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7TH EHF SCIENTIFIC CONFERENCE

The tribulations of the 2019 pandemic had a lasting effect on the global community and, with conviction, changed our sport and the lens through which we viewed it; in 2021, this was mostly still online. Nonetheless, and to put it in the most positive sense, it dramatically broadened our horizons to the untapped potential embedded within our sport. Therefore, it is truly a pleasure to present the 7th EHF Scientific Conference once again as an in-person event and welcome you to Porto.

The European Handball Federation, together with its education partner, the Union of University Handball Teachers (UUHT), and in close collaboration with the Faculty of Sport at the University of Porto has gathered over 150 participants to partake in this 2-day conference to highlight 4 keynote speakers, 35 presentations, and 10 poster presentations. At the heart of the 7th Scientific Conference is the theme 'Sustainability in Handball – Circle of a Handball Life'.

Over the course of a year, the EHF Methods Commission, chaired by Pedro Sequeira, alongside the EHF Competence Academy & Network (CAN) and the EHF Expert Panel carefully selected the abstracts that you will find in this body of work. The carefully crafted programme with contributions from medical, technical, and scientific experts continue to provide a stable basis to serve this platform of academic exchange. The presentations that cover, among other topics, anti-doping, grassroots handball, injury prevention and rehabilitation, in addition to mental health and nutrition reflect the considerable efforts to research and development still undertaken within handball.

The success of the EHF Scientific Conference remains a key indicator of how handball continues to develop in the technical and methodical realm; sport, and handball in particular, is not immune to the changes at the social, economic, and ecological levels as reflected in these presentations. Thus, it is our duty to persistently keep pace, adapt, and re-envisage how we act within the global handball community. It is our responsibility towards those whose work we continue and carry forward, and our obligation to those who come after us.

Therefore, in closing, I thank the organisers of 7th edition of this conference, as well as the keynote speakers, the presenters and, above all, the participants who understand that the development of handball for the betterment and progression of the sport is not finite.

Sincerely,

Michael Wiederer
President

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UNVEILING THE HIDDEN DANGERS OF CONCUSSIONS – THE INVISIBLE AND UNDERRATED RISK IN HANDBALL GOALKEEPING

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Summary

The main purpose of this study was to get a clearer picture about what concussions are, how often they actually happen in handball goalkeeping, and with what kind of concussion symptoms many handball goalkeepers have to deal. Bringing a bigger awareness about severity and complexity of concussion consequences to handball goalkeepers, players, coaches, referees, parents, and everyone else involved in handball can help in concussion prevention, and it can improve recovery time after suffering some of the concussion symptoms.

There is an obvious lack of research and understanding on the topic of concussions in handball, and it is one of the main goals of this study to help with that.

Keywords

Concussion, traumatic brain injury, handball goalkeeper, sport-related concussion

Introduction – what are concussions?

The occurrence of concussions and the complexity of concussion symptoms in handball goalkeeping is much more prevalent than what is commonly known in handball world. Additional challenge for goalkeepers is that many concussions are not reported and stay undiagnosed, which results in returning to play with a few or several concussion symptoms. Untreated concussion symptoms are not only challenging for handball goalkeeper's performance, but also for their everyday life.

In certain tactical situations in handball, shooters can execute shots from as close as 3 - 4 meters away from the goalkeeper, with shot speed of over 100 km/h. When goalkeepers get such a powerful shot in the head, it can often result with a concussion.

The word "concussion" comes from the Latin word "concutere", which means "to shake violently." Concussion is a type of traumatic brain injury which affects the brain function. Concussion is usually caused by a strong impact to the head, face, neck, or body that sends a strong force to the head which causes a rotation of the head and sets the brain in motion inside of the skull.

What happens during a strong impact to the head is that the brain gets immediately “squashed” out of its shape, it moves and twists. The head moves forward, the brain falls behind, and then the brain catches up and smashes into the skull. It rebounds off the skull and then it continues to hit into the other side of the skull. When the head twists and turns, the damage can happen between the left and right hemispheres of the brain.

The brain is one of the softest substances in the body, and as the head is moving back and forth, the brain is twisting and turning, and the tissue in it is getting stretched. This stretches the axons – long trunks and branches of nerve cells that carry the information in the brain. The axons can manage a slow stretch, but if they get stretched very quickly, by a sudden impact – then the parts of the nerve fibres will get damaged. It’s about the speed of the “stretch” that is going to have an impact on the concussion consequences. It’s also about the degree of injury to the axons that predicts how severe symptoms of a concussion will be, and how long it will take to recover from them.

The two main reasons for why concussions occur, based on previous studies, are the linear acceleration–deceleration and rotational acceleration–deceleration of the head. Injuries that occur in a specific area are caused by the linear acceleration, while rotational acceleration causes both injuries in a specific area and in a wider area.

Based on the latest research, a concussion is more likely to happen when someone is hit and when the head rotates to the left or to the right. Movement forward-backwards is more common for handball goalkeepers, especially in the cases when the ball comes straight into the goalkeeper’s face. Rotation to the left or to the right seems to be much more dangerous, and it happens in instances when the ball rebounds from the left or right goal post and it ends up hitting a goalkeeper's head from one of the two sides.

It's important to note that a direct impact to the head is not required for a concussion to happen. A hard hit to the body can cause a whiplash motion to the brain, which can result in a concussion. Another important fact is that not everyone will black out from a concussion: 9 out of 10 people do not black out. It is also possible to have a concussion and not realize it. What is very dangerous and what can lead to disastrous outcomes is if a goalkeeper is returned to play too soon after sustaining a concussion.

The long-term consequences of concussions in handball goalkeeping are still widely underestimated and not very well known.

Concussion diagnosis

Unlike the rest of the body – the brain has no pain receptors, so we can't be aware of how bad the damage inside of the brain is. Even though the brain has billions of neurons, it doesn't have any pain receptors. The pain from a headache that is common after sustaining a concussion comes from other nerves, some of which are inside the blood vessels in the head, and are communicating to the brain that something is wrong.

Concussion diagnosis is based on clinical judgment together with the data gathered from specific assessment tools. A goalkeeper can have multiple concussion signs and symptoms to as few as only one and still be diagnosed with a concussion. Concussion can't be seen on routine x-rays, MRIs or CT scans. Concussions are invisible injuries, and as such very often stay unreported and untreated.

There is no single test that can diagnose concussion, and different tools are available to help in diagnosis. A test that is often used by health care professionals in other sports is the Sport Concussion Assessment Tool—5th Edition (SCAT5). The SCAT5 involves questions about symptoms, short testing of cognitive functions such as concentration and memory, and a screening neurological examination that includes evaluation of eye movements, balance, and coordination.

Putting a goalkeeper back in the game or a practice too soon after suffering a strong shot in the head is very dangerous and it greatly increases a chance of sustaining a concussion.

Returning to training too soon after suffering a concussion could lead to getting a second concussion. Getting a second concussion compounds the damage, it makes it much harder to heal, and a goalkeeper could have long-term effects such as chronic headaches, depression, vision problems or difficulties focussing.

Concussion symptoms

If a concussion is suspected, a handball goalkeeper should be removed right away from the court. Assessment begins with evaluation for concussion symptoms such as a strong headache, blurry or double vision, neck pain, light or sound sensitivity, weakness or tingling in the arms or legs, or decreased level of consciousness.

The most common issues that tend to arise after sustaining a concussion include headaches, coordination, vestibular reflexes, attention issues, balance, problems with visual system, positional habituation, physical strain, and activity progression with change of direction. However, the system that seems to be impacted more often and more consistently than the others is the visual system.

Important to mention is that convergence insufficiency is present in 1 out of 2 people with concussion.

The most common symptoms of concussion include headache, nausea or vomiting, sleep problems, fatigue, clumsiness, blurred vision, light sensitivity, sound sensitivity, balance problems, slurred speech, irritability, confusion, feeling foggy or dazed, attention difficulties, slowed thinking, memory problems, depression, anxiety, ringing in ears, loss of consciousness, etc.

Concussion is not likely to be something that's happening on the outer surface of the brain, but something that's happening much deeper, towards the centre of the brain.

In more serious cases – this type of brain injury may lead to bleeding in or around the brain, and these symptoms may develop immediately or later. An interesting detail is that in some cases a hard hit is not necessary to have the brain damage as a consequence. The truth is – one hard shot will cause the concussion and the other hard shot will not cause it.

Methods and Results

An online survey was conducted and made available on www.vanjaradic.fi and was answered by 103 goalkeepers (59 female and 44 male) of different skill and experience levels (mean age 26.92 ± 1.49) from 34 countries.

Out of 103 surveyed goalkeepers, all of them sustained a concussion at least once during a practice or a match in their handball goalkeeping career, 20 of them sustained 2 concussions, and as many as 11 of them suffered more than 10 concussions in their career.

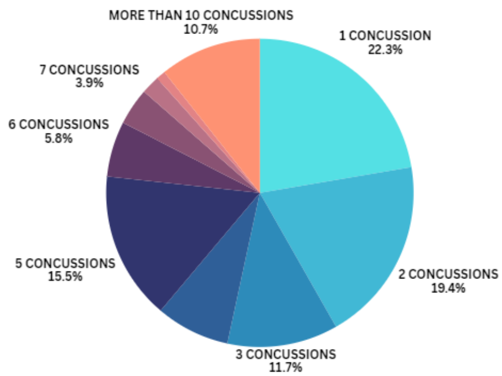

Image 1 - Total number of sustained concussions per goalkeeper based on respondent survey

Out of these 103 goalkeepers, 70 of them continued playing in the goal (during the same practice or a match) after getting a strong shot in the head, and 33 of them sat on the bench and stopped playing for the given practice or a match after suffering a strong shot in the head.

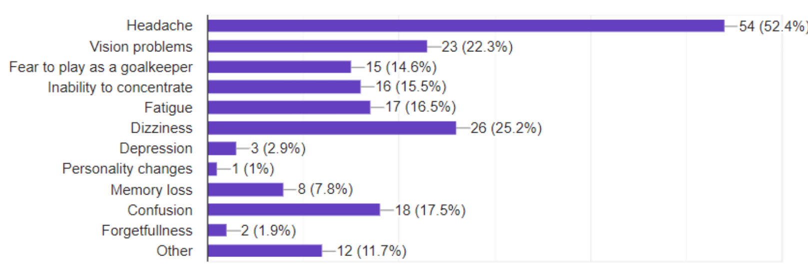

Image 2 - Responses to one of the survey questions about what are the most disturbing consequences / effects / symptoms that goalkeepers had after sustaining at least one or more concussions

All 103 goalkeepers experienced some or all the 11 concussion symptoms offered in the survey, and for 12,6% of goalkeepers, the symptoms and difficulties caused by one or a few concussions have not stopped even a few years after sustaining them and are still ongoing.

12 out of 103 goalkeepers had to quit playing handball due to the consequences of sport related concussions which they suffered after getting a strong shot in the head.

The respondents had a chance to enter additional symptoms that they have struggled with, which were not stated in the survey, and these are some of the most common responses they gave: inability to speak for a while, tinnitus, anxiety, cervical sprain, tremor, suicidal thoughts, and neck pain.

One of the survey questions was about what is the biggest challenge that they are facing in handball goalkeeper training and games now because of and after sustaining one or more concussions, and here are some of their answers: trauma-extreme fear of the ball; needing to take way longer rest in quietness before games or practices; I tend to hide in the goal, to cover and protect my face all the time now; dealing with almost everyday headaches; constant fear of getting a new concussion - it feels like I can never give 100% in practices or games because of that fear; dizziness; I get tired faster, and my heart rate increases sooner; difficulties to concentrate; memory loss; forgetfulness; in my country handball is the source of income, so despite the challenges I have after a concussion, I have to just continue playing; fear to position properly in the goal or to attack the shooter; hard time focusing; blurred vision; noise sensitivity - audience in the sports hall; light sensitivity in sports halls.

Another one of the survey questions was about what is the biggest challenge that they are facing in their everyday life overall now because of and after sustaining one or more concussions. 20 goalkeepers reported that they don't have any challenges after suffering one or more concussions, but all the others reported different, ongoing challenges in their everyday life, and these are some of their answers: not being able to be social as I used to be; fatigue; inability to concentrate; vision problems - inability to do my school work on a computer; having to take days off from handball or work because of my headaches; I feel less confident overall; loss of motivation; depression; headaches every day; hearing problems; migraines 4-5 times a month; forgetfulness; noise sensitivity; light sensitivity; tinnitus; very bad short term memory; blurry vision; constant irritation and pain of the eye on the side of the head where I got the shot (even 20 years after suffering the concussion and an eye injury); loss of self-confidence; anxiety; permanent cervical pain and dizziness; mood changes; easily caused nausea.

The last question in the survey was if there was anything else that they would like to add about the topic of concussions in handball goalkeeping, and most of their responses resonated with this statement: "I wish that there was more knowledge shared in handball community about concussions. Goalkeepers, players, and coaches don't have enough knowledge about concussions, so there is a lack of compassion and understanding for a teammate who is suffering with a concussion. We need to perform on an equally high level as we did before this kind of injury, with constant headaches, vision problems, lack of motivation, or even with depression, and we are not getting needed support and understanding from our teammates and coaches. I felt very lonely and misunderstood when I was injured with a concussion, and I wish that my teammates and coaches would have been there for me more to support me."

Discussion and Conclusion

If a goalkeeper sustains a concussion during the game or a practice, they should step out of court, sit on the bench, and be screened by a medical professional. The brain needs time to properly heal, this is why taking a rest after getting a strong hit in the head is very important. Goalkeepers should not return to play the same day if they have any of the potential concussion symptoms.

