pgnig-superliga.pl/pl/handball/pgnig-superliga,2042/45960/matches/all?round_id=1) (accessed November 7, 2022). Written permission to use statistical reports of the matches played was obtained from the owner PGNiG Superleague Ltd. The variables included in Table 1 were recorded, as well as the number of goals in each period of the match (0–10 min., 11–20 min., 21–30 min., 31–40 min., 41–50 min., 51–60 min.).

### 2.2. Procedures

493 matches of men's handball at the highest level of competition in Poland (14 teams) were analyzed. The material was collected for each team. The study included matches played in the 2019/2020 sports season ( $n=156$ ) before the COVID-19 pandemic (Pre-COVID-19), 2020/2021 ( $n=163$ ) during the COVID-19 pandemic (COVID-19), and in the 2021/2022 season ( $n=174$ ) (Post COVID-19). Matches that ended in a regulation game time (60 minutes) were included in the analysis. Matches that ended in a draw in regulation time were not included (in the Polish competition system, matches ending in a draw are subject to overtime in the form of penalty kicks).

The 2019/2020 (Pre-COVID-19) season began on August 30, 2019, and ended on March 11, 2020.

Table 1  
Used abbreviations and variable names

GSc	Numbers of goals scored
GDef	Number of goals defeated
7mG	Number of 7 m goals
7mTh	Number of 7 m throws
Th	Number of all throws
AccTh	Number of accurate throws
MissTh	Number of missed throws
9mG	Number of 9 m goals
9mTh	Number of 9 m throws
6mG	Number of 6 m goals
6mTh	Number of 6 m throws
FB	Number of fast breaks
FBG	Number of fast break goals
Fouls	Number of fouls
OffFouls	Number of offensive fouls
2 min	Number of 2 min suspensions
RC	Number of red cards
Th%	All throw efficiency [%]
7m%	7 m throw efficiency [%]
9m%	9 m throw efficiency [%]
6m%	6 m throw efficiency [%]
GK%	Goal keeper efficiency [%]
GK7m%	7 m goalkeeper efficiency [%]

88 first-round matches and 68 second-round matches were analyzed in a given season. During the playing season, there were no sanitary restrictions related to the COVID-19 pandemic, as well as no restrictions related to limits on the number of spectators in the stands.

The 2020/2021 season began on September 5, 2020, and ended on June 6, 2021. In the indicated season, 81 games in the first round and 82 games in the second round of play were analyzed. The games were held under a sanitary regime related to the COVID-19 pandemic, with players undergoing medical tests for COVID-19. Between September 5 and October 25, by national law, the stands could be filled to 25% capacity during matches. During this period, fans were required to adhere to sanitary regulations, including wearing protective masks, hand disinfection, and social distancing as mandated by state regulations. Starting from October 26 until the end of the season, games were held without public spectators.

The 2021/2022 season began on September 3, 2021, and ended on May 24, 2022. In a given season, 82 matches played in the first round and 92 in the second round of play were included in the analysis. During the playing season, there were no sanitary restrictions related to the COVID-19 pandemic, as well as no restrictions related to limits on the number of spectators in the stands.

The collected study material was subjected to statistical analyses taking into account the

