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Analyzing the effects of competitive fatigue on body composition and functional capacities of youth elite handball players

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Abstract

Handball demands intense movements like rapid direction changes and physical contact. Consecutive competitions expose player fatigue and weaknesses due to the sport's exhaustive nature. Therefore, the aims of this study are two-fold: (i) to investigate the impact of competitive fatigue on the body composition of youth elite handball players, and (ii) to analyze the impact of concentrated competition on their functional capacity performance. Seventeen young male handball players (age: 16.2 years, height; 177.8 cm, body mass: 73.0 kg) were assessed twenty-four hours before (TM1) and after the competitive period (TM2) in body composition, static strength, lower- and upper-body explosive strength, speed, agility, balance, and flexibility indicators. A Wilcoxon Signed Rank Test was conducted to assess differences in body composition and functional capacities assessment between TM1 and TM2. Regarding results, body mass significantly increased in TM2 ($p < 0.01$), while increases in waist circumference and body fat percentage were not statistically significant. Functional capacity assessments revealed a significant decline in jumping performance (CMJ and SJ; $p \leq 0.01$). Speed and agility assessments showed worse performance in TM2, significantly increasing 30 m sprint time ($p \leq 0.01$). Balance indicators showed no significant differences, with mixed results in performance across different conditions. In sum, evaluating vertical jumps and long-distance maximum speed (i.e., 30 meters) could be valid tests for measuring and controlling fatigue in young elite handball players. Future research should regularly monitor young handballers after the competition to analyze the entire fatigue recovery process.

Keywords: *team sports, adolescents, physical fitness, vertical jumps, sprinting*

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Introduction

In handball, players must continuously perform movements with maximum or submaximal effort without having time to fully recover in between (Petruzela et al., 2023). Since teams are not allowed to purposefully slow down the game by delaying or holding onto the ball without moving forward or trying to get a goal opportunity, handball players must frequently perform rapid direction changes, repeated accelerations, physical contact with other players, leaps, and shoots during competition (Kale & Akdoğan, 2020). During the competition, players must repeatedly perform high-intensity activity, followed by brief periods of low-intensity activity to quickly recover (Wagner et al., 2019). According to previous research, optimizing high-intensity actions and recovery depends on the strength and power capacities of both upper and lower limb muscles (Hermassi et al., 2017). Consequently, players' physical attributes seem to impact their match performance (Leuciuc et al., 2022). Moreover, the literature has reported that proper training control for evaluating physical fitness is crucial to minimize fatigue and the risk of injury during competition while optimizing players' performance (Tyshchenko et al., 2019). Besides functional capacities, age, body composition, technical skills, and tactical awareness are relevant variables for handball players' performance (Molina-López et al., 2020).

In the meantime, fatigue is noticeable when a player can no longer sustain the required level of effort, whether in training or competition (Marcora et al., 2009). As a result, physical and physiological components have been studied in the past years, suspecting that fatigue may significantly and negatively impact players' performance (Silva et al., 2018). The speed of actions (Coutinho et al., 2018) decreases the effectiveness of technical skills performance, such as passing and shooting (Mohr et al., 2003). Indeed, long-term and short-term fatigue influence players' performances (Wu et al., 2019), which may be enhanced during competition with a busy fixture calendar. The short recovery periods between matches seem to impact functional capacity performance, particularly sprinting and jumping abilities (Alba-Jiménez et al., 2022). Simultaneously, insufficient recovery periods are related to increased injury risk (Jones et al., 2017). Although the competitive and training intensity of professional players is naturally more demanding than that of young players, 3 days with 3 games exposes the aforementioned concerns.

However, to our knowledge, research regarding the effects of consecutive competition days on elite youth handball players' body composition and functional capacities is still lacking. This information is of interest to players and coaching staff to deploy managing strategies during competition to avoid the detrimental impact of fatigue and to provide adequate training programs according to competition demands. Therefore, the aims of this study were twofold: (i) to investigate the impact of competitive fatigue on the body composition of youth elite handball players, and (ii) to analyze the impact of a 3-day concentrated competition on players' functional capacity performance.

Materials and Methods

Participants

Seventeen male adolescent handball players aged 16.2 ± 1.1 years (height: 177.8 ± 7.5 cm, body mass: 73.0 ± 12.1 kg) participated in this study. All these players compete in regional competitions weekly and only compete at the national level once a year based on a concentration system (i.e., three games in 3 days).