The most common scenario that can be seen in handball is that goalkeepers either just continue playing after sustaining a very hard shot in the head and being knocked down, or they return to play after only a few minutes.

In handball world, it is considered as a "weakness" for a goalkeeper to go out of the court and sit on the bench after suffering a hard shot in the head. This narrative needs to be changed because of the severity and longevity of complications that can be caused by concussions.

The least that handball coaches and handball goalkeeper coaches should do is to get more educated about concussions, concussion symptoms, potential complications, possible concussion prevention steps and to know that with proper rest - the recovery can last only up to 10 days. Instead, we are putting goalkeepers in dangerous situations, and we are potentially delaying their recovery time by returning them to play immediately after they suffer a hard shot in the head.

When goalkeepers or players get a knee, ankle, wrist, back or a shoulder injury - the effects of those injuries are visible, and players are "allowed" to get out of the game and to take a rest. Whereas after getting a strong shot in the head and being knocked down – that injury is not visible, and goalkeepers are expected to just ignore what happened and to continue to play.

The bravest thing to do in these kinds of situations is to take a break after suffering a hard shot in the head, and to understand that unlike with a sprained ankle, or with a broken finger - the concussion is an invisible injury which needs an immediate attention and care.

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COMPARATIVE ANALYSIS BETWEEN GENDER OF THE PERFORMANCE WHILE PLAYING EMPTY NET AT ELITE HANDBALL

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Summary

Modification of the Rules of the Games (IHF, 2016) allow playing with empty net (EN) may have different strategies conceptions for both genders. Results registered, for both gender, most of the actions during the exclusion´s context. Playing 7vs6 with EN was used more by male teams (40.8%) than female teams (23.8%). Statistically significant relationship was found ($p<0.05$) with the game time and playing 7vs6 with EN. Moreover, quick throw-off and direct shots were registered more in male than in female teams.

Key words: goalkeeper change; offensive performance; attack efficacy; number of players in court, gender comparison.

Introduction

Last modification in the Rules of the Game of Handball in 2016 that affected the most the development of the matches is the change in rule 4.1, which allows teams to attack with 7 field players without the obligation to have one identified as goalkeeper or goalkeeper (IHF, 2016). Rules are the same for both genders, although some anthropometric or physiological profile differences (Wagner et al., 2019) generate contrasts in the specific physical requirements of handball depending (Michalsik & Aagaard, 2015) which leads to different tactical behaviours in the game (Quiñones et al., 2020).

Since it became possible to play with empty net (EN) without the need of identifying one of the players as a goalkeeper, handball experienced an authentic revolution generating a large number of teams playing with 7 field players against 6 defenders assuming the risk involved in playing with EN (Antón, 2019). In their counterpart, Haugen & Guvåg (2018) argue that this strategy affected negatively as it decreased the uncertainty of the results increasing, even more, the competitive imbalance.

Bonjour & Tortajada (2019) analysed the offensive finalizations while playing EN during 2018-2019 Women's EHF Champions League handball and found that teams chose to play with EN almost systematically when they suffered a disciplinary sanction (73.56% of the cases). Moreover, Botejara (2021) studied the strategic use of rule 4.1 in all matches at Men Euro 2018. Results showed that the strategy of attacking 6x6 with EN during exclusions was widely accepted by the teams (57.3% of all EN cases) followed by 7x6 EN (27.2%). Trejo-Silva & Bonjour (2021) studied the 6x6 and 7x6 EN finalizations during semifinals and finals at men´s Euro and World

Championships (2017-2020) finding that, of 1451 offensive actions analysed, 5.9% were played in 7x6 EN.

Based on the above and the lack of comparative studies between genders, we believe it is important to study in depth the effectiveness of using rule 4.1playing with EN and the differences that may exist, offensively or defensively, between genders. For this reason, the aim of the study was to analyze and compare the context of offensive and defensive efficiency in handball when using the goalkeeper-player change during the final phase of elite male and female championships.

Methodology

Sample consisted in all the finalizations registered while playing EN during 22 matches (11 men and 11 women) of the final stages (play-off and Final 4) of the EHF Champions League 2020-21 and 2021-22. A total of 362 actions were registered, 211 in men and 151 during women games. Observational methodology steps were followed (Anguera & Hernández, 2013). An "ad hoc" instrument was created. A recording instrument was developed by using the Lince software (Gabín, Camerino, Anguera & Castañer, 2012).

For the analysis of the consequences after offensive actions, finalizations ended in seven meters, goals plus exclusion and exclusions were considered as "Stop time" (in fact, time is stopped by referees in all of them). After these sequences (33 in men and 17 in women), a subsequent phase of counterattack would not exist, therefore withdrawal cannot be perceived. Moreover, finalizations were grouped as follows: i) absolute efficiency (goal, goal and exclusion, seven meters goal, seven meters and exclusion); ii) relative efficiency (exclusion) and iii) failure (no goal). Statistical analysis was performed using Excel, SPSS v 26.0 (SPSS, Chicago, 2013) and JASP v0.16.3.0. The confidence interval used was 95%. The Pearson's Chi-Square test was performed, as well as Cramer's V coefficient and adjusted standardized residuals (ASR).

Results

A total of 362 actions in which the offensive possession was completed playing with EN were registered in the 22 matches analysed. In men, a total of 211 sequences were observed (19.1 ± 8.7 per game) and in women 151 sequences (13.7 ± 4.3 per game). In men, 40.8% of the total actions registered corresponded to 7x6 EN, while in women, only 23.84%. The 6x6 EN was used in 44.08% of the actions in male and 67.55% in female (Table 1).

Table 1. Distribution of the different types of playing with empty net compare by gender.

Type of Empty Net	Men	Women
5x5 Empty net	0.47%	0.66%
5x6 Empty net	0.47%	0.66%
6x5 Empty net	10.90%	7.28%
6x6 Empty net	44.08%	67.55%
7x5 Empty net	3.32%	0.00%
7x6 Empty net	40.76%	23.84%

Table 2 presents that absolute efficacy in men (49.29%) is higher than in women (42.38%) when playing with EN. Relative efficacy shares similar percentage values, 7.58% in men and 4.64% in women, with the greatest difference in the failure of the offensive action (52.98% of the female finalizations in comparison with 43.13% in male matches)

Table 2. Types of offensive efficacy compared by gender.

	Men	Women
Absolute Efficacy	49.29%	42.38%
Relative Efficacy	7.58%	4.64%
Failed	43.13%	52.98%

Regarding the use of this strategy in relation with the game time a statistically significant relationship was found ($p < 0.05$, men Cramer's V: 0.256, women Cramer's V: 0.289). In women, the period from minute 40:00 to 49:59 was the one that registered more actions, while in men it was the last 10 minutes of the first half (Table 3). In reference to the different types of using the EN strategy, in men matches 7x6 EN was likely to be used from minute 20:00 to 24:59 (ASR 3.8) and between minute 10:00 and 19:59 in women matches (ASR 3.9).

Table 3. Distribution of the use of EN strategy by men and women along game timeline.

Game time	Men	Women
00:01 to 09:59	6.64%	3.31%
10:00 to 19:59	14.69%	21.85%
20:00 to 24:59	9.95%	4.64%
25:00 to 30:00	13.27%	7.28%
30:01 to 39:59	12.32%	15.89%
40:00 to 49:59	20.85%	25.17%
50:00 to 54:59	11.85%	13.25%
55:00 to 60:00	10.43%	8.61%

When observing the immediate consequences of changing the goalkeeper for a field player, it was found that in both genders there was a statistically significant relationship between finishing during the positional attack and the subsequent effectiveness of the retreat ($p < 0.05$). In both men's and women's teams, losing the ball tends to result in conceding a goal, while finishing the offensive action with a goal is unlikely to result in a counterattack ending in goal from the opposing team (Table 4).

Table 4. Finalization grouped in goal and no goal, and its immediate consequence for men and women.

	Men					Women				
	FWCA	SWCA	FT	GGT	NC	FWCA	SWCA	FT	GGT	NC
Finalization										
Goal			30.43 %		69.57 %			26.79 %		73.21 %
No goal	13.95 %	11.63 %		18.60 %	55.81 %	20.51 %	17.95 %		15.38 %	46.15 %

Note: FWA: 1st wave counterattack; SWCA: 2nd wave counterattack; FT: fast throw-off; GGT: goal to goal throw; NC: no counterattack.

Discussion

In this study, a high frequency in the use of 7x6 EN was observed, with 40.76% of the records in men and 23.84% in women. This coincides with the findings of Botejara (2021) in men, following the 6x6 EN as the most frequent use. In every tournament, there always seems to be a team that uses this strategy more frequently than the others, which influences in the number of situations registered for 7x6 EN. For example, in the study of Botejara (2021), from positions 1 to 4, this strategy was predominantly used by Denmark. Moreover, Prudente et al. (2022) when studying solely the use of 7x6 EN at Men Euro 2020, recorded a total of 123 sequences in 28 matches, with Portugal being responsible for 55% of the observed cases, similar to what was recorded in the present study by the teams of Kiel and Aalborg in the men competition.

The difference in the use of 7x6 EN between genders may be multifactorial. Previous studies find anthropometric and physiological differences (Wagner et al, 2019 and Michalsik & Aagaard, 2015) that generate different offensive combinative play (Quiñones et al, 2020) and the demands, advantages and disadvantages presented by the use of the 7x6 EN (Antón, 2019). The decrease of the available space in the areas closest to the goal (6 meters) generated by the frequent use of 3:4 offensive systems with a tendency to use the pivots in the lateral areas and the defence in inferiority would generate as mentioned by Antón (2019) the loss of defensive depth, which consequently, generates greater ease for the attackers to find situations of throws from the 9-meter or intermediate zone (between 6 and 9 meters).

The way of strategically interpret Rule 4.1 varies according to gender. Of all the cases registered when playing EN, the use of 6x6 EN in women was lower in percentage terms (67.55% against 73.5%) than in the study by Bonjour et al (2021). An increase of 7x6 EN in females can be observed, which causes the relative percentage of 6x6 EN to decrease. In relation to the 6x6 EN in men, Botejara (2021) found that teams at semifinals and medal games, 6x6 EN is observed in 52.7% of the cases, which is higher than the 44.08% registered in the present study.

The efficacy in women obtained similar values, slightly lower (42.38% against 45.5%) than those obtained by Bonjour et al (2021). Flores & Macías (2021) in men obtained a total efficacy of 35.5%, taking into consideration all actions with EN, away from the absolute efficacy values of 49.29% obtained in present study. The authors found that in the semifinals, finals and third place in the 2019 men's World Cup, the teams obtained an attacking success of 31.3% when using the

7x6 EN, while club teams in the present study registered an absolute efficacy of 53.49%. It is possible to visualize, with two and three years of difference, a substantial improvement in the quality of the attacks when using this strategy.

The periods with the highest frequency use of playing EN varied according to gender. In men from 20:00-30:00 minutes, the highest use was visualized, while in women from 40:00 to 49:59 minutes, which coincides with the findings of Botejara (2021) corresponding to the so-called critical moments of the game (Rogulj, Foretić & Burger, 2011). It is in these periods of the game that exclusions happen, which consequently increases EN plays, which is confirmed by the high percentage of 6x6 EN actions (Trejo-Silva et al 2022; Trejo-Silva et al 2020; Prieto, Gómez & Sampaio 2015).

In both men and women, there is a statistically significant relationship between how the positional attack is finished and the immediate defensive consequence in terms of the subsequent finishing phase of the opposing team ($p < 0.05$; Male Cramer's V: 0.355, Female Cramer's V: 0.347). In both genders, it was also found a statistical relationship between how the positional attack was finished with the efficacy of the subsequent retreat ($p < 0.05$; Male Cramer's V: 0.342, Female Cramer's V: 0.266). When a turnover is conceded, it was likely to receive a goal afterwards in both men (ASR 4.8) and women (ASR 3.6). However, the most frequent consequence after a scoring a goal was not receiving a counterattack by the opponents (ASR 3.2 in women and 3.0 in men). The results of this study in the male branch (69.57% of the times that a goal is scored, no counterattack is received) are similar to those found by Botejara (2021) who mentions that 77.3% of the times that a team scores while playing EN, no counterattack is received. Bonjour et al (2021) found that in women, the most frequent offensive sequence when the previous action ends in a goal is that a counterattack is not generated and an organized defence system is stablished, which coincides with the results of the present study where there is no counterattack in 73.21% of the sequences that end in a goal.

Conclusion

In both men and women, the strategy used the most was 6vs6 EN during exclusions. High values of the use of 7x6 EN in comparison with previous studies, being significantly higher in men than in women. On one hand, while playing with EN and finalizing in turnover, the most frequent sequence is to receive an opponent's counterattack that ends in a goal. On the other hand, if the offensive action while playing EN ends in scoring a goal, it is usual not to receive a counterattack and, therefore, not to receive a goal in the defensive retreat.

It would be interesting in future studies, to go deeper into the problem of this study, taking into account the finalizations as well as the throwing zones. This would make it possible to obtain stronger conclusions about the causes of the differences in the offensive and defensive behaviours of the teams when comparing men and women.

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EFFECTIVENESS OF INVOLUNTARY MUSCLE CONTRACTION IN A HYPERBARIC CHAMBER ON MUSCLE METABOLISM IN HANDBALL PLAYERS

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Keywords: Hyperbaric environment, Muscle StO_2, Handball player,

Summary

The purpose of this study was to clarify muscle oxygen dynamics during muscle contraction under hyperbaric environment, focusing on the forearm flexor muscles of handball players. Muscle oxygen consumption and reoxygenation during involuntary muscle contraction in the oxygen chamber tended to increase in a hyperbaric environment compared to an atmospheric environment.