Table 2  
General statistics of the three seasons

Variables	1	2	3	Differences
	Pre-COVID-19 M (SD)	COVID-19 M (SD)	Post-COVID-19 M (SD)	
GSc	27.46 (5.65)	27.57 (5.25)	27.88 (5.38)	ns
GDef	27.46 (5.65)	27.57 (5.25)	27.88 (5.38)	ns
7mG	2.81 (1.67)	2.94 (1.77)	2.75 (1.5)	ns
7mTh	3.97 (2.05)	3.98 (2.04)	3.71 (1.79)	ns
Th	46.21 (5.19)	45.63 (5.27)	45.71 (5.14)	ns
AccTh	38.81 (5.31)	38.43 (5.25)	38.96 (5.26)	ns
MissTh	7.39 (3.15)	7.26 (3)	6.75 (3.08)	K-W H(2, N=986)=7.98; $p=.0185$ ; $\eta^2=.006$ ; $1 > 3^*$
9mG	5.49 (2.56)	5.42 (2.65)	5.06 (2.48)	ns
9mTh	12.81 (4.54)	12.22 (4.35)	11.51 (4.39)	K-W H(2, N=986)=15.01; $p=.0006$ ; $\eta^2=.013$ ; $1 > 3^{***}$
6mG	19.17 (5.68)	19.22 (5.06)	20.07 (5.03)	K-W H(2, N=986)=9.37; $p=.0092$ ; $\eta^2=.007$ ; $3 > 1^*$
6mTh	29.36 (6.21)	29.38 (5.52)	30.43 (5.44)	K-W H(2, N=986)=8.34; $p=.0155$ ; $\eta^2=.006$ ; $3 > 1^*$
FB	4.98 (3.40)	4.46 (3.01)	4.65 (3.04)	ns
FBG	3.56 (2.84)	3.28 (2.59)	3.56 (2.55)	ns
Fouls	26.86 (7.80)	27.26 (7.08)	26.52 (6.91)	ns
OffFouls	2.33 (1.65)	2.28 (1.62)	2.05 (1.64)	ns
2 min	4.29 (2.04)	4.68 (1.90)	4.33 (1.76)	ns
RC	0.24 (0.47)	0.29 (0.55)	0.19 (0.41)	ns
Th%	59.36 (9.53)	60.41 (9.16)	60.94 (9.23)	ns
7m%	71.82 (25.57)	73.81 (24.06)	75.53 (25.41)	ns
9m%	43.3 (16.6)	44.19 (15.13)	44.68 (17.76)	ns
6m%	64.96 (11.16)	65.22 (10.22)	65.70 (9.81)	ns
GK%	29.50 (8.86)	28.45 (8.65)	28.78 (8.74)	ns
GK7m%	22.66 (25.01)	16.27 (21.05)	19.02 (24.86)	K-W H(2, N=962)=10.18; $p=.0062$ ; $\eta^2=.009$ ; $1 > 2^*$

Legend: K-W: Kruskal-Wallis test; \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ ; ns: no significant.

Pre-COVID-19, COVID-19, and Post-COVID-19 playing seasons. The statistical procedure carried out also took into account the round of the playing season (first, second), in each of the analyzed seasons.

### 2.3. Statistical analysis

The collected material was subjected to statistical analysis. Normality of distribution was determined using the Shapiro-Wilk test, and homogeneity of variance using the Levene test. Since the assumptions of normality of distribution and homogeneity of variance were not met, non-parametric tests were used for intergroup comparisons. The Mann-Whitney U test was used for comparisons between two independent groups. Comparisons between three independent groups were made using the Kruskal-Wallis test. The level of statistical significance was taken as  $p < 0.05$ . The eta-square ( $\eta^2$ ) was used to determine the effect size [ES] (<0.01-no effect, 0.01–0.059-small effect, 0.06–0.139-intermediate effect, >0.14-large effect) (Cohen, 1988). All statistical analyses were performed using TIBCO Statistica 13.3 and Microsoft Office Excel software for Microsoft 365 version 2308.

### 3. Results

The results of the statistical analyses for comparing the collected material in the context of the playing season are presented in Table 2.

The results presented show that in the Pre-COVID-19 season, the players made more MissTh than in the Post-COVID-19 season ( $p=.0185$ ;  $\eta^2=.006$ ), however, the value of  $\eta^2$  indicates that there was no effect. It was shown that in the Pre-COVID-19 season, players made an average of 1.3 more 9mTh throws than in the Post-COVID-19 season ( $p=.006$ ;  $\eta^2=.013$ ), and the effect size is small. Statistical analysis indicates that the Post-COVID-19 season is characterized by a higher 6mG ( $p=.0092$ ;  $\eta^2=.007$ ) and 6mTh ( $p=.0155$ ;  $\eta^2=.006$ ) count with respect to the Pre-COVID-19 season. However, the effect size results indicate a lack of effect. The results show a higher GK7m% in the Pre-COVID-19 season than in the COVID-19 season ( $p=.0062$ ;  $\eta^2=.009$ ). The difference is 6.39%, however, the  $\eta^2$  value indicates no effect.