Study design

The study was conducted during the season 2021/2022. Players were evaluated the day before the beginning of the national concentrated competition (TM1) and the day after the return from that same competition (TM2). All players were assessed in one morning, from 8:00 a.m. to 11:00 a.m., with a break between assessments. The timeline of the study design is displayed in table 1. All the protocols were conducted in a physical performance laboratory by trained staff from the research team. The field tests were conducted in a covered area appropriate for them and monitored by trained research team staff. The study protocol was approved by the Faculty of Human Kinetics Ethics Committee (CEIFMH N°22/2022) and followed the Declaration of Helsinki. Participation was voluntary, and informed consent was signed before data collection.

Body composition

Height was measured to the nearest 0.01 cm using a stadiometer (SECA 213, Hamburg, Germany). Body composition was evaluated using a hand-to-foot bioelectrical impedance analysis (InBody 770, Cerritos, CA, USA) during the early morning while participants were fasting. Participants were barefoot and only wearing their underwear. On the platform, their feet were placed on the defined spots, and their arms were placed nearly 45º from their trunk until the assessment was concluded. The waist circumference assessment was performed just above the iliac crest using a non-elastic measurement tape. The participants were standing position with arms hanging freely.

Static strength

The dominant and non-dominant handgrip was used to evaluate static strength. The protocol included three alternated trials for each arm using a hand dynamometer (Jamar Plus+, Chicago, IL, USA). Participants were standing and asked to hold a dynamometer in one hand, laterally to their trunk, with the elbow at 90º. Participants squeezed the dynamometer as hard as possible from this position for about two seconds. If the dynamometer touched the participant's body, the assessment was repeated. The rest interval between trials was 60 seconds, and the best score of the three trials was retained for analysis.

Upper-body explosive strength

The 3-kg medicine ball throw was used to assess upper-body explosive strength. All subjects began with a familiarization session. A brief description of the optimal technique was given, suggesting a release angle to achieve a maximum throw distance . The test consisted of standing with the feet parallel to each other and throwing the heavy ball as far as possible with both hands behind the head (throw-in), using an explosive forward movement . Each player made three repetitions, and the best performance was considered for evaluation.

Lower-body explosive strength

The countermovement jump (CMJ) and the squat jump (SJ) were used to evaluate the vertical jumping capacity . Participants performed four data collection trials 30 seconds apart. Although indications endorse a 1-minute passive rest between jumps to ensure muscular recovery , the issue is not consensual in the literature. In our study, due to time restrictions, we considered a rest period of 30 seconds between each jump. Some studies have presented shorter recovery times, such as 20 s and

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30 s between each repetition . The data were collected using the Optojump Next (Microgate, Bolzano, Italy) system of analysis. Participants were encouraged to jump to maximum height during testing. After the protocol explanation, participants were allowed three experimental trials to ensure correct execution.

For the CMJ, participants began standing, with feet placed hip-width to shoulder-width apart. Participants dropped into nearly 90° of knee flexion from this position, followed by a maximal-effort vertical jump. To avoid the influence of arm swing, the hands remained on the hips for the entire movement For the SJ, the participants started in a squat position of approximately 90° knee flexion, followed by a maximal-effort vertical jump. The participants reset to the starting position after each jump.

The Three-Jump Test (3JT) began from an upright standing position, with both feet flat. Participants tried to cover as much distance as possible with three forward jumps, alternating left, right, left or right, left, right, according to the sequence of supports they normally use to execute a handball suspension throw. The distance covered was measured to the nearest 1 cm using a tape measure.

Linear speed

Participants performed maximal sprints at 5-, 10- and 35-m. Sprint time was recorded in seconds using Witty-Gate photocells (Microgate, Bolzano, Italy), and the best of two trials was retained for analysis. Participants recovered between sprints by walking back to the start line for 2 min between trials.

Non-reactive agility

Non-reactive agility was evaluated through the t-test. The t-test is a 4-directional agility and body control test that assesses the ability to change direction rapidly while maintaining balance and without losing speed. Participants sprinted 9.14 m straight, then shuffled 4.75 m to the left side. Next, participants shuffled to the right side 9.14 m and immediately shuffled 4.75 m back. Finally, participants run backwards until they pass the starting point. Test time was recorded in seconds using Witty-Gate photocells (Microgate, Bolzano, Italy).