Introduction

In Japan, hyperbaric environment stays of around 1.3 atm are often used to keep sports enthusiasts and athletes in good physical condition. Pressurising the chamber to 1.3 atm slightly increases the amount of oxygen dissolved in the blood of athletes who remain in the chamber. The purpose of using oxygen chambers in athletes is mainly to recover from sports fatigue, which is thought to be aimed at increasing systemic metabolic activity through oxygen supply. Psychological and physiological studies conducted to date, such as with hyperbaric oxygen inhalation, have observed psychological changes in subjective mood, with suppression of negative mood[1)], and physiological changes in autonomic nervous activity, particularly in the parasympathetic nervous system, with improvement[2]. However, studies focusing on muscle and tendon have not produced consistent findings. Larsson et al. reported an increase in muscle oxygen saturation (StO_2) in the thumb muscle during hyperbaric ambient oxygen therapy (2.8 atm, 100% O_2) [3], while Kubo et al. after 80 min (including 10 min of pressurisation and 10 min of decompression) in a hyperbaric environment at 1.3 atm, 50% O_2, stated that no significant changes in Achilles tendon StO_2 were observed[4]. The effects of hyperbaric environmental stays on the oxygen dynamics of individual muscles have not yet been fully verified due to limitations of the measurement environment and differences in experimental conditions, such as degree of pressure, duration of action, and presence or absence of muscle contraction[5, 6]. No studies have been found comparing muscle oxygen saturation during the generation of involuntary muscle contractions using Electric Muscle Stimulation (EMS) on skeletal muscle under two conditions: atmospheric pressure and hyperbaric environment. It is assumed that intramuscular dissolved oxygen is increased in an oxygen chamber. Observing muscle oxygen consumption and recovery kinetics during electrical repetition of continuous muscle contraction and relaxation in this environment could provide a basis for exploring whether oxygen chambers contribute to sports performance and sports conditioning in athletes. Thus, the effects of short-term stays in oxygen chambers with a safe pressure of around 1.3 atm on limb muscle tissue circulation have not been clarified. The aim of this study was to determine the skeletal muscle StO_2 and the levels of oxygen consumption and reoxygenation during electrically induced muscle contractions during the oxygen chambers stay, focusing on the forearm muscle group of handball players.

Methods

Subjects: The subjects were four male elite university handball players. The average age of the subjects was 21.5 ± 1.8 years, height 1.74 ± 0.01 m and weight 76.0 ± 10.4 kg. They were players who had been playing handball for 4 -7 years and training 6 days/week, 3 h/day. Subjects were given a full explanation of the purpose, content, and procedure of the experiment, as well as the safety and side effects of the oxygen chamber and electrical muscle contraction (EMS), and their consent to participate in the study was obtained in writing. The study was approved by the Fukuoka University Ethics Committee (Permit No. 23-06-02).

Experimental Protocol: The experiment was conducted in the Sports Medicine Laboratory, Faculty of Sports Science, Fukuoka University. Subjects were placed in a sitting rest position for 15 min after entering the laboratory. Thereafter, they were placed in a supine position on a bed, and a StO_2 measurement probe (near-infrared spectrometer) of approximately 5 cm was attached to the test muscle, and gel pads for EMS energisation were attached to both sides of it. The near-infrared spectrometer for StO_2 measurements was activated and 5 min resting measurement was performed. EMS energisation was then applied for 5 min to induce involuntary muscle contraction in the test muscle. After the measurement during muscle contraction was completed, a 20-min recovery measurement was performed. All measurements were completed in a total of 30 min: at rest (5 min), during muscle contraction (5 min) and during recovery (20 min). At the end of the test, the measuring device was removed from the subjects, and they were allowed to leave the room after checking their physical condition. The test was conducted under two conditions: atmospheric pressure conditions and hyperbaric conditions (1.3 atm).

Measuring Muscles and Measurement Items: The muscles tested were the forearm flexor muscle group, at the proximal 1/3 point on a line connecting the medial epicondyle of the humerus to the middle of the wrist joint. The main measurement was muscle oxygen saturation (StO_2) in the forearm flexor muscle group using a near-infrared spectrometer; StO_2 was measured non-invasively using a near-infrared spectrometer (ASTEM, Japan), which is harmless to the human body. Using the difference in absorbance between oxygenated and deoxygenated Hb in biological tissue, the total Hb and oxygenated and deoxygenated Hb levels at 1.5 cm under the probe were measured and StO_2 was calculated from each value.

Electrical Stimulation (EMS) of the Forearm Flexor Muscle Group: Quantitative muscle contraction-relaxation movements were generated electrically in order to observe oxygen consumption and reoxygenation in the test muscle. The EMS energisation pads (Sakai Medical, Japan) were applied to the forearm flexor muscle group, on both sides of the near-infrared spectrometer. The electrical stimulation volume was 25 v, 30 Hz and the electrical stimulation duration was 6 sec. (1.5 sec. ascending, 3.0 sec. continuous, 1.5 sec. descending). Energisation (6 sec.) and no stimulation (3 sec.) were intermittently continued for 5 min.

Measuring Conditions:

1, Atmospheric pressure environment; oxygen partial pressure 160 mmHg

2, Hyperbaric environment at 1.3 atm (oxygen chamber; Time World, Japan); oxygen partial pressure 207 mmHg

In the hyperbaric environment experiment, subjects were fitted with each measuring device and then placed in a supine position in the oxygen chamber. The chamber hatch was closed and resting measurements (5 min) started when the pressure reached 1.3 bar from the start of pressurisation, after which the EMS was energised. Measurements in the atmospheric and hyperbaric environments were performed on separate days.

Statistical Analysis: All data obtained are presented as mean ± SD. A paired t test was used to compare StO_2 during muscle contraction in atmospheric and hyperbaric environments. Statistical significance was set at 5%. SPSS was used for statistical analysis.

Results and Discussion

A typical StO_2 change in this experimental protocol was shown in Figure 1.

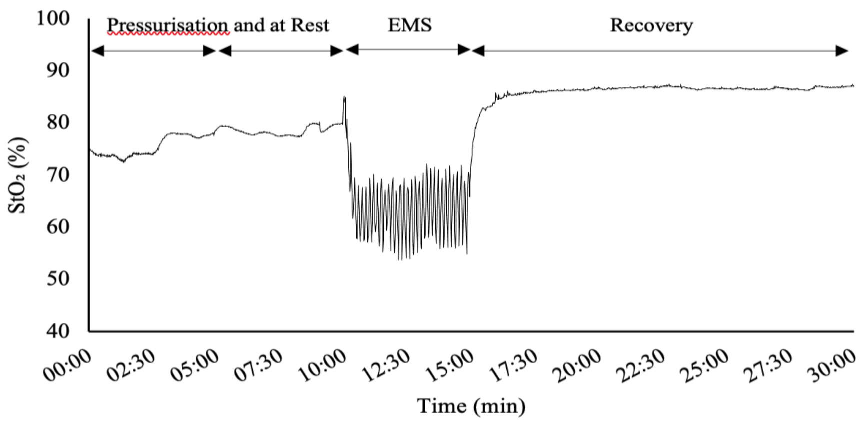

Figure 1. Typical Example of StO_2 change during the experiment

It took approximately 5 min for the air pressure in the oxygen chamber to increase to 1.3 atm. After the air pressure in the oxygen chamber stabilised at 1.3 atm, resting measurements were taken for 5 min, followed by 5 min of electrical stimulation. Spike StO_2 changes indicated muscle oxygen consumption and reoxygenation due to muscle contraction and relaxation. After the EMS was terminated, muscle StO_2 recovered quickly, and the extent of this recovery stabilised at a higher level than at rest. It was predicted that hyperaemia occurred in the forearm where muscle contraction occurred.

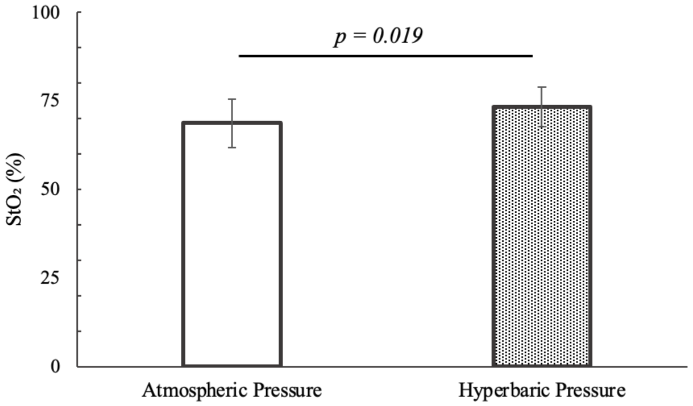

Figure 2. StO_2 at rest of atmospheric and hyperbaric pressure

A comparison of resting StO_2 in atmospheric and hyperbaric environments was shown in Figure 2. The StO_2 of the resting forearm flexor group was significantly higher at hyperbaric than at atmospheric pressure ($p<0.05$), with an average of 68.7% at atmospheric pressure and 73.3% at hyperbaric pressure. According to Kubo et al[4], the blood volume and oxygenated haemoglobin in the gastrocnemius muscle and Achilles tendon were shown to increase after staying in the oxygen chamber at 1.3 atm. These parameter changes gradually increased from 10 minutes after the chamber stay. In the present study, subjects' forearm muscle StO_2 tended to increase with hyperbaric environments, but there is not much evidence that StO_2 increases with hyperbaric chambers of around 1.3 atm. On the other hand, it was also predicted that the hyperbaric environment had an effect on the autonomic nervous system, in particular peripheral vasodilation due to increased parasympathetic activity[7]. Changes in resting peripheral blood volume and muscle StO_2 due to a transient hyperbaric environment could be influenced by increased blood oxygenation and autonomic nervous system activity. Figure 3 shows the reduction in muscle StO_2 when involuntary muscle contractions are induced in a hyperbaric environment. Comparing the change in StO_2 during EMS-induced muscle contraction with that at rest, the change in StO_2 at atmospheric pressure was -24.0% and at hyperbaric pressure -34.4%, with the change in StO_2 during EMS-induced muscle contraction being significantly higher at hyperbaric than atmospheric pressure ($p<0.05$). This means that the level of oxygen consumption during muscle contraction was greater in the hyperbaric environment than in the atmospheric pressure environment. On the other hand, Figure 4 shows the average percentage of muscle StO_2 reoxygenated during the 3 sec period when EMS energisation was stopped. StO_2, which was reduced by EMS-induced muscle contraction, recovered 36.6% under atmospheric pressure condition and 41.0% under hyperbaric condition during muscle relaxation. The percentage of muscle StO_2 recovery tended to be greater under hyperbaric conditions than under atmospheric pressure ($p=0.09$). After 5 min of EMS was completed, muscle StO_2 showed a significant increase (Figure 5). The extent of this increase was significantly higher in the hyperbaric pressure conditions than in the atmospheric conditions ($p<0.05$; Comparison of resting mean and peak StO_2 after the end of EMS).

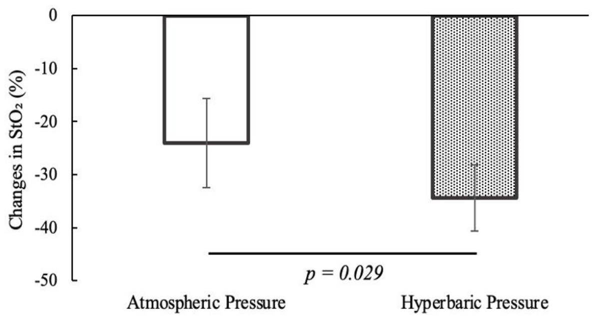

Figure 3. EMS-induced StO_2 reduction during muscle contraction

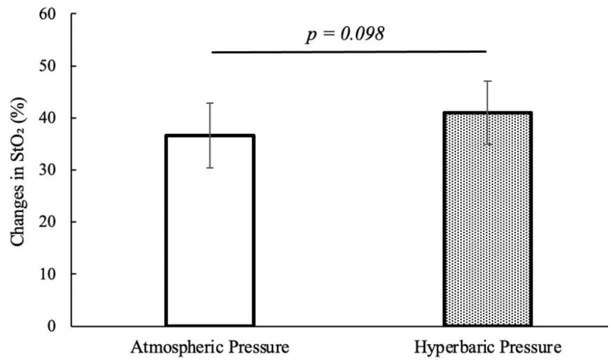

Figure 4. Reoxygenation during muscle relaxation during EMS cessation (Percentage change from bottom)