The obtained results of the statistical analyses for comparisons of the collected study material between the sports seasons included in the study by a round of

Table 3a  
Handball statistics in first and second round of the seasons

Variables	Round	1	2	3	Differences
		Pre-COVID-19 M (SD)	COVID-19 M (SD)	Post-COVID-19 M (SD)	
<b>GSc</b>	<b>First</b>	27.35 (5.48)	27.53 (5.34)	27.66 (5.1)	ns
	<b>Second</b>	27.61 (5.88)	27.61 (5.19)	28.1 (5.64)	ns
<b>GDef</b>	<b>First</b>	27.35 (5.48)	27.53 (5.34)	27.66 (5.1)	ns
	<b>Second</b>	27.61 (5.88)	27.61 (5.19)	28.10 (5.64)	ns
<b>7mG</b>	<b>First</b>	2.8 (1.67)	2.93 (1.81)	<b>2.93 (1.52)</b>	ns
	<b>Second</b>	2.82 (1.68)	2.94 (1.73)	<b>2.57 (1.47)</b>	ns
<b>7mTh</b>	<b>First</b>	4.04 (2.07)	3.98 (2.11)	<b>3.98 (1.77)</b>	ns
	<b>Second</b>	3.88 (2.03)	3.98 (1.99)	<b>3.45 (1.78)</b>	K-W H(2, N=484)=7.81; p=.0201; $\eta^2 = .012$ ; 2 > 3*
<b>Th</b>	<b>First</b>	46.16 (4.98)	45.37 (5.22)	45.86 (5.07)	ns
	<b>Second</b>	46.27 (5.46)	45.85 (5.32)	45.57 (5.21)	ns
<b>AccTh</b>	<b>First</b>	38.8 (5.05)	38.24 (5.18)	39.04 (5.14)	ns
	<b>Second</b>	38.84 (5.65)	38.59 (5.32)	38.88 (5.38)	ns
<b>MissTh</b>	<b>First</b>	7.36 (2.9)	7.13 (3.07)	6.81 (3.06)	ns
	<b>Second</b>	7.43 (3.46)	7.37 (2.94)	6.68 (3.11)	ns
<b>9mG</b>	<b>First</b>	5.39 (2.61)	5.42 (2.75)	5.19 (2.4)	ns
	<b>Second</b>	5.61 (2.51)	5.42 (2.57)	4.93 (2.57)	K-W H(2, N=484)=6.41; p=.0406; $\eta^2 = .009$ ; 1 > 3*
<b>9mTh</b>	<b>First</b>	12.42 (4.32)	12.33 (4.25)	11.75 (4.21)	ns
	<b>Second</b>	13.31 (4.78)	12.11 (4.44)	11.28 (4.56)	K-W H(2, N=484)=15.61; p=.0004; $\eta^2 = .028$ ; 1 > 3***
<b>6mG</b>	<b>First</b>	19.16 (5.47)	19.18 (4.81)	19.54 (4.85)	ns
	<b>Second</b>	19.18 (5.97)	19.26 (5.28)	20.59 (5.16)	K-W H(2, N=484)=8.99; p=.0112; $\eta^2 = .015$ ; 3 > 1*
<b>6mTh</b>	<b>First</b>	29.59 (6.18)	29.01 (5.29)	30.06 (5.14)	ns
	<b>Second</b>	29.06 (6.27)	29.71 (5.71)	30.79 (5.71)	K-W H(2, N=484)=8.81; p=.0122; $\eta^2 = .014$ ; 3 > 1*
<b>FB</b>	<b>First</b>	<b>5.49 (3.51)</b>	<b>4.11 (2.86)</b>	4.57 (3.16)	K-W H(2, N=502)=15.11; p=.0005; $\eta^2 = .026$ ; 1 > 2***, 3*
	<b>Second</b>	<b>4.33 (3.15)</b>	<b>4.77 (3.12)</b>	4.73 (2.93)	ns
<b>FBG</b>	<b>First</b>	<b>3.82 (2.89)</b>	3.05 (2.5)	3.49 (2.56)	K-W H(2, N=502)=7.28; p=.0262; $\eta^2 = .011$ ; 1 > 2*
	<b>Second</b>	<b>3.23 (2.76)</b>	3.49 (2.67)	3.62 (2.54)	ns