Flexibility

Sit and reach tests were used to assess flexibility . The protocol used a sit-and-reach trunk flexibility box (32.4 cm high and 53.3 cm long) with a 23 cm heel line mark. Participants sat barefoot before the box, with the knee fully extended and the heel placed against the box. Then, participants were asked to put their hands on each other, palms down, and push forward the measuring cycle. The forward position was repeated twice, and the third forward stretch was held for 3 s, corresponding to the test score. First, the test was conducted unilaterally (right and left leg) and then bilaterally. Two trials were performed, and the best score was used for analysis.

Balance

Balance was assessed using the Biodex Balance System SD (Biodex, Shirley, NY, USA). Before each testing, the equipment was adjusted to the participant's height. Participants were allowed to practice with the protocols through a single training session to guarantee the protocols' understanding and minimize learning effects during the testing phase. The rest interval between testing sessions was set at 60 seconds.

The protocol was performed in an unilateral stance with participants barefoot for bilateral comparison. During the assessment, the overall stability index (OSI), anteroposterior stability index (APSI), and mediolateral stability index (MLSI) were measured under four levels of platform stability for 20 s. Level 4 was the most stable, and level 1 was the most unstable. The indexes' scores show the deviation from the horizontal position; therefore, lower scores indicate better balance .

Statistics

Descriptive statistics are presented as means ± standard deviation. All data were checked for normality using the Shapiro-Wilk test. A Wilcoxon Signed Rank Test was conducted to assess differences in body composition and functional capacities before (TM1) and after competition (TM2). The effect size (r) was calculated by dividing the z value by the square root of N and interpreted using Cohen criteria as follows: 0.1 > r < 0.3 (small), 0.3 > r < 0.5 (medium), and ≥ 0.5 (large). All analyses were performed using IBM SPSS Statistics software 28.0 (SPSS Inc., Chicago, IL, USA). The significance level was set at 0.05.

Results

Figure 1 illustrates an overview of the percentage changes in the studied variables between pre-competitive (TM1) and post-competitive (TM2) assessments. Overall, the results show that in all the body composition variables, on

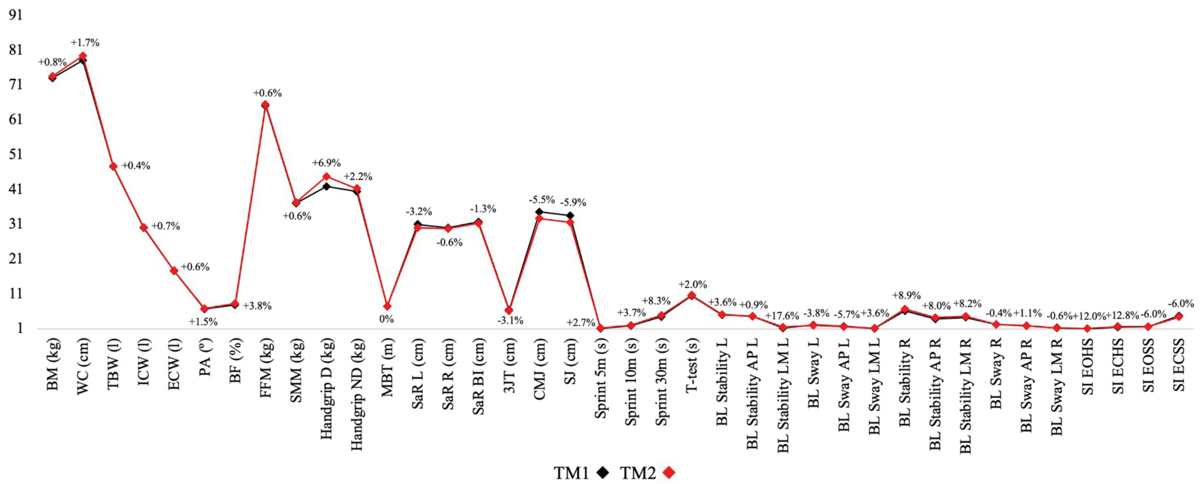

Figure 1. Overview of percentage changes in variables between pre-competitive assessments (TM1) and post-competitive assessments (TM2)

average, there was an increase of between 0.4% and 3.8%. Regarding to the functional capacities assessments, the results of the handgrip with both limbs showed improvements of between 2.2% and 6.9%. On the other hand, in the physical tests of flexibility and vertical and horizontal jumps, the results were worse after the competitive period, with lower percentages of between 0.6% and 5.9%. In addition, the players showed higher average results in the linear sprints (5m, 10m, and 30m) and t-test, between 2% and 8.3%. It should be noted that these values represent worse results since these are speed and agility tests in which a shorter time corresponds to a better performance. Finally, in the balance variables, it was possible to observe that 10 of the 16 indices increased their oscillation, which shows a worse average index after the competitive period, with negative values between 0.9% and 17.6%.