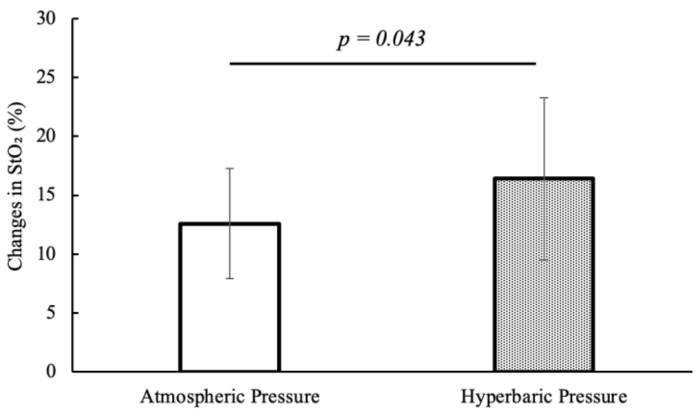

Figure 5. Changes in StO_2 at rest before and after EMS

These results predicted that when muscle contractile exercise occurs in a hyperbaric environment at 1.3 atm, the level of oxygen consumption is greater than in an atmospheric pressure environment and, accordingly, the level of reoxygenation during muscle relaxation is greater. In the present study, detailed muscle oxygen consumption cannot be calculated because blood flow to the forearms was not restricted. However, the large drop in muscle StO_2 that occurred simultaneously with the EMS energisation rhythm inferred vasoconstriction and oxygen consumption due to muscle contraction. Previous studies have not demonstrated that hyperbaric environmental exposure has a positive effect on subsequent exercise performance, and there was no effect of hyperbaric environmental stays on improving exercise performance in either aerobic or short-duration high-intensity exercise[5,8,9)]. On the other hand, Ishihara[10)] compared physiological changes between inhalation of 35% O_2 concentration and exposure to a high-pressure environment (21% O_2) at 1.3 atm after exercise. In this study, he reported that blood oxygen saturation was higher and lactate elimination after exercise was faster in the 1.3 atm hyperbaric environment stay than in the 35% O_2 inhalation. Furthermore, this level of high-pressure environment also resulted in a significant increase in skin blood flow. Thus, several previous studies suggest that hyperbaric environmental stays of around 1.3 to 2.8 atm have little effect on subsequent exercise performance, while being useful for conditioning, such as recovery from fatigue, muscle function and muscle soreness[11)]. The originality of this study is that involuntary muscle contractions were induced during the hyperbaric environment stay, and muscle oxygenation dynamics were observed in real time. The fact that oxygen consumption and reoxygenation levels were greater in the hyperbaric environment was a very interesting response. Exposure to high-pressure would be expected to increase dissolved oxygen in the bloodstream as well as oxygen bound to Hb. Periodic strong muscle contractions in a hyperbaric environment would be expected to increase the muscle blood volume in the during relaxation, allowing oxygen to be transported more efficiently to the small blood vessels, including capillaries. Training with muscle contraction under hyperbaric conditions has the potential to increase the degree of oxygen consumption and recovery in peripheral muscle tissue, and clarification of muscle oxygen dynamics by validation under various barometric conditions may be a valuable resource in exploring efficient muscle training.

Conclusion

Muscle oxygenation dynamics were examined in university male handball players during involuntary muscle contractions in the forearm during a stay in a hyperbaric environment. The results showed that forearm muscle StO_2 increased slightly during the hyperbaric environment stay and that oxygen consumption and reoxygenation levels during muscle contraction were significantly increased during the hyperbaric environment compared to atmospheric pressure.

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SHORT-TERM INACTIVITY AFTER WARM-UP AFFECTS THE PHYSICAL PERFORMANCE IN FEMALE ELITE TEAM HANDBALL PLAYERS

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Summary

In team handball, unlimited substitutions are allowed during the game, which means that despite previous inactivity on the bench for substitutes, players can be sent on the court and immediately have to perform at maximum intensity. Thus, the aim of this study was to examine the effects of inactivity after a match warm-up on the physical performance and physiological responses of female elite team handball players but also to investigate possible connections between the examined parameters. Twelve female adult elite field players were examined. All tests were carried out in two different situations: (a) immediately after a standardised match warm-up and (b) after the same protocol, but further followed by a 15-minute inactivity period. The present results showed that the effects of short-term inactivity counteracted to some extent the physical and physiological benefits that the players derived from warming up. The results also indicated that lower body temperatures caused by a short period of inactivity lead to a reduction in especially jumping performance, which could potentially impair the performance of the players during match-play.

Keywords: Female team handball, warm-up, inactivity, physical performances, physiological parameters.

Introduction

Handball is one of the fastest team sports, characterised by repeated jumps, accelerations and decelerations, changes of direction, body contacts and a variety of different technical game actions adapted to the changing dynamics of game tactics (Michalsik et al., 2013, 2014, 2015; Michalsik & Aagaard, 2015). A warm-up program is crucial to prepare the players to perform optimally in subsequent activities and to prevent injuries both during training and in competition (McCrary et al., 2015).

Some studies in soccer have reported that passive recovery during half-time decreased muscle temperatures and reduced physical performance like sprint, jump and dynamic strength (Lovell et al., 2013; Mohr et al., 2004). Lack of preparation for the second half could be a reason for the lower number of high-intensity runs in the second half, in soccer games. In the first few minutes of the exercise that comes after half-time, it has been observed that both cognitive and physical performance suffer. Additionally, during this time, an elevated risk of injury has been noted (Hammami et al., 2018; Russell et al., 2015; Silva et al., 2018).

In basketball, post-warm-up inactivity lead to a decrese in physical and physiological responses, including countermovement jump, heart rate, core and skin temperatures (Crowther et al., 2017). Also, basketball players who remained inactive after warm-up experienced a relatively quick decline in their ability to jump and run (Galazoulas, 2012).

A typical pre-game warm-up is necessary for a number of intermittent team sports and lasts for about 30 minutes. Before a team handball game, all players will undergo the match warm-up routine with some individual warming-up. After warm-up, players generally use the time before the start of the game for hydration, injury or equipment issues, and tactical instructions from coaches. When the actual match starts substitutes who are not in the starting line-up must sit on the bench before entering the field. Sometimes substitutes must immediately enter te playing area, and other times they are informed a little in advance that they will be brought on to play in the game. If there is enough room, these players might do a brief warm-up behind the benches. Unfortunately, it is nearly impossible to warm up properly behind the benches in many sports halls in Romania due to their infrastructure.

Some strategies for maintaining heat have been proposed, such as having the replacements wear training suits to maintain a reasonable temperature in their muscles.

The primary aim of this study was to investigate the effects of total inactivity after match warm-up on physical performance and physiological responses (off-court) of elite team handball players. The study's secondary goal was to investigate potential relationships between the parameters under investigation, using a comparative analysis framework, before and after the period of total inactivity that comes after the match warm-up.

Methods

Twelve elite female field players (n = 12; age, 31.9 ± 4.05 years; weight, 66.1 ± 5.8 kg; height, 173 ± 3.8 cm and body mass index, 2.2 ± 0.2 kg/cm2) from a team in the first Romanian Female Team Handball League participated in the study. The team was divided into two groups of six players each (Group 1 and Group 2), in pairs for each position (left-wing, right-wing, left back, right back, centre and pivot. The study was approved by the Ethics Committee of the University of Galati, Romania and the Ethics Committee of the Galati Community and was conducted in accordance with accepted ethical standards and with the principles of the Declaration of Helsinki in sport and physical activity research.

Experimental design

The testing procedure used is presented in Figure 1. Before the evaluation test rounds, all players went through the same 30-minute standardized warm-up program. Group 1 players were tested in the first week of September and Group 2 players in the second week, using the same testing protocol. After the first evaluation (T1-AW), each group was instructed to sit on the bench and remain completely inactive until the second evaluation (T2-IB). This strategy was chosen because if the warm-up ended at the same time, the time taken to evaluate the entire team would have resulted in too long a wait and certainly affected the results of some tested players towards the end. Simulating the changes between players in the middle of the first half (minute 15) was suggested, which means that the time of inactivity on the bench was chosen to be 15 minutes. This is a changing situation that often occurs in both the 1st and 2nd half of elite handball games. During this period, the benefits of warm-up could be lost if the transition between warm-up and the start of a match lasts longer than 15 minutes and an effective post-warm-up strategy is lacking (Silva et al., 2018). Players wore jerseys and shorts, with no tracksuits during inactivity. This happened because players only wear their tracksuits during the cold season and they were not instructed otherwise.

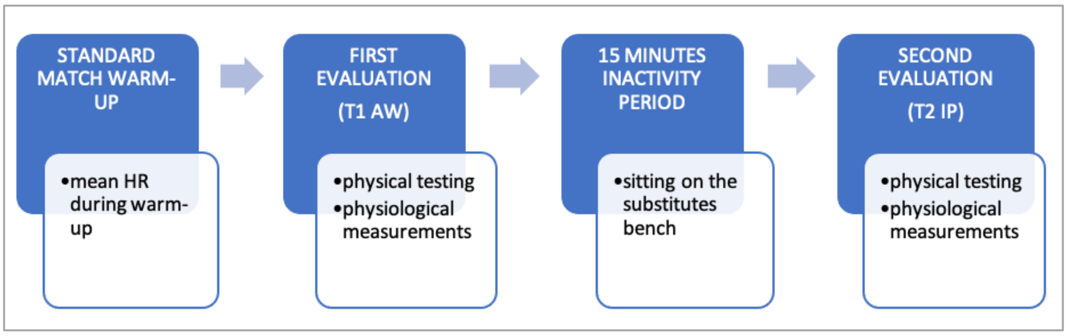

Figure 1. The testing procedure used

Warm-Up

Before the evaluation protocols, all players went through a 30-minute warm-up routine as they would in a typical match. This involved going through a set of exercises structured in two distinct parts: the general warm-up, which is composed of individual or collective exercises, without the ball, under the guidance of the team's physical trainer, and the handball-specific warm- up, which involved the repetition of the usual technical-tactical actions, with guidance from the head coach.

Physical evaluation

Players performed four physical tests focused on assessing combined strength-speed qualities and determining anaerobic power output: the countermovement jump with arms fixed (CMJ AF) without additional load was used as a test to measure lower body strength; the squat jump (SJ) was used to assess the ability to produce explosive force during concentric movements (Van Hooren & Zolotarjova, 2017); the medicine ball toss test (MBTT) with rotational throw, both from the right side (MBTT-R) and the left side (MBTT-L), was included to determine maximal anaerobic power and explosive power in the upper limbs; the 10 m acceleration Test (TA 10m) was used to measure players' ability to accelerate over short distances.

The stopwatch was used for TA 10m and the PUSH tape device (version 2.0) was used for the jump and medicine ball tests. PUSH 2.0 (Strength Inc., Toronto, Canada) is a micro technological device that allows wireless measurement and reporting of data, over a range of 9 meters, thanks to the Integrated Bluetooth 5.0 chip. The device also has a built-in triaxial accelerometer that determines the linear acceleration and a gyroscope, that detects changes in body position relative to a reference point. The technology behind PUSH 2.0 allows multiple and even simultaneous testing of athletes in a relatively short period of time.

Physiological Evaluation

The physiological testing included five measurements, all aimed at identifying the potential changes in physiological values between the standard warm-up (SW) and the period of inactivity (IP). For the heart rate (HR) study, Garmin Fenix 5S smartwatches were used and distributed to the players before the warm-up. HR values were recorded during the standard warm-up and at T2- IP. Body temperature (BT) was recorded with the Veroval DS 22 infrared thermometer immediately at T1-AW and T2-IP. Blood lactate (BLC) and serum glucose (G) were measured with the Accutrend Plus device. Capillary blood samples were collected by the team´s medical staff. Blood oxygen saturation (SpO_2) was measured at T1-AW and at T2-IP by placing the IMDK pulse oximeter (Model C101A2, Version V1.1) on the player's finger.

Results

The results are presented as arithmetic group means (standard deviations and coefficient of variation) in Table 1. The t-test for dependent samples (repeated measurements) and Pearson correlation coefficient were used, where a value of the statistical significance coefficient $p < 0.05$ was considered significant.

Physical tests

Descriptive data, group means, standard deviations (±SD) and the coefficient of variation (Cv), *p*-values of the t-test for dependent samples for all variables are presented in Table 1.

Table 1. Results obtained in the physical tests, before and after the short-term inactivity

Test	Parameter	T1 AW (N= 12)		T2 IP (N=1 2)		t	Sig.
		Mean ± SD	Cv%	Mean ± SD	Cv%		(2-tailed)
CMJ AF	JH (cm)	34.57 ± 2.04	5.89	33.00 ± 3.36	10.19	1.38	0.180
	RSI1 (cm/s)	0.43 ± 0.06	14.53	0.35 ± 0.07	21.00	**2.88**	**0.009***
	PP (w)	2.71 ± 0.22	8.04	2.55 ± 0.11	4.21	**2.24**	**0.039****
	PV (m/s)	2.39 ± 0.13	5.44	2.46 ± 0.14	5.50	1.20	0.242
SJ	JH (cm)	29.99 ± 3.49	11.63	28.50 ± 3.34	11.71	1.07	0.298
	RSI1 (cm/s)	0.90 ± 0.06	6.81	0.79 ± 0.08	9.58	**3.88**	**0.001***
	PP (w)	2.49 ± 0.21	8.53	2.32 ± 0.16	6.92	**2.28**	**0.033****
	PV (m/s)	2.31 ± 0.12	5.31	2.40 ± 0.13	5.51	1.81	0.084
MBTT-R	PP (w)	10.59 ± 3.78	35.67	9.97 ± 3.54	35.50	0.42	0.682
	PV (m/s)	6.77 ± 1.09	16.17	6.83 ± 1.17	17.10	- 0.13	0.894
MBTT-L	PP (w)	9.63 ± 2.55	26.50	8.36 ± 2.35	28.11	1.27	0.219
	PV (m/s)	6.15 ± 0.96	15.68	6.69 ± 1.06	15.85	- 1.31	0.204
TA	10 m (s)	2.14 ± 0.10	4.67	2.19 ± 0.10	4.37	- 1.25	0.223

Abbreviations: CMJ AF= countermovement jump arms fixed; SJ= squat jump; MBTT-R= medicinal ball right throw; MBTT-L= medicinal ball left throw JH= (jump height); RSI1= (reactive strength index); PP= (peak power); PV= (peak velocity);

t = t value;

Sig. (2-tailed) = t significance level;

**= p<0.01 differences between T1-AW and T2-PI;*

***= p<0.05 differences between T1-AW and T2-PI.*

Short-term inactivity after warm-up caused a decrease in the reactive strength index and the peak power index specific to the countermovement jump with arms fixed (RSI1 CMJ-AF:

p<0.01 and PP CMJ-AF: p<0.05), and the squat jump (RSI1 SJ: p<0.01 and PP SJ: p<0.05), as shown in Table 1. No differences between evaluations, before and after inactivity, were found for the medicinal ball throwing test (MBTT) and the 10 m acceleration test (TA 10m test).