Legend: K-W: Kruskal-Wallis test; **bold**: differences between first and second round \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ ; ns: no significant

play are presented in Tables 3a and 3b. In addition, an analysis was carried out between the first and second rounds of each season.

Analysis of the data in Table 3a indicates that in round two, the COVID-19 season performed significantly more 7mTh than in the Post-COVID-19 season ( $p = .0201$ ;  $\eta^2 = .012$ ), however, the effect size is small. In round two of the Pre-COVID-19 season, players scored significantly more 9mG than in the Post-COVID-19 season ( $p = .0406$ ;  $\eta^2 = .009$ ), however, the effect size indicates it is small. The same situation occurs in the overall number of 9mTh ( $p = .0004$ ;  $\eta^2 = .028$ ), however, the effect size is small. The results indicate that the number of 6mG ( $p = .0112$ ;  $\eta^2 = .015$ ) and 6mTh ( $p = .0122$ ;  $\eta^2 = .014$ ) in round two is higher in the Post-COVID-19 season than in the Pre-COVID-19 season and the effect size is small. Analysis of the data showed that teams performed a higher number of FBs in the first

round of the Pre-COVID-19 season than in the other seasons ( $p = .0005$ ;  $\eta^2 = .026$ ). The number of FBs in the first round is higher in the Pre-COVID-19 season than in the COVID-19 season ( $p = .0262$ ;  $\eta^2 = .011$ ). The effect size of the significant differences shown is small.

Analysis of differences between rounds of the Pre-COVID-19 season indicates that teams had higher FG (U M-W  $Z = 3.12$ ;  $p = .001814$ ;  $\eta^2 = .031$ ) and FBG (U M-W  $Z = 2.09$ ;  $p = .036614$ ;  $\eta^2 = .014$ ). The effect size of the differences shown is small. The opposite is true in the COVID-19 season, where FB numbers are higher in the second round (U M-W  $Z = -2.00$ ;  $p = .045083$   $\eta^2 = .011$ ) and effect size is small. Post-COVID-19, round one showed higher abundance of 7mG (U M-W  $Z = 2.71$ ;  $p = .006769$ ;  $\eta^2 = .022$ ) and 7mTh (U M-W  $Z = 2.16$ ;  $p = .030775$ ;  $\eta^2 = .014$ ). The effect size of the differences shown is small.