Table 2 presents descriptive statistics for body composition and the results of the comparison between TM1 and

Table 1. Timeline of the study design

Pre-Competitive Assessments (Day before competition)	National Competition (Duration of three days)	Post-Competition Assessments (Day after competition)
Body composition	Day 1: Match at 8 P.M.	Body composition
Functional capacities	Day 2: Match at 4 P.M.	Functional capacities
Balance	Day 3: match at 1 P.M.	Balance

Table 2. Descriptive statistics for body composition variables and results of the comparison between pre-competitive assessments (TM1) and post-competitive assessments (TM2)

Variable	TM1	TM2	Wilcoxon Signed Rank Test	
	Mean ± SD	Mean ± SD	z	p
CA (years)	16.2 ± 1.1			
Height (cm)	177.8 ± 7.5			
Body mass (kg)	73.0 ± 12.1	73.6 ± 12.2	2.665	≤ 0.01
Waist circumference (cm)	78.1 ± 6.9	79.4 ± 6.6	1.870	0.06
TBW (l)	47.6 ± 6.6	47.8 ± 6.7	0.700	0.48
ICW (l)	30.0 ± 4.1	30.2 ± 4.2	1.481	0.14
ECW (l)	17.6 ± 2.5	17.7 ± 2.6	0.000	1.0
Phase angle (º)	6.7 ± 0.6	6.8 ± 0.6	1.262	0.21
Body fat percentage (%)	7.9 ± 4.4	8.2 ± 4.4	1.198	0.23
Fat-free mass (kg)	65.1 ± 9.1	65.5 ± 9.3	1.068	0.29
Skeletal muscle mass (kg)	37.1 ± 5.4	37.3 ± 5.4	1.340	0.18

CA: chronological age; TBW: total body water; ICW: intracellular water; ECW: extracellular water.

Table 3. Descriptive statistics for functional capacities and results comparison between pre-competitive assessments (TM1) and post-competitive assessments (TM2)

Variable	TM1	TM2	Wilcoxon Signed Rank Test	
	Mean ± SD	Mean ± SD	z	p
Handgrip dominant side (kg)	41.9 ± 7.9	44.8 ± 7.1	1.917	0.06
Handgrip non-dominant side (kg)	40.4 ± 7.1	41.3 ± 6.0	0.308	0.76
Medicine ball throw (m)	7.5 ± 1.7	7.5 ± 1.5	0.315	0.75
Sit and reach left (cm)	31.0 ± 7.3	30.0 ± 6.9	1.136	0.26
Sit and reach right (cm)	30.0 ± 7.4	29.8 ± 6.9	0.402	0.69
Sit and reach bilateral (cm)	31.7 ± 7.2	31.3 ± 7.3	0.750	0.45
3JT (cm)	6.4 ± 0.5	6.2 ± 0.8	1.578	0.12
CMJ height (cm)	34.6 ± 6.4	32.7 ± 4.8	2.486	≤ 0.01
SJ height (cm)	33.6 ± 6.3	31.6 ± 5.0	2.415	0.02*
5 m linear sprint (s)	1.13 ± 0.09	1.16 ± 0.11	0.909	0.36
10 m linear sprint (s)	1.88 ± 0.09	1.95 ± 0.16	1.506	0.13
30 m linear sprint (s)	4.47 ± 0.21	4.84 ± 0.73	3.386	≤ 0.01
T-test (s)	10.46 ± 0.62	10.67 ± 0.85	0.355	0.72

3JT: three-jump throw; CMJ: countermovement jump; SJ: squat jump.

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TM2. Regarding significant differences found when comparing both moments, body mass was significantly higher in TM2 compared to TM1 ($z = 2.665$, $p < 0.01$, large effect size). Also, waist circumference ($z = 1.870$, $p = 0.06$) and body fat percentage ($z = 1.198$, $p = 0.23$) were higher in TM2 than in TM1, however, the differences were not significant. In the remaining variables, no significant differences were found between assessment moments.