Physiological measurements

The results of all physiological measurements are shown in Table 2. Mean HR was higher after warm-up than after inactivity (121±8 vs.87.6±7 beats·min^{-1}, p<0.001). Significant changes also occurred in body temperature after 15 minutes of inactivity (37.8 °C vs. 36 °C, p<0.001). The values for BL, G and S O_2 did not differ between the two situations.

Table 2. Results from the physiological tests, before and after the inactivity period

Physiological Parameter	T1 AW (N=12)		T2 IP (N=12)		t	Sig. (2-tailed)
	Mean ± SD	Cv%	Mean ± SD	Cv%		
HR (bpm)	*121.75 ± 8.07*	*6.56*	*87.58 ± 6.97*	7.96	11.10	***0.001****
BL (mmol/L)	*1.72 ± 0.43*	*25.19*	*1.57 ± 0.31*	20.06	0.97	0.342
G (mg/dL)	*89.58 ± 3.99*	*4.45*	*88.17 ± 4.30*	4.88	0.84	0.412
Tc (°C)	*37.73 ± 0.24*	*0.49*	*36.09 ± 0.49*	0.65	18.84	***0.001****
S O2 (SpO2)	98.67 ± 0.49	0.50	98.75 ± 0.45	0.46	- 0.43	0.670

Abbreviations: T1 AW= first evaluation after warm up (or during warm-up for HR values); T2 IP=second evaluation after inactivity period; HR= heart rate; BL= lactic acid; G= glycaemia; T_C= body temperature; S O2= oxygen saturation in the blood t = t value;

Sig. (2-tailed) = t significance level;

********= p<0.01 differences between T1-AW and T2-IP.*

Correlations between physical and physiological parameters

Only variables whose changes showed significant differences between the initial and final tests (identified with t-tests) were included in this analysis After multivariate correlation analysis, based on Pearson's r-correlation coefficient, it was found that statistically significant positive correlations exist between all analyzed variables at a significance level of p < 0.01 (see Table 3).

Table 3. Correlations between values (R-values) of variables that underwent significant changes between the first and second test.

			1	2	3	4	5
Physiological measurements	1	Heart rate					
	2	Core temperature	***0.93***				
Physical tests	**3**	Reactive strength index CMJ AF	***0.87***	***0.71***			
	4	Peak power CMJ AF	***0.94***	***0.91***	***0.82***		
	5	Reactive strength index- SJ	***0.96***	***0.92***	***0.79***	***0.96***	
	6	Peak power- SJ	***0.94***	***0.91***	***0.83***	***0.98***	***0.95***

Abbreviations: CMJ-AF- countermovement jump with arms fixed; SJ -squat jump

*** The correlation is significant at a significance threshold of 0.01 (2-tailed).*

Table 4 shows the existing connections between changes identified previously and presented in Table 3. Two significant correlations were identified, one between the RSI 1-CMJ AF index and the PP-CMJ AF index ($r=0.59$, $p<0.05$) and another between the PP-SJ and T_c ($r=0.60$, $p<0.05$).

Table 4. Correlations between the decrease in the values (R-values) of physical and physiological indices

after the short-term inactivity period.

			1	2	3	4	5
Physiological measurements	1	HR Evolution					
	2	T_c Evolution0.52					
Physical tests	**3**	RSI 1- CMJ AF Evolution	-0.3	-0.51			
	4	PP- CMJ AF Evolution	0.26	-0.27	***0.59****		
	5	RSI 1- SJ Evolution	-0.15	-0.24	0.02	-0.02	
	6	PP- SJ Evolution	0.38	***0.60****	-0.52	-0.24	0.02

Abbreviations: HR= heart rate; T_c= body temperature; RSI 1-CMJ-AF- reactive strength index countermovement jump with arms fixed; PP-CMJ-AF- peak power countermovement jump with arms fixed; RSI 1 SJ – reactive strength index squat jump; PP SJ- peak power squat jump.

** The correlation is significant at a significance threshold of 0.05 (2-tailed)*

Discussion

The present study aimed to examine the possible changes in performance and physiological, parameters in female elite team handball players after 15 minutes of total inactivity on the bench once they completed a standardised match game warm-up session. Our hypotheses were confirmed. After 15 minutes of total inactivity on the substitution bench, RSI 1 and PP decreased by 19% and 6%, respectively, in the case of CMJ AF, and by 15% and 7%, respectively, in the case of SJ. The results confirm the negative effects of inactivity on explosive loads such as lower-limb jumping identified in previous studies in soccer or basketball. According to Galazoulas et al. (2012) there was a linear drop in jumping performance as players rested, ranging on average, from 13% at 10 min of rest to 20% at 40 min of rest. Nevertheless, these effects have never been examined in elite female team handball before.

In our study, short-term inactivity had a greater negative impact on lower-limb explosive force tests than upper-limb tests. Contrary to jump performance, no significant changes were found in medicinal ball throwing test and the 10 m acceleration test. This means that the short-term period of inactivity had no impact on upper body performance and speed-related performance.

In this study, HR was used as an exercise intensity predictor with reference to the mean HR_{max} (176.5 bpm) for the entire team, recorded during the two friendly games that were played with the same players, prior to the present study. During the standard warm-up in the experimental design, the mean HR was 122 bpm (69% of HR_{max}). After 15 minutes of inactivity, resting HR values dropped drastically during total inactivity, to 49% HR_{max} (87.58 ppm) which falls into the low-intensity effort category.

The results showed that a short period of inactivity leads to a significant decrease in T_c values, 4% below the initially achieved value. In a similar basketball study, Crowther et al. (2017) found that after only 6 minutes of inactivity, physiological outcomes indicated a ~0.5 °C decrease in body temperature (T_c) and a ~2.0 °C decrease in abdominal temperature (T_a). The beneficial effects of increasing muscle and body temperature before any physical activity are mainly related to the intensification of the rate of muscle contraction through the amplification of nerve impulses (Bishop, 2003a). On the other hand, reducing the temperature by one-degree Celsius causes a 3% decrease in performance (Sargeant, 1987), a fact supported and demonstrated by the results of our research. Along these lines, Mohr et al. (2004) discovered that rewarming during the halftime of a soccer match was effective in maintaining sprint running performance that was decreased while resting. The decline in sprint running performance during the halftime of a soccer match was also linked to the decline in body and muscle temperature during the same period.

Interestingly, some of the present findings contradict the original hypothesis which stated that blood lactate values will rise during the inactivity period. When examining the capillary lactate dynamics between the first and second tests found that the results fall into the category of normal mean values at rest (T1-AW: 1.72 ± 0.43 mmol/L and T2 IP: 1.57 ± 0.31 mmol/L). BLC values could have been higher immediately after exercise, reflecting the immediate production of lactate during anaerobic metabolism. This produces doubts over the results attained. One can speculate that this could be due to the timing of lactate measurement after physical effort, as blood samples were collected at 3 minutes post-exercise and not immediately after the warm-up.

The main finding of this study was that resting for 15 minutes after a standard warm-up in elite female team handball resulted in a rapid decrease in performance in vertical jumping. Moreover, results showed a significant relationship between the evolution of T_c values and the evolution of values of peak jumping power SJ after 15 minutes of inactivity ($r=0.60$, $p<0.05$). These findings are consistent with the results of other studies on ball games, which identified a strong connection between the decrease in body temperature and the reduction in athletic performance in jumping (Crowther et al., 2017; Galazoulas, 2012).

Conclusions

In Romania, the substitutes in team handball games stay on the side-line and wait on the bench in a seated position before entering the court to play.

From the best of our knowledge this research is the first to support the idea that inactivity impairs physical and physiological function in female team handball players.

In conclusion, it can be stated that the decrease in physical performance in the jump tests of the team handball players after the inactivity period can be associated with the concomitant decrease in body temperature. Thus, the inclusion of warm-up activities for substitute handball players should be encouraged in order to maintain the benefits gained during the standard game warm-up. Wearing tracksuits when inactive could also keep body temperature a little longer.

Because this study focused on off-field physical testing, future studies should also examine the potential effects of complete cessation of activity on on-field physical performance measures (e.g., change of direction speed and aerobic capacities).

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CORRELATION BETWEEN THE TIME REQUIRED FOR THE 180° CHANGE OF DIRECTION AND RESULTS OBTAINED IN THE TEST 8 × 40 M

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Summary

The purpose of this study was to determine a) whether there is a significant correlation between the time required for the 180° change of direction (COD) and the total time obtained in the test 8 × 40 m test; b) whether there is a significant correlation between the time required for the 180° COD and the fatigue index obtained in the same test. The results obtained show that the effective executions of COD are important in achieving the final total result in the test in question, but it shows less association with the fatigue index.

Key Words: handball, agility test, change of direction.

Introduction

Agility is a specific form of speed that is characteristic of sports dominated by movement structures that require various changes in the direction of movement. Sports experts define it as the combined ability of strength, speed, and coordination, as the ability to accelerate, stop and quickly and appropriately change the position of the body with optimal neuro-muscular control, and as the ability to quickly change movement in space and time, without losing balance, speed and body control (Brittenham, 1996; Gredelj, Metikoš and Momirović, 1975; Pori, 2007).

In complex sports such as handball, agility is one of the most important motor skills (Chatzopoulos, Galazoulas, Patikas and Kotzamanidis, 2014; Milanović, Sporis, Trajkovic, James and Samija, 2013). The ability to accelerate and maintain speed is important from the point of view of which players will be included in the counterattack, which will be able to quickly return to the defence and which will be able to quickly prevent the opponents' counterattack. Experts state that individuals with a higher level of agility should be able to control their body more easily in both competitive and training situations. The latter was also confirmed by some research, which proved the connection between agility, rhythm, coordinated movement and timing, which is why many people associate it with preventive exercise (Brown and Ferrigno, 2005; Zatsiorsky and Kraemer, 2009).

A quick change of movement direction (body rotation between 90° and 180°) is extremely important for successful handball play. Due to the fast pace dictated by modern handball, players find themselves in situations where they must quickly change the direction of movement (COD). Above all, we have in mind the 180° COD, which we discuss in our article.

The goal of COD (180° turn) is to decelerate (stop) movement in the original direction as quickly as possible and then accelerate in the new direction of movement as quickly as possible. To make it easier to understand the COD, we need to understand some physical laws, which are already described by Newton's law of action-reaction, the impulse-momentum relationship (driving force), the moment of inertia, etc. are guiding principles that we must consider in understanding certain technical characteristics of a COD (Hewit, Cronin, & Hume, 2012).

Methods

Sample

The test sample included 55 handball players who were selected as candidates for the Youth and Yunior men's handball national team of Slovenia in the 2017/2018 season. When selecting the sample, we did not consider handball players who did not pass the test successfully (injury, incorrect execution of tasks, etc.).

Table 1

Proportion of subjects according to playing position

Playing position	RW	RB	CB	P	LB	LW	GK	All
Number	5	8	11	6	9	7	9	55
Share %	9,1	14,5	20,0	10,9	16,4	12,7	16,4	100

Legend. RW – right wing; RB – right back; CB – central back; P pivot; LB – left back; LW – left wing; GK -goalkeeper

Table 2

Basic data of participants

	Subjects				
	N	$\bar{x}$	S	Min	Max
Age (years)	55	17,47	1,63	15	20
Body height (cm)	55	186,74	6,48	174	203
Body mass (kg)	55	82,91	9,42	63	104

Legend. N – number; $\bar{x}$ – average means; SD – standard deviation; Min – minimum; Max - maximum

Variables

Based on the obtained results, we made a summation of the times in all eight repetitions.

To calculate the fatigue index, we used the formula that, according to Glaister, Howatson, Pattison and McInnes (2008), reflects the most realistic result:

FI = (100 × (total sprint time ÷ ideal sprint time)) – 100.

The total sprint time represents the sum of the times in all repetitions, the ideal sprint time represents the number of sprints × the fastest time, and the FI represents the proportion of the fatigue index.

With the help of video analysis, which we performed in the Kinovea program 0.8.15., we also establish the time that an individual needed to make 180° COD. This time was defined by the time elapsed between the last step of running in the original direction of run (the measurement time began at the first touch of the foot, with which the subject began to perform a 180° COD and pushed off in the new direction of run) and sprinting at a distance of 5 m in the new direction of movement after a 180° COD (the measurement time ended when the subject with the centre of the hips came perpendicular to the placed marker, which marked a distance of 5 m).

Figure 1. A sequence of pictures illustrating the turn in the "8 x 40m" test.

The first and second pictures left present braking before the COD, the middle picture stopping action and pictures on the right side the transition to a sprint in a new direction.

Results

Correlation between the 180° COD time and the total time of the 8 x 40 m test

The correlation between CODs time and total time of the 8 × 40 m test was made using three variables: the average time of all times in the 8 × 40 m test, the average time of all times in the first COD, and the average time of all times in the second COD.