Table 3b  
Handball statistics in first and second round of the seasons

Variables	Round	1	2	3	Differences
		Pre-COVID-19 M (SD)	COVID-19 M (SD)	Post-COVID-19 M (SD)	
<b>Fouls</b>	<b>First</b>	26.67 (7.87)	27.52 (7.13)	<b>27.56 (7.13)</b>	ns
	<b>Second</b>	27.11 (7.74)	27.02 (7.04)	<b>25.5 (6.56)</b>	ns
OffFouls	<b>First</b>	2.21 (1.63)	<b>2.5 (1.7)</b>	2.02 (1.63)	K-W H(2, N=502)=7.3; $p=.026$ , $\eta^2=.011$ ; $2 > 3^*$
	<b>Second</b>	2.49 (1.66)	<b>2.08 (1.54)</b>	2.07 (1.66)	ns
<b>2 min</b>	<b>First</b>	4,4 (2)	4.84 (2.03)	<b>4.66 (1.76)</b>	ns
	<b>Second</b>	4.14 (2.08)	4.54 (1.78)	<b>4.01 (1.7)</b>	K-W H(2, N=484) = 7.11; $p=.0286$ , $\eta^2=.011$ ; $2 > 3^*$
<b>RC</b>	<b>First</b>	0.22 (0.48)	0.29 (0.58)	0.23 (0.44)	ns
	<b>Second</b>	0.26 (0.46)	0.29 (0.52)	0.16 (0.38)	ns
<b>Th%</b>	<b>First</b>	59.22 (9.56)	60.65 (9.24)	60.32 (9.03)	ns
	<b>Second</b>	59.54 (9.51)	60.19 (9.12)	61.56 (9.41)	ns
<b>7m%</b>	<b>First</b>	70.54 (26.15)	73.72 (25.23)	74.43 (25.45)	ns
	<b>Second</b>	73.5 (24.79)	73.89 (23.04)	76.65 (25.41)	ns
<b>9m%</b>	<b>First</b>	43.67 (16.06)	43.37 (15.22)	45.04 (17.72)	ns
	<b>Second</b>	42.82 (15.02)	44.92 (15.05)	44.33 (17.84)	ns
<b>6m%</b>	<b>First</b>	64.56 (11.43)	66.12 (10.35)	64.69 (10.17)	ns
	<b>Second</b>	65.49 (10.81)	64.41 (10.05)	66.7 (9.37)	ns
<b>GK%</b>	<b>First</b>	29.72 (8.94)	28.30 (8.94)	29.49 (8.86)	ns
	<b>Second</b>	29.21 (8.29)	28.59 (8.41)	28.07 (8.59)	ns
<b>GK7m%</b>	<b>First</b>	23.59 (26.21)	<b>11.83 (17.98)</b>	18.33 (24.1)	K-W H(2, N=494)=18.33; $p=.0001$ , $\eta^2=.033$ ; $1 > 2^{***}$
	<b>Second</b>	21.44 (23.38)	<b>20.24 (22.78)</b>	19.73 (25.69)	ns

Legend: K-W: Kruskal-Wallis test; **bold**: differences between first and second round; \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ ; ns: no significant

The results in Table 3b showed a significantly higher number of OffFouls in round one of the COVID-19 season compared to Post-COVID-19 ( $p=.026$ ;  $\eta^2=.011$ ). The effect size of these differences is small. The analysis showed that the COVID-19 season recorded a significantly higher number of 2 min in the second round than in the Post-COVID-19 season ( $p=.0286$ ;  $\eta^2=.011$ ), however, the effect size is small. The GK7m% in the first round of the Pre-COVID-19 season is significantly higher than in the COVID-19 season ( $p=.0001$ ;  $\eta^2=.033$ ), and the effect size is small.

Comparisons of statistics in the first and second rounds of play in the COVID-19 season indicate a higher number of OffFouls in the first round with respect to the second round (U M-W  $Z=2.26$ ;  $p=.021103$ ;  $\eta^2=.015$ ) effect size is small. The second difference in the season in question is in GK7m%, where significantly higher rates occur in the second round (U M-W  $Z=-3.479$ ;  $p=.000195$   $\eta^2=.036$ ) effect size is small. Post-COVID-19 shows significantly higher values between rounds played involving Fouls (U M-W  $Z=2.68$ ;  $p=.007323$ ;  $\eta^2=.022$ ) and 2 min (U M-W  $Z=3.36$ ;  $p=.000653$ ;  $\eta^2=.035$ ). The effect size of these differences is small.