Table 3 shows descriptive statistics for functional capacities and the comparison results between TM1 and TM2. Overall, players presented higher scores for the handgrip strength in TM2 (dominant limb: $z = 1.917$, $p = 0.06$; non-dominant limb: $z = 0.308$, $p = 0.76$). In contrast, significantly lower performance levels were observed in the jumping assessments in TM2 compared to TM1 (CMJ: $z = 2.486$, $p = \leq 0.01$, large effect size; SJ: $z = 2.145$, $p = 0.02$, large effect size). Additionally, higher scores for speed and agility tests were registered in TM2, indicating worse performance. However, statistically significant differences were only found in the 30 m linear sprint time ($z = 3.386$, $p = \leq 0.01$, large effect size).

Table 4 resumes descriptive statistics for balance indicators and compares the results between TM1 and TM2. Overall, no statistically significant differences were detected between moments. The results vary between better and worse balance scores at TM2. The players showed higher scores in the stability lateromedial left and right ($z = 1.207$, $p = 0.23$ and $z = 0.970$, $p = 0.33$, respectively), corresponding to decreased performance at TM2. Besides, values attained with eyes open and closed in the hard surface condition were higher at TM2, indicating worse performance. In contrast, scores observed with eyes open and closed in the soft surface condition were lower at TM2, indicating better balance ability.

Table 4. Descriptive statistics for balance variables and comparison of the results between pre-competitive assessments (TM1) and post-competitive assessments (TM2)

Variable	TM1	TM2	Wilcoxon Signed Rank Test	
	Mean ± SD	Mean ± SD	z	p
BL Stability Overall Left	4.94 ± 3.07	5.12 ± 2.70	0.213	0.83
BL Stability Ant Post Left	4.55 ± 3.22	4.59 ± 3.01	0.213	0.83
BL Stability Lat Med Left	1.25 ± 0.63	1.47 ± 0.68	1.207	0.23
BL Sway Overall Left	2.09 ± 0.56	2.01 ± 0.50	0.402	0.69
BL Sway Ant Post Left	1.74 ± 0.61	1.64 ± 0.46	0.118	0.91
BL Sway Lat Med Left	1.10 ± 0.30	1.14 ± 0.32	0.497	0.62
BL Stability Overall Right	6.16 ± 2.79	6.71 ± 2.67	1.018	0.31
BL Stability Ant Post Right	3.87 ± 2.55	4.18 ± 2.70	0.118	0.91
BL Stability Lat Med Right	4.27 ± 2.06	4.62 ± 2.02	0.970	0.33
BL Sway Overall Right	2.28 ± 0.72	2.27 ± 0.67	0.497	0.62
BL Sway Ant Post Right	1.88 ± 0.63	1.90 ± 0.69	0.213	0.83
BL Sway Lat Med Right	1.27 ± 0.44	1.20 ± 0.25	0.355	0.72
SI EOHS	0.92 ± 0.33	1.03 ± 0.37	0.710	0.48
SI ECHS	1.48 ± 0.52	1.67 ± 0.63	1.302	0.19
SI EOSS	1.58 ± 0.53	1.57 ± 0.38	0.118	0.91
SI ECSS	4.70 ± 1.00	4.41 ± 1.22	1.231	0.22

BL: balance; Ant Post: anteroposterior; Lat Med: lateromedial: SI EOHS: sway index eyes open hard surface; SI ECHS: sway index eyes closed hard surface; SI EOSS: sway index eyes open soft surface; SI ECSS: sway index eyes closed soft surface.

Discussion

The present study aimed to investigate the impact of competitive fatigue from a concentrated competition on body composition and functional capacities of youth elite handball players. The results indicated that the evaluation of vertical jumps and the long-distance maximum speed test (i.e., 30 meters) are valid tests for measuring and controlling fatigue in young elite handball players after three consecutive days of competition. In addition, the results also showed that the regeneration process of the variables analyzed in terms of body composition is quickly completed in this specific context.

Impact of Competitive Fatigue on Body Composition

Regarding body composition, no significant differences were observed in overall variables, except for body mass. However, the other variables considered for analysis (i.e., waist circumference, total body water, intracellular water, extracellular water, body fat percentage, fat-free mass, and skeletal muscle mass) increased their values, although without statistical significance. Indeed, the literature reinforces that there may be an association between an increase in the above-mentioned variables and a significant increase in body mass (Martins et al., 2022). First of all, it's important to note that the average daily weight change is around two kilograms. Therefore, a statistically significant variation of an average of 600 grams may not be clinically significant regarding the biological structures of the players in the sample. Yet, body composition is vital since being physically prepared for competition has been reported as probably the main element reducing players' susceptibility to fatigue following handball matches (Ronglan et al., 2006). Players might thus benefit from more targeted high-intensity exercises like sprinting, leaping, and more intense eccentric exercises, reducing minor muscle ruptures following high-intensity activity (Harper et al., 2019).