Table 3

Basic statistical characteristics of the first and second 180° COD and the 8×40 m test

	N	$\bar{x}$	S	Min	Max	S-W	pS-W
First COD (s)	55	1,50	0,083	1,35	1,68	0,96	0,10
Second COD (s)	55	1,53	0,078	1,38	1,71	0,98	0,48
8 × 40 m (s)	55	8,42	0,382	7,70	9,30	0,96	0,63

Legenda. N – number; $\bar{x}$ – average value; S – standard deviation; Min – minimum; Max – maximum; S-W – Shapiro Wilk test; pS-W – statistical significance of Shapiro-Wilk test

The basic statistical characteristics of the average time of the first and second COD and the average time of the 8×40 m sprint test are given in Table 3. We can conclude that the time of the second COD is slightly worse due to the onset of fatigue, which occurs after several repetitions. Also, based on the results obtained, we can conclude that the differences in the final times of the 8 × 40 m test appeared due to the ability to accelerate, speed and speed endurance and not from the technique of the COD or COD speed, as we can see that on average, subjects performed CODs equally fast in both the first and second COD.

Table 4

Correlation between the time of both 180° COD and the total time of the 8 x 40 m test

	N	**p-value**	**PCC**
First COD	55	0,00	0,835
Second COD	55	0,00	0,735

Legend. N – number; p-value – statistical significance; PCC – Pearson correlation coefficient

Results in Table 4 show the correlation between the average times of the first and second 180°COD and the total time of the 8 x 40 m test. There are statistically significant ($p < 0.05$) correlations between the time of both CODs and the total time of the 8 × 40 m test. Pearson's correlation coefficient (0.835 for the first COD and 0.735 for the second COD) indicates a high or a strong linear relationship with the time of the 8 × 40 m test. So, the faster the COD, the better the total time of the 8 x 40m test.

Correlation between 180° COD time and fatigue index in the 8 x 40 m test

Fatigue is defined as a decline in power or force and speed, resulting in reduced muscle strength (Fitts, 2008). Three variables were used to analyse the relationship between COD time and fatigue level in the 8 × 40 m test: fatigue index, average time of all repetitions in the first COD, and average time of all repetitions in the second COD.

Table 5

Basic statistical characteristics of first and second 180° COD and fatigue index

	N	**M**	**S**	**Min**	**Max**	**S-W**	**pS-W**
First COD (s)	55	1,50	0,083	1,35	1,68	0,96	0,10
Second COD (s)	55	1,53	0,078	1,38	1,71	0,98	0,48
FI (%)	55	4,17	2,19	0,87	9,64	0,97	0,13

Legenda. N – number; – average value; S – standard deviation; Min – minimum; Max – maximum; S-W – Shapiro Wilk test; pS-W – statistical significance of Shapiro-Wilk test

Results in Table 5 show the basic statistical characteristics of the first and second COD and the fatigue index. The average value of the fatigue index is 4.17%, the minimum value is 0.87%, and the maximum value is 9.64%. The lower the percentage of fatigue, the better prepared the handball player is in terms of anaerobic capacity and power. According to some data about the FI value published in literature (Glaister et al., 2009), we can say that the result of our subjects is relatively good.

Table 6

Correlation between the time of both 180° CODs and fatigue index in 8×40 m test

	N	p-value	PCC
First COD (s)	55	0,00	0,39
Second COD (s)	55	0,02	0,31

Legend. N – number; p-value – statistical significance; PCC – Pearson correlation coefficient

Results in Table 6 show the correlation between the times of both CODs and the fatigue index in the 8 × 40 m test. There is a statistically significant correlation ($p < 0.05$) between the two CODs and the fatigue index. Even though there is a statistical significance ($p < 0.05$), the Pearson correlation coefficient both for the first COD (0.39) and for the second COD (0.31) indicates a low or weak connection. We conclude that fatigue has a slight effect on the speed of the turn, but that there are other factors that also affect the speed.

Discussion and Conclusions

When comparing the CODs time with the total time achieved in the 8 × 40 m test, we found a high or a strong linear relationship both in the first COD and in the second. So, we can conclude that it matters how quickly individuals perform 180°COD. We must note once again that this is to a greater extent about acceleration after the COD or explosive power and not for the COD technique itself, because as we described above, we found different COD times in spite similar biomechanical characteristics of COD.

When comparing the COD time with fatigue, we found out its influence on speed of COD. To calculate the fatigue index, we used a formula that proved to show the most realistic values. Based on the average value of the fatigue index of subjects, we can say that they are very well physically prepared, and that coaches or fitness trainers keep up the good work. In doing so, they should use high-intensity interval training, repeated sprints and games with adapted rules for training, as these methods have been shown to be the most effective for improving both aerobic and anaerobic capacity.

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CORRELATION BETWEEN THE TIME REQUIRED FOR THE 180° CHANGE OF DIRECTION AND TWO DIFERENT MOTORIC PARAMETERS

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Summary

The purpose of this study was to determine whether there is a significant correlation between the time required for the 180° change of direction (COD), time obtained in 5-m sprint and the jumping height in the »counter movement jump« test. A statistically significant correlation ($p < 0,05$) exists between the both CODs and the jumping height in the »counter movement jump« test. There is also a statistically significant ($p < 0.05$) correlation both in the first COD and in the second COD and time obtained on 5 m sprint.

Key Words: handball, agility test, change of direction.

Introduction

When determining the athletic performance in team sports, tests involving multiple consecutive sprints are very popular. Such tests usually consist of repeated short sprints in one direction followed by a short pause (Glaister et al., 2009). Due to the specific requirements of each sport, coaches, fitness trainers, etc. recommend that certain metabolic abilities be tested in conditions that mimic what happens in a match, as this would give results that would show a realistic picture of an individual's physical fitness (Hermassi et al., 2014). Since the playing handball is characterized by high-intensity activities with frequent changes of direction (COD), a test that includes a COD in addition to sprinting in one direction is more suitable for this purpose. The test that includes CODs is the 8 × 40 m repeated sprint test with changes in the direction of movement (hereinafter: the "8 × 40 m test"). In this test, the subject runs a 40 m long polygon and makes two CODs. First, subject runs in a straight direction for 10 m to the first marker, makes a 180° turn, then runs 20 m to the second marker, again makes a 180° turn and crosses the line where he started. Repeat the mentioned task 8 times. After each repetition, there is a 20-second break. As reported by Baker, Ramsbottom and Hazeldine (1993), this test can be used to assess anaerobic capacity and strength of the subjects. In the case of short-term sprints and rapid COD, this energy process dominates. Acceleration from rest to maximum speed, for example after a pass or when defending in sports games, is called starting speed (Ušaj, 2003). In other words, this type of speed can also be called starting acceleration. Since in many sports games (including handball), athletes must develop as much speed as possible in the shortest possible time, this ability is very important. It is related to the speed of direction changes and the speed of stopping (Čoh and

Bračič, 2010). Explosive power is very important in sports where athletes must develop as much speed as possible in the shortest possible time (quick changes of direction, jumps, accelerations, sprints, etc.), i.e., also in handball. It is a type of strength that manifests itself as overcoming effort or loads with the maximum possible acceleration (Ušaj, 2003). Explosive power represents the interaction between power and speed. Mechanically, explosive power represents the interaction between the amount of work done (the product of force and velocity) (Haff and Nimphius, 2012).

Because of everything described, in the research we were interested in how the time obtained in first and in the second COD in the "8 x 40 m test" is related to the result achieved in the jump with the counter movement - CMJ (explosive and elastic strength) and to the time achieved in the 5 m sprint with a high start (starting acceleration from the standing start).

Methods

Sample

The test sample included 55 handball players who were selected as candidates for the Youth and Yunior men's handball national team of Slovenia in the 2017/2018 season. When selecting the sample, we did not consider subjects who did not pass the test successfully (injury, incorrect execution of tasks, etc.).

Table 1

Proportion of subjects according to playing position

Playing position	**RW**	**RB**	**CB**	**P**	**LB**	**LW**	**GK**	**All**
Number	5	8	11	6	9	7	9	**55**
Share %	9,1	14,5	20,0	10,9	16,4	12,7	16,4	**100**

Legend. RW – right wing; RB – right back; CB – central back; P pivot; LB – left back; LW – left wing; GK -goalkeeper.

Table 2

Basic data of participants

	Subjects				
	N	$\bar{x}$	**S**	**Min**	**Max**
Age (years)	55	17,47	1,63	15	20
Body height (cm)	55	186,74	6,48	174	203
Body mass (kg)	55	82,91	9,42	63	104

Legend. N – number; $\bar{x}$ – average means; SD – standard deviation; Min – minimum; Max – maximum.

Variables

With the help of video analysis, which we performed in the Kinovea program 0.8.15., the time that an individual needed to make 180° COD in “8 x 40 m test”, was established. This time was defined by the time elapsed between the last step of running in the original direction of run (the measurement time began at the first touch of the foot, with which the subject began to perform a 180° COD and pushed off in the new direction of run) and sprinting at a distance of 5 m in the new direction of movement after a 180° COD (the measurement time ended when the subject with the centre of the hips came perpendicular to the placed marker, which marked a distance of 5 m).

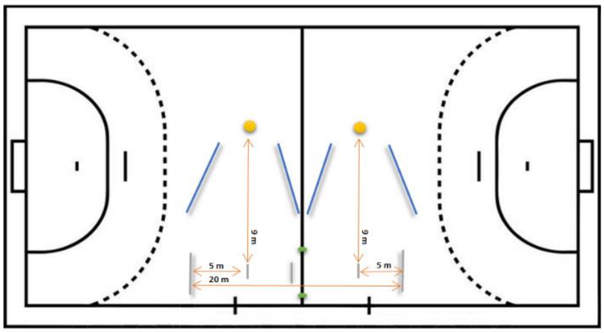

Figure 1. Illustration of 8 × 40 m polygon layout.

Cameras were positioned in the middle of each part of the polygon. The recording angle covered the entire course of the test and enabled the analysis of both CODs.

To obtained 5 m sprint time, the 30 m sprint test with a standing start, was used. This test was measured using a laser meter LDM-301. To determine push-off power, the counter movement jump (CMJ) test was used. Test were performed in the Kinesiology-Biomechanics Laboratory at the Faculty of Sports in Ljubljana. Push-off power was determined with the help of a tensiometric plate.

Results

Correlation between the 180° COD time obtained in 8 x 40 m test and the height of jump in CMJ test.

CMJ has become a very popular procedure for determining the contractile properties of the muscles of the lower limbs and thus the push-off power. It is a movement in which the muscle is actively stretched prior to its contraction, which allows it to develop greater force (Bobbert, Gerritsen, Litjens, and Van Soest, 1996).

Table 3

Basic statistical characteristics of the first and second 180° COD and the height of jump value obtained in CMJ test.

	N	$\bar{x}$	SD	Min	Max	S-W	pS-W
First COD (s)	55	1,50	0,083	1,35	1,68	0,96	0,10
Second COD (s)	55	1,53	0,078	1,38	1,71	0,98	0,48
CMJ (cm)	47	38,20	0,841	29,08	53,90	0,96	0,09

Legend. N – number; $\bar{x}$ – average value; SD – standard deviation; Min – minimum; Max – maximum; S-W – Shapiro Wilk test; pS-W – statistical significance of Shapiro-Wilk test.

The basic statistical characteristics of the average time of the first and second COD and height of jump in the CMJ test are given in Table 3. The average height of the jump in the mentioned test is 38.20 cm, the maximum height is 53.90 cm, and the minimum is 29.08 cm.

Table 4

Correlation between the time of both 180° COD and the height of jump value obtained in CMJ test.

	N	p-value	PCC
First COD	55	0,00	0,58
Second COD	55	0,00	0,46

Legend. N – number; p-value – statistical significance; PCC – Pearson correlation coefficient.

Results in Table 4 show the correlation between the average times of the first and second 180° COD and the height of jump values obtained in CMJ test. There are statistically significant ($p < 0.05$) correlations between the time of both CODs and the height of jump value obtained in CMJ test. Pearson's correlation coefficient (0.580 for the first COD and 0.460 for the second COD) indicates a moderate to low linear relationship with the height of jump value. Based on such a result, we can conclude that results (time) obtained in the CODs, are positively associated with the jump height values obtained in CMJ test.

Correlation between 180° COD time and 5 m sprint time in the first 5 m of the sprint test 30 m with a stand start.

When analysing the relationship between the 180° COD time and the time in the first 5 m of the sprint test 30 m with a stand start, three variables were used: the average time of all times in the first COD, the average time of all times in the second COD and the time in 5 m.

Table 5

Basic statistical characteristics of first and second 180° COD and the time in the first 5 m of the sprint test 30 m with a stand start

	N	$\bar{x}$	SD	Min	Max	S-W	pS-W
First COD (s)	55	1,50	0,083	1,35	1,68	0,96	0,10
Second COD (s)	55	1,53	0,078	1,38	1,71	0,98	0,48
T_{5m} (s)	47	1,05	0,007	0,96	1,17	0,98	0,53

Legend. N – number; $\bar{x}$ – average value; S – standard deviation; Min – minimum; Max – maximum; S-W – Shapiro Wilk test; pS-W – statistical significance of Shapiro-Wilk test.

Results in Table 6 show the statistical characteristics of the first and second COD and time achieved at 5 m. The average time on 5 m is 1.05 s, the minimum time is 0.96 s, and the maximum is 1.17 s. Due to injuries only 47 subjects successfully completed the "30 m sprint with a high start from a standing position" test.

Table 6

Correlation between the time of both 180° CODs and the time in the first 5 m of the sprint test 30 m with a stand start

	N	p-value	PCC
First COD (s)	47	0,00	**0,47**
Second COD (s)	47	0,02	**0,34**

Legend. N – number; p-value – statistical significance; PCC – Pearson correlation coefficient.