The results of the study regarding the number of goals scored in each match period with respect to round and season of play are presented in Table 4. It was shown that there were no differences in the recorded parameters between the seasons included in the study. In the 0–10 min match period in the Pre-COVID-19 season, teams scored significantly more goals in the second round than in the first round (U M-W  $Z=-2.00$ ;  $p=.045472$ ;  $\eta^2=.012$ ). Post-COVID-19, during the 21–30 min match period in round two, players scored significantly more goals than in round one (U M-W  $Z=-1.97$ ;  $p=.049067$ ;  $\eta^2=.012$ ). In both cases discussed, the effect size is small. In the other cases, as well as overall (without considering the round of games), no statistically significant differences were found.

#### 4. Discussion

Analyses of the collected survey material indicate significant statistical differences overall (excluding the first and second rounds of the season) between the seasons covered in the five parameters studied (MissTh, 9mTh, 6mG, 6mTh, GK7m%).

Table 4  
Scored goals in match periods in the first and second rounds of the seasons

Period of match [min]	Round	1	2	3
		Pre-COVID-19 M (SD)	COVID-19 M (SD)	Post-COVID-19 M (SD)
<b>0–10</b>	<b>First</b>	<b>4.18 (1.77)</b>	4.26 (1.7)	4.62 (1.83)
	<b>Second</b>	<b>4.54 (1.85)</b>	4.3 (1.75)	4.46 (1.54)
<b>11–20</b>	<b>First</b>	4.52 (1.73)	4.54 (1.72)	4.47 (1.51)
	<b>Second</b>	4.73 (1.67)	4.46 (1.61)	4.6 (1.68)
<b>21–30</b>	<b>First</b>	4.6 (1.85)	4.63 (1.64)	<b>4.49 (1.8)</b>
	<b>Second</b>	4.47 (1.78)	4.57 (1.74)	<b>4.93 (1.76)</b>
<b>31–40</b>	<b>First</b>	4.59 (1.7)	4.54 (1.74)	4.61 (1.61)
	<b>Second</b>	4.5 (1.6)	4.51 (1.58)	4.71 (1.74)
<b>41–50</b>	<b>First</b>	4.42 (1.86)	4.57 (1.71)	4.44 (1.76)
	<b>Second</b>	4.53 (1.74)	4.75 (1.7)	4.6 (1.66)
<b>51–60</b>	<b>First</b>	5.05 (1.74)	5 (1.85)	5.02 (1.87)
	<b>Second</b>	4.85 (1.8)	5 (1.72)	4.8 (1.75)

Legend: **bold**: differences between first and second round.

When discussing the demonstrated differences, they should be considered simultaneously. The numbers of MissTh and 9mTh in the Post-COVID-19 season are lower than in the Pre-COVID-19 season. The reverse is true for 6mG and 6mTh. The demonstrated differences may indicate recent trends of the handball game in which the number of throws from 9 m is decreasing, while the number of throws from 6 m is increasing (Smolarczyk, 2023). A decrease in the number of MissTh and 9mTh while an increase in 6mG and 6mTh may indicate that throws made from farther distances (>9 meters) are characterized by higher technical sophistication, in which precision and throwing power play a key role, while throws made from 6 meters offer greater goal-scoring opportunities (Pueo et al., 2022). This is supported by the results of previous studies indicating that throws from the 6th meter are more effective than those from the 9th (Pueo et al., 2022; Smolarczyk, 2023). Longitudinal studies also indicate a trend toward increased offensive efficiency including throwing (Pascual et al., 2023). Thus, it can be conjectured that the latest handball game is becoming more dynamic and relies on the skills of passing and penetrating the defensive zone to bring about a throw-in from close to the goal, which is more effective (Smolarczyk, 2023). It should be added, however, that despite the statistical significance shown for MissTh, 6mG, and 6mTh, the  $\eta^2$  measure shows no effect, while for 9mTh it is small. It should be added that the same differences were shown for the second round of play, with no differences registered in the first round (Table 3a). This indicates a general trend in handball over recent seasons, which is confirmed by other research results (Smolarczyk, 2023). It should also be added that in

the second round sometimes the importance of the match is greater due to the clarification of the situation and the fight for the championship, medals, and retention in the league. Such a state of affairs can translate into greater commitment and taking action aimed at the result of the final sport. In the official statistics of the PGNiG Superleague Ltd. regarding shots taken and goals scored, it is not recorded from which positions they were taken and from which zones of the court. Previous research results indicate differences in the number and effectiveness of throw-ins in relation to the position and location from which the throw-in is made (Pueo et al., 2022, 2023). Therefore, it should be concluded that the lack of these data is one of the limitations of the results presented in this publication.