Evaluation of Functional Capacities: Jumping and Sprinting

Regarding functional capacities, on average, the players significantly increased their lower-body explosive strength (countermovement jump and squat jump) from TM1 to TM2. Worldwide, researchers and coaching staffs have relied on the countermovement jump and squat jump to assess players' lower-body explosive strength levels (Asimakidis et al., 2024; França et al., 2022; Molina-López et al., 2020). As expected due to the fatigue effect, players decreased their performance in both vertical jumping tasks. According to the literature, high-intensity actions (i.e., sprints, jumps, and changes of directions) are related to lower-body strength capacity (Hermassi et al., 2017), which might be affected by fatigue levels accumulated due to game demands and congested calendars (Alba-Jiménez et al., 2022). When objectively interpreting the outcomes of our study, a key breakthrough in our research was the precise demonstration that evaluating vertical jumps can serve as a reliable metric for monitoring fatigue control in handball, particularly among young elite players.

Meanwhile, the results of the present study indicate decreases in linear sprints and changes in direction performance between TM1 and TM2. However, results were only statistically significant in the 30 m linear sprint. In that specific speed test, there was an increase of nearly 0.37 seconds in the total running time, corresponding to a decreased performance. Interestingly, the time spent in the 5 m and 10 m linear sprints, and t-test have also increased after the competitive period, which should also be related to accumulated fatigue. Recent investigations have shown that restoring the sprint and vertical jump measurements requires 24 to 72 hours of recovery time to their pre-competitive levels of neuromuscular function (Thomas et al., 2018). After a tough competition, this function decline may extend for up to four days (McLean et al., 2010). In general, these studies highlight the value of personalized monitoring processes in team sports to deploy adequate intervention programs to avoid the detrimental effects of fatigue (Alba-Jiménez et al., 2022).

Fatigue Effects on Balance Performance

Finally, although an overall performance decrease from TM1 to TM2 was observed in balance variables, the differences were not statistically significant. To the best of our knowledge, the research on the influence of competitive fatigue on young handballers' balance indices is limited. However, the literature has underlined the need to integrate dynamic balance processes throughout training sessions. In football, it has been suggested that fatigue affects players' functional stability during match play (Greig & Walker-Johnson, 2007). Elite football players experience fatigue in the final 15 min of each half, which is related to deficits in postural balance during that particular match timeframe (Mohr et al., 2005). As a result, diminished postural stability may help explain why injuries happen around the conclusion of each half of the game (Brito et al., 2012). Indeed, introducing balance content throughout training sessions may increase movement effectiveness and reduce the risk of injury (Daneshjoo et al., 2022).

Study Limitations

Despite its scientific validity, the present study has some limitations that should be mentioned. First, the lack of longitudinal assessment limits comparing the results to pre- and post-competition testing sessions. Collecting longitudinal data would allow a more extensive analysis of the players' baseline characteristics and the short-term effects of congestive competitions on body composition and functional capacities. Furthermore, the fact that each player's playing time was not one of the variables controlled and taken into account does not allow us to differentiate in body and physical terms between players with a higher competitive load and those with a lower competitive load. Even though the influence of competitive fatigue in young handballers is still a scarce topic in the literature. Still, this study reports novelty findings in exploring vertical jump evaluations as a reliable fatigue monitor and control measurement that can be applied in youth elite handballers.

Conclusions

This study demonstrate the validity of using vertical jumps as a measure of fatigue after a concentrated competition in young handball players. In addition, it was also shown that body composition variables were regenerated quickly after the competitive period. These results are essential for technical staff to understand the type of preparation for these demanding periods of competition and the type of assessments they could use to measure their young players' fatigue. It is also essential to retain these findings and consider them for the prevention and recovery processes of sports injuries and the period of return to competition. Future studies should follow and evaluate the groups evaluated more regularly, especially after the competition, so that it is possible to monitor the recovery process after competitive fatigue.

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Declaration of Interest Statement

The authors declare no conflict of interest.

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Institutional Review Board Statement

This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the Faculty of Human Kinetics, (CEIFMH Nº22/2022), and followed the ethical standards of the Declaration of Helsinki for Medical Research in Humans (2013) and the Oviedo Convention (1997).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from all players to publish this paper.

Data Availability Statement

The data presented in this study are available upon request from the corresponding author.

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