Table 6 shows the correlation between the times of both CODs and the time obtained at 5 m of the sprint test 30 m with a stand start. There is a statistically significant ($p < 0.05$) correlation both for the first and second COD and time obtained at 5 m. Pearson's correlation coefficient indicates a low or weak correlation (0.34) with the second COD and the medium or moderate correlation (0.47) with first COD. A possible explanation is that the speed of the second COD is more affected by fatigue compared to the first COD. During the second COD, however, strength responsible for powerful execution decreases somewhat.

Discussion and Conclusions

Despite moderate or even low correlation between jump height obtained in CMJ and time measured in both 180° CODs in "8 x 40 m test", we conclude that explosive power is one of the important factors that affects the effectiveness of COD execution, as well as the ability to accelerate after it. The essence of a good jump with the opposite movement is efficient or strong braking and rapid transition to acceleration or pushing off, and that's exactly how the mechanics of changing direction is (stopping or braking and then accelerating or pushing off in a new direction). A similar conclusion can be drawn regarding the correlation between the time required for 180° COD and the time achieved in the 5 m sprint. Here again, the correlation is weaker in the second COD. We speculate that metabolic factors (anaerobic) are important in the second COD due to fatigue rather than force production.

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CONSEQUENCES AND FREQUENCY OF CONVERGENCE INSUFFICIENCY IN HANDBALL GOALKEEPERS

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Summary

This research aimed to determine the frequency and consequences of convergence insufficiency (CI), the importance of proper eye convergence, and to put some light on the current lack of research on this topic among handball goalkeepers and in handball in general.

Keywords

Handball goalkeeper, vision training, convergence insufficiency, eye convergence

Introduction

The visual system is the primary sensory system for receiving information essential for every action of a handball goalkeeper in a match or practice session, and it is also the most neglected system in handball goalkeeper training.

The importance of visual system in handball goalkeeping

Specifically in handball goalkeeping - the main sensory system for taking in an external information is from the visual system.

In handball, but also overall in life, we get about 70% of all input about the outside world through our visual system.

In research, we can find different percentages on the role of the visual system but most research data agree that the sensory input that helps determine motor output is about 70% derived from the visual system.

Further, the research data agrees that another 20% of the input we get from the vestibular system, and the remaining 10% is from our proprioceptive input.

By far, the most important and the most complex sense for humans is vision. We perceive up to 80% of all impressions by means of our eyesight.

Every single action of a handball goalkeeper is initiated by visual input.

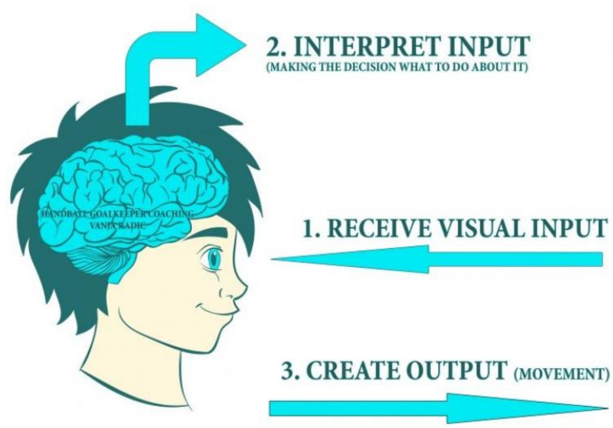
Since we get about 70% of all input about the world through our visual system, and since almost half of our brain is involved in visual processing, it should be clear why we need to include the visual system in goalkeeper training. Making the decision about the goalkeeper's movement in the goal is directly impacted by the quality of the visual input that goalkeeper's brain gets and perceives.

In order for the brain to perceive a clear information, our both eyes need to be able to see a clear image, and to work together, as a team.

Receiving and processing a visual input

There are three main steps that happen while the brain is receiving and processing visual input:

Receiving visual input – it happens every time when the information comes in through our eyes (an incoming ball, player's movement, etc.)



Interpreting visual input – after receiving the visual input, our brain then needs to interpret it and make a decision about what to do about it

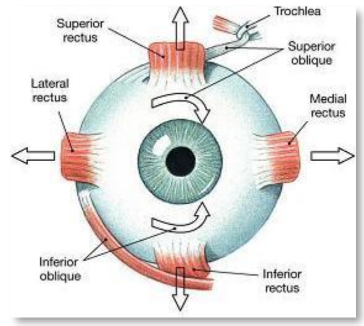
Creating the output – positioning, correcting position, or making a save movement

There are two perspectives of the visual system:

Biomechanics (physical aspect of the eyes)

Neurology (how your brain processes visual information)

Biomechanics

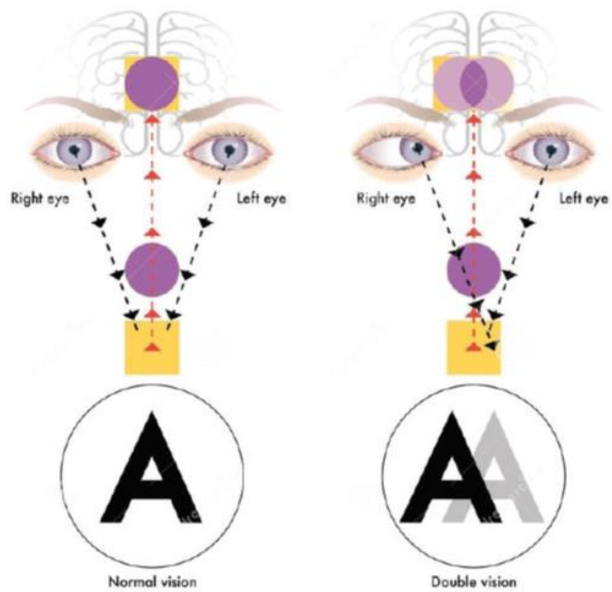


Each eye has six muscles that move it. For the brain to get accurate visual information from the eyes - the six muscles of the left eye have to be synchronized with the six muscles of the right eye.

Each eye muscle has its range of motion, which has to be used for optimal functioning and maintenance of the muscle.

But how often do we train eye muscles and move them to their full range of motion?

Eye teaming - binocular vision



Eye teaming (also known as binocular vision) is a visual skill that allows both eyes to work together as a team in a very precise and coordinated way. Eye teaming is also the basis for being able to have a good depth perception.

The left and right eyes are positioned slightly apart from one another, which allows them to capture slightly different perspectives of the same scene / image. The brain then blends these two separate images into a single, more complete, and more detailed image.

To be able to have a good vision, both eyes need to be able to capture images clearly, to send them to the brain, and for the brain to process the information from the two eyes and to combine the images captured by our two eyes into a single, cohesive image - to "see" the final image.

The binocular vision makes it possible for us to have depth perception, which is an extremely important aspect of vision. Processing images properly and clearly with both eyes enables the visual system to see in 3-D and to judge distances between objects, as well as to detect movement (all of which are important for handball goalkeepers).

When the ability of both eyes to work together to process visual stimuli is compromised, amongst several other challenges, it may also affect physical coordination in sports. Even when each eye has a good visual acuity - the ability to see clearly by itself, unless both eyes work together, blurred vision and/or a lack of depth perception can lead to coordination problems, or to different sports deficiencies.

Convergence insufficiency is one of the most common eye teaming problems.

Convergence Insufficiency

Eye Convergence is the ability of both eyes to move inwards, towards the nose, which is a necessary eye movement when tracking an incoming object. Eye Convergence Insufficiency (CI) is when the eyes struggle to work together when focusing on a nearby object. CI happens when the nerves that control our eye muscles fail to function correctly. For instance, when someone with CI looks at something up close, only one of their eyes may turn in, and the other eye turns out or stays focused in the centre. So instead of both eyes rotating toward each other to focus on the object, one or both eyes tend to drift outward, or away from each other. When this happens, the brain receives different visual information from the two eyes, which is causing a double or blurry vision, and a whole series of other challenges that are connected to that.

Convergence insufficiency is very common after a sport-related concussion.

When transferred to handball goalkeeping, some of the most common problems that convergence insufficiency can cause are:

- trouble catching a ball, or any other object
- a ball can appear closer or further away than it actually is
- loss of concentration
- impaired depth perception
- coordination problems
- reacting too early or too late to the shot, etc.

A really important distinction needs to be made - a person can see clearly and pass the 20/20 eye chart test and still have convergence insufficiency. Since the vision screenings only test distance vision acuity, they can't detect the presence of CI, and this is how a lot of handball goalkeepers end up having the CI not even knowing it.

Prevalence of convergence insufficiency

Even though CI can present at nearly any age, it is important to acknowledge that it's the most common in the young adult population. Prevalence of the CI range varies among studies, ranging from 1.7% to 33%. The incidence of CI in the general population is estimated to be 0.1 to 0.2%. There doesn't appear to be a correlation between gender and CI.

Convergence Insufficiency is a very common eye movement dysfunction in which eyes are not working together as a team while focusing on a near target. It's an eye teaming problem in which the eyes have tendency to drift outward while doing some eye close work.

Convergence insufficiency is very common after a sport-related concussion – it's present in 1 out of 2 people with concussion.

Methods

A total of 64 goalkeepers of various skill and experience levels from Finland, Sweden, Norway and Germany participated in this study (36 females, 28 males, mean age, 14.12 ± 0.42 years).

To collect information about the convergence insufficiency, the modified and simplified version of the near point of convergence (NPC) test was used.

Near point of convergence (NPC) is the point of intersection of the lines of sight of the eyes when maximum convergence is utilized.

The modified version of the NPC test based on a review of the literature was used, and it was consistently used for testing of all participants.

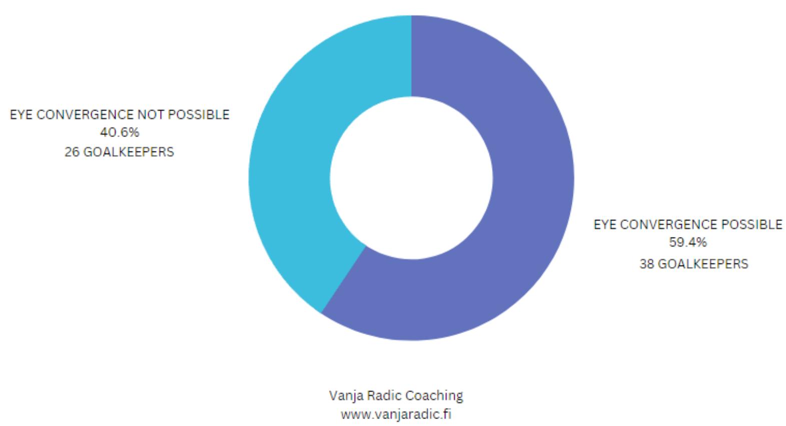
The specific modification included:

- the size of the target (all participants used the tip of their index finger as the target)
- the participant started the target (an index finger) at arm's length away, and moved it toward the center of their eyes
- the participants were seated
- the whole process was recorded with a video camera

The NPC was not established for this modified version of the test, because the main goal was to see only if both eyes could stay focused on an incoming target (the top of an index finger), and if the participants could keep both eyes converged - focused on the tip of the index finger placed on the middle of their nose, or between their eyes for a total of 3 seconds. Blurring of the image / the target was ignored because it is a normal reaction. An examiner observed an outward deviation of one or both eyes.

Result

In the modified version of the NPC test, it was discovered that a total of 38 goalkeepers (59,4%) could keep both eyes converged while focusing on a target, and 26 goalkeepers (40,6%) were not able to do it.



Since there doesn't appear to be a correlation between gender and CI, the participants were not split by gender.

Most of the participants who struggled to keep their both eyes converged had one of their eyes completely turned out, like presented in examples below.

Discussion and conclusion

Since the visual system is the primary sensory system for receiving information essential for every action of a handball goalkeeper, and since it is also the most neglected system in handball goalkeeper training, further investigation of this topic in handball is recommended.

It was indicated in this work that a lot of young goalkeepers have convergence insufficiency which is causing a lot of different challenges, but mostly it's causing problems with depth perception, reacting too early or too late on shots, loss of concentration, coordination problems, etc.

The consequences of CI can have negative impacts on goalkeeper performance, and potentially affect the save success rate.

The results of this work show that CI is very common among young goalkeepers, and it should be recognized as such, approached and worked on.

Further research is necessary to bring this topic closer to coaches and athletes in handball, and to start understanding the importance and the impact of it on goalkeepers, and also on players performance.

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DESCRIPTIVE ANALYSIS IN SMALL-SIDED GAMES WITH DIFFERENT CONFIGURATIONS IN U12 HANDBALL

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SUMMARY

There is a wide variety of game constructs—game forms—to introduce beginners to handball and modulate long-term player development. This study aimed to describe the impact of small-sided games on the game balance and game-play participation of U12 handball players. Ten players (five girls) took part in the study (n = 10). We concluded that numerical advantage might be a strategy to increase the volume of play.

INTRODUCTION

After the paradigm shift in the teaching of team games (from behaviourist to cognitivist and constructivist), modified games have become an essential pedagogical tool in creating stimulating and rich learning environments for learners (Pill et al., 2023). Thus, in contrast to the more traditional technical-analytical approaches centred on the adult formal game, the concepts of "pre-sport" and mini-sport emerged, along with the use of modified games and forms of play as a means of training (Estriga & dos Santos Graça, 2022a). The small-sided games (SSGs) are modified games played in smaller spaces with adapted rules and a smaller number of players than the formal games (Sarmento, 2018). The SSGs are a tool to develop tactical-technical behavior and physical skills in a similar context to the formal game (Rodrigues et al., 2022).