The demonstrated differences in the overall aspect showed a significantly lower GK7m% in the COVID-19 season than in the Pre-COVID-19 season. The same difference is found in the first round of play. Several variables may be contributing to this state of affairs. Previous research indicates that playing games without an audience during the COVID-19 season in basketball increases the precision and efficiency of free throws in basketball (Markwell et al., 2022; McHill and Chinoy, 2020; Paulauskas et al., 2022), which may also translate to handball and provide a kind of advantage for the throwing player through the precision of the throw, while making effective defense more difficult for the goalkeeper. For GK7m%, a significant difference was also shown between the first and second rounds, which may indicate that the goalkeepers adapted quickly to the new playing conditions, so there was an increase in effective interventions. A factor affecting the lower values

obtained in this area may also be due to the disruption of the training cycle for goalkeepers and the performance of home training and thus the characteristics of the effort may have changed. The specifics of the game in the goalkeeper's position are particularly focused, in addition to physical preparation, on technique during the actual shots on goal (throwing hand positioning, throwing strength, throwing technique, throwing range, throwing direction, positioning in relation to the thrower and the goal), which is almost impossible under the conditions of home training, which focused mainly on motor (strength and endurance) preparation (Fikenzer et al., 2021; Paludo et al., 2022). A decrease in training intensity and volume should also be pointed out (Hermassi et al., 2021; Mon-López et al., 2020). The results may have been no less influenced by COVID-19 infection in goalkeepers, which may have reduced power output (Lässing et al., 2022), which is one of the most important characteristics of the goalkeeper position.

The results relating to 7mTh in Round 2 of the season indicate a higher number in COVID-19 than in Post-COVID-19. The same results were obtained in the 2 min variable, which can be considered related results, which may be due to the characteristics of sports combat in handball. In many situations, exceeding the allowed defensive play is punished by a throw-in from 7 m and exclusion of the player for 2 min. This condition may be influenced by the COVID-19 pandemic period, in terms of limited defensive training, which is a collective activity and requires the involvement of all players. Effective defensive play requires proper interaction and the need for home training may have translated into an inability to improve defensive tactics. From a physiological point of view, after the training sessions held at home, the level of endurance capacity decreased (Fikenzer et al., 2021), and there was an increase in HR in the shuttle run test in zones 5, 6, 7, and an increase in lactate concentration (Font et al., 2021), which may translate into a decrease in the exercise capacity of defensive players and result in delayed interventions, the consequence of which may be fouled for which team and individual penalties are dictated. During the pandemic, matches played with empty stands may have had the effect of reducing referee bias (favoring the home team), as indicated by studies in soccer (Sors et al., 2023; Tilp and Thaller, 2020; Wunderlich et al., 2021), which may explain the results obtained. The differences in the number of OffFouls in the first round between the season during

the pandemic COVID-19 and Post-COVID-19 can be explained by the arguments presented above.