In 1994, the International and European Handball Federations jointly launched the concept of mini handball. In the construction of the mini-handball form of play, key structural changes in the rules of the game that are commonly accepted by the community stand out, such as the reduction in the number of players and the dimensions of the court, the goal, and the ball. Mini handball brings us a philosophy marked by a clear shift away from traditional approaches centred on the adult game model and training methodologies focused on performance and specialization. It also seeks to rescue the pleasure of the game, playfulness, and respect for the stages of psychomotor and affective development of the child. However, there is still a mismatch in the conceptions and game forms implemented in different contexts.

While some regions of the world and some countries introduce handball to children through forms of play based on numerical advantage with low defensive pressure, others adopt full-court individual defence. In addition, in some regions, such as Germany and parts of Spain, children can be exposed to the formal game (7x7 on an official field), similar to that of adults, even before the age of 10 (Estriga & dos Santos Graça, 2022a, 2022b). Therefore, it seems relevant to investigate how different game forms affect the opportunities to perform different game skills and their success. In that sense, we seek to analyse the game balance and how changing key game features affects the game actions from an inclusive and game-play participation perspective. Thus, this study aimed to describe the effects of different SSG configurations (or Basic Game Forms) on the game balance and game-play participation of U12 handball players.

METHODS

A set of ten players (n= 10), with five girls, participated in this exploratory study. All players practiced handball in a Portuguese club belonging to the U12 category (mean age 10 years ± SD 1 year). All the participants had between three months and two years of practice and trained between two and three times a week. Each training session lasted 1h30.

Procedures

This research was approved by the local Ethics Committee (CEFADE 24_2023) and followed the tenets of the Declaration of Helsinki regarding research with human beings.

We carried out different small-sided games in which we modified the game configurations (table 1). The key game features changed, including the ratio between attackers and defenders, defence type (full court marking or zonal), action constraints or scoring system (e.g., the ball must pass through everyone before shooting), and ball characteristics (regular or soft).

Each small-sided game lasted 10 minutes, with a 10-minute interval between games. The order in which the games were set up was randomly determined. All players took part in three games in which there were five players on each team. The teams were kept the same during all the games. However, in game 4 (4x3+GR), one player was randomly removed from each. It is important to note that the children involved in the research had already experienced these forms of play during the club's training sessions. Table 1 below describes the forms of play used in this work by age group.

Table 1. Configurations of the SSGs

SSG 1		**SSG 2**	
Game format	GK+4x4+GK	Game format	GK+4x4+GK
Pitch Size	28 x 15m	Pitch Size	28 x 15m
Type of ball	Size 0	Type of ball	Size 0
defence	Full-court individual marking	defence	Zone / in line
Other constraints	The goalkeeper can advance until midfield; Whoever scores becomes goalkeeper.	Other constraints	Goalkeeper stands; Change the goalkeeper after 5 minutes of the game.

SSG 3		SSG 4	
Game format	5x(4+GK)	Game format	4x(3+GK)
Pitch Size	28 x 15m	Pitch Size	28 x 15m
Type of ball	Size 0	Type of ball	Soft
defence	Zone / in line	defence	Zone / in line
Other constraints	Players can only score after passing the midfield. The ball must pass through everyone before shooting.	Other constraints	The ball must pass through everyone before shooting.

The data was collected in a single moment at the club's own facilities, on courts marked out for the specific purpose. An HD camera (GoPro Hero 11, California, USA) was used to record the SSGs and the action that took place. The camera was positioned perpendicularly to the court and above it, providing a full view of the game. After recording the SSG, we carried out a notational analysis based on video analysis.

Instruments

To carry out the systematic game analysis, we used the Team Sports Performance Assessment Tool (TSAP) (Grehaigne & Godbout, 1997), which is a tool based on direct observation and notational analysis that aims to analyse the context and dynamics of the game observed. In order to do so, collective tactical-technical observation categories were determined, taking into account the number of goals, shots, passes, receptions, steals, and dribbles, among others. Table 2 below shows the categories analysed as well as their descriptions.

Table 2. Categories analysed

Observation Categories by Team	
Game Balance (Goals)	Number of goals / Number of attacks
Game Balance (Shots)	Number of shots / Number of attacks
Volume of passes	Sum of passes (offensive and neutral passes)
Volume of Play	Sum of actions: passing, dribbling, stealing the ball, losing the ball, receptions and total shots

Data Analysis

An exploratory analysis of the results was carried out using simple descriptive statistics (volume of play, volume of passes, finishing opportunities, and number of goals scored).

Reliability

To analyse inter- and intra-rater agreement, two observers watched and analysed 10% of the recorded videos, according to (Tabachnick et al., 2013). The intra-class correlation coefficient of consistency (observer and subjects) (Weir, 2005) was then used to check the reliability of the observations. The results indicated 0.919 and 1.000

for the inter- and intra-rater analyses, respectively, which in both cases were considered excellent (Cicchetti, 1994).

RESULTS

Game Balance. Table 3 below shows the results for the Game Balance observed between the teams for all the SSGs applied. In the Balance (Goals) variable, only in SSG 1 there was a success rate of more than 50%, i.e., for every two attacks, team A scored a goal. In all the other SSGs, the Game Balance (Goals) was lower in absolute values for all the teams. In terms of Game Balance (Shots), both teams attempted to shoot in the majority of attacks in all forms of play.

Table 3. Game Balance

SSGs	Teams	Balance (Goals)	Mean Balance Between Teams	Balance (Shots)	Mean Balance Between Teams
SSG 1 **GK+4x4+GK**	**Team A**	56%	47%	83%	75%
	Team B	39%		67%	
SSG 2 **GK+4x4+GK**	**Team A**	30%	33%	95%	80%
	Team B	35%		65%	
SSG 3 **5x(4+GK)**	**Team A**	43%	38%	79%	69%
	Team B	33%		60%	
SSG 4 **4x(3+GK)**	**Team A**	30%	36%	70%	77%
	Team B	42%		84%	

Volume of Play. Table 4 below shows the data relating to the volume of play in each form of play analysed. The results suggest that in matches 3 and 4, characterized by numerical superiority, there was a greater volume of play or actions, considering absolute values, for example, the number of passes in SSG 4 almost doubled compared to SSG 1.

Table 4. Volume of Play, passes and finishing attempts (and goals)

SSGs	Key features	Ball type	Volume of Play		Volume of passes		Finishing attempts (goals)	
			TEAM A	TEAM B	TEAM A	TEAM B	TEAM A	TEAM B
SSG 1 **GK+4x4+GK**	Individual marking	Standard (bouncing)	109	82	61	46	15(10)	12(7)

SSG 2 **GK+4x4+GK**	(4-0) Zone defence	Soft	110	90	59	49	19(6)	13(7)
SSG 3 **5x(4+GK)**	(4-0) Zone defence	Soft	122	106	98	81	11(6)	9(5)
SSG 4 **4x(3+GK)**	(3-0) Zone defence	Soft	131	93	111	70	14(6)	16(8)

DISCUSSION

The idea of creating a proper dynamic difficulty balance (not too hard or too easy) or game balance to provide a stimulating and evolving game-play experience for both teams and players is an important issue in game initiation (Burton et al., 2011). The results shown in Table 3 suggest a greater Game Balance (Goals) in SSG 1 (with full court individual marking) in relation to the other SSGs (with zone defence). Regarding Game Balance (Shots), both teams attempted to shoot in most of their attacks in all SSGs. In addition, there were more attacks and a greater volume of play in games 3 and 4.

When we look at the results of the variable Game Balance (Goals), which shows the ratio between the number of attacks and goals, we see that it ranged from 30 to 56%. Koekoek et al. (2022) propose that to be considered a balanced game, this ratio should vary between 40 and 59%. Consequently, if we look at the results of the average Game Balance (Goals) of the games, we consider game 1 to be balanced and games 2, 3, and 4 to be slightly imbalanced (Koekoek et al., 2022). In this way, we can see that there was similar attacking and defensive success in game 1, while there was greater defensive success in the other games- since the Game Balance (Goals) was SSG 2: 33%, SSG 3: 38%, and SSG 4: 36%. These results may have occurred due to various reasons. In game 1, it is possible that the way the game was played contributed to this result, since there was one-on-one defence all over the court, and this might have increased the chances of success in 1v1 situations for the attack and made defensive actions, such as cover-ups, more difficult. On the other hand, in games 2, 3, and 4, we observed greater defensive success, i.e., the defence (including goalkeepers) managed to prevent the goal most of the time. In these games, the defences were zonal, which may have made it more challenging for the attack to create opportunities to finish without defensive opposition. The lined-up defence can facilitate defensive coverage because there is less space between the defenders, which may have contributed to greater defensive success. In game 3, even with one extra attacker, the defence was more successful than the attack. We speculate that for beginners in the sport, even with an extra player, the line defence can make it challenging to create clear chances to finish without or with little opposition, and consequently fewer goals were scored. Finally, it should be noted that in game 4, even in a game with fewer players (less complex), the defences were still more successful than the attack. The constraints of having to pass the ball to all the players before shooting, as well as using a soft ball (to discourage dribbling), may have contributed to the results of this research. Nevertheless, we are trying to describe and reflect on the results observed here without determining their causes or generalizing them. Modifying the game configurations generates consequences, and the challenge for coaches is to find ways of using them to achieve the learning objectives set.

Although we believe that the Koekoek et al. (2022) criteria is a useful tool for observing whether games are balanced between attack and defence, we decided to also study the relationship between the number of attacks and shooting opportunities. This decision was motivated by the understanding that shooting initiatives have pedagogical value, even if they are not successful. For game forms 1, 2, 3, and 4, there was an advantage in the attack, which took shots in the majority of attacks and might also be a promising environment for learning. This result could prompt coaches to focus on improving defensive performance in order to promote a greater balance between offensive and defensive success (Koekoek et al., 2022). However, considering that there were many shots, the percentage of successful shots was below 40% in most games (except game 1). Therefore, one can imagine that the shots were taken with opposition, from places closer to the sidelines of the court (less favourable), from a long distance considering the strength and power capabilities of the players, and/or from less adequate shooting decisions. Unfortunately, since we did not carry out enough analysis to know if these factors occurred, these possibilities are speculative and can be addressed in future work. objectives set.

The results obtained in Table 4 revealed that the games with numerical superiority had a higher volume of play, i.e., the total number of actions such as passing, receiving, stealing the ball, losing the ball, receptions, etc. These factors may have been due to the rule that the ball must pass through everyone before a shot is taken. In addition, the goalkeeper became a court player when his/her team was on the attack and had to return after his/her team lost possession of the ball. This factor may have contributed to the attack seeking to get the ball past everyone quickly, as well as shooting quickly, in order to score before the goalkeeper returns to the goal and/or position himself properly.

This work has various limitations, such as having a low sample size since we were unable to recruit more participants, which impacted our analysis and the possible potential for deeper conclusions. We also did not analyse individual participant data, which could have helped us to justify our results and expand the possibilities of interpretation, as well as collaborate more with the practice of future coaches.

FINAL REMARKS AND FUTURE WORK

As argued for, we believe that handball games with beginners can benefit from analysing the game balance and difficulty adjustments targeted at creating a well-balanced and challenging game for both teams and players. This led to dynamic game-balancing concerns to avoid undesired player emotions, such as boredom and frustration, or a lack of game play quality and variety in game constraints. Therefore, in this study, changing SSG configurations (lined-up defence and offensive advantage) and rules (e.g., the ball must pass through everyone before shooting and no bouncing) might have contributed to increasing the number of passes between all players, leading to a more participative and inclusive game. On the other hand, when playing with numerical equality and individual marking, a higher score appeared.

In summary, this paper provides an overview of how changing the game configurations and rules can potentially be a useful pedagogical source for dynamic game balancing and creating the intended player experience for game skill learning. Conversely, a more detailed game action analysis is needed to effectively confirm the effects detected here and better understand the reasons targeting this age category and low level of game experience.

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HOW COACHES SEE THE USE OF TECHNOLOGY IN SPORT: PRELIMINARY RESULTS

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Introduction

In the evolving landscape of sports, the integration of technology has become an increasingly prevalent and transformative force. Coaches, as main responsible of athletic development and strategy, stand at the forefront of this technological revolution. Their perspectives and approaches toward adopting and utilizing technological advancements shape the trajectory of sports performance, training methodologies, and competitive outcomes.

From a historical standpoint, the relationship between coaches and technology in sports has been both symbiotic and dynamic. Early adoption of innovations like video analysis by coaches such as Dorrance in soccer - Coach Logic (Cairns & Muir, 2016), or Belichick in American football laid the groundwork for a technological shift in coaching methodologies (Cairns & Muir, 2016; Gatz, 2009; Turnin & Want, 2023).

However, the rapid proliferation of technology in recent years has brought forth an array of novel tools and data-driven solutions, presenting coaches with a nuanced set of opportunities and challenges. Experts have explored the intricate intersection between technology and coaching, highlighting the potential for enhancing skill acquisition, performance analysis, and injury prevention (Beanland et al., 2014; Rittenberg et al., 2022; Southgate et al., 2016).

Yet, amidst the promises of improved performance lies a terrain rife with complexities. Coaches navigate a landscape where wearable tech (Adesida et al., 2019; Luckzak, 2020), data analytics (Nunes et al., 2020), virtual reality (Farley et al.., 2019), and artificial intelligence converge (Araújo et al., 2021; Dhar, 2017), raising questions about the balance between human intuition and data-driven decision-making in coaching methodologies (