The results obtained indicating differences between the studied seasons in the first round of the season indicate a decrease in the abundance of FB and FBG during COVID-19 and Post-COVID-19 in relation to Pre-COVID-19. The indicated decrease is consistent with previous studies in this area and indicates recent trends in handball (Smolarczyk, 2023). The lower abundance of FBs and FBGs in the COVID-19 season compared to Pre-COVID-19 may be related to several factors. These include the changes that have occurred in the context of home training in both training volume and content (Fikenzer et al., 2021; Hermassi et al., 2021; Mon-López et al., 2020) and physiological parameters (Font et al., 2021; Paludo et al., 2022) with COVID-19 infection (Lässing et al., 2022). The ability to conduct FB is contingent on a high level of technical and tactical defensive operations (Font et al., 2022) and adequate speed and endurance preparation, as indicated by previous research results (García-Sánchez et al., 2023). The decrease in the present parameters during COVID-19 may be the reason for the differences shown. It should also be pointed out that the abundance of FB and FBG in the first round of the Pre-COVID-19 season is higher than in the second round. Such a condition may indicate technical and tactical changes taking place in the teams, the general fatigue of the players with the ongoing season, as well as the rank and mental attitude to the matches because in the second round comes the main phase of the fight for the highest sporting result, as well as maintenance in the highest competition class. Differences between the number of FBs depending on the round of the COVID-19 season indicate higher values in the second round, which may be due to the adaptation of players and coaching staff to the conditions of the matches both in terms of technical and tactical measures and motor preparation. The same argument can be used to explain the reduction in the number of OffFouls in the second round of the season in question. The results obtained indicate a lower number of 7mG, 7mTh, Fouls, and 2 min in the second round of the post-COVID-19 season are largely related. There may be many reasons for this, so it requires additional research covering this issue. Research should include analysis of training content, level of motor preparation, technical and tactical activities, and values relating to fatigue in a wide range. The same analyses should include the differences in the number of goals scored in each



period of the match according to the Pre-COVID-19 (0–10 min) and Post-COVID-19 (31–30 min) rounds of the season. At the same time, it should be pointed out that the comparison of goals scored according to the period of the match showed no differences between the game seasons included in the study.

In all the statistically significant differences obtained, the effect size values indicate that there is no effect, or that the effect is small. Similar results were obtained in basketball (Paulauskas et al., 2022), which may be indicative of the characteristics of the changes that occurred in the seasons covered by the study. Therefore, it is necessary to look for areas in which large changes occurred (high effect size values) in the context of the seasons before, during, and after the COVID-19 pandemic. The analysis of the literature indicates a substantive need for a study focusing on performance analysis in handball, where the independent variable will be the venue (home, away) to determine whether the absence of fans differentiates the selected actions of players and entire teams.

#### 4.1. Limitations

Only team statistics were analyzed. They lack reference regarding the location and tactical situation of throws in the context of the position and sector of the field. Previous research indicates that these are factors that differentiate the number and effectiveness of throws (Pueo et al., 2022, 2023). A specific limitation of the present study is also the lack of information on the implemented training content, especially during the COVID-19 pandemic. In the context of the COVID-19 season data, information on quarantines of entire teams as well as player infections was not obtained, which could also be reflected in the results (Lässing et al., 2022).

## 5. Conclusions

The increasing number of throws and goals from the 6th meter along with a decrease in the number of throws from the 9th meter indicates the latest trends in handball especially in round two of the sports season. Therefore, it is necessary to review and adjust the training content (technique, tactics, offensive and defensive) in the period before and during the second round of the sports season.

The demonstrated differences between the activities of handball teams during the COVID-19 pandemic and the rest of the season indicate a dis-

ruption of the training process and a reduction in the impact of fans on the course of matches. A reduction in the number of offensive fouls and an increase in the number of quick attacks and the effectiveness of goalkeepers' interventions from 7 meters in the second round of the COVID-19 season indicates the adaptation of players to the new conditions created by the pandemic and its associated restrictions.

The results indicate a substantive need to continue further research related to performance analysis in the context of the venue (home, away) for determining the impact of Home Advantage during the pre, during, and after COVID-19 pandemic seasons.

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## 6. Conflict of interest

The authors declare no conflict of interest with the present research.

## 7. Author contributions

PK design of the study, performed the statistical analysis, wrote the first draft of the manuscript. MSz, JL, MSm organized the database. All authors contributed to conception, manuscript revision, read, and approved the submitted version.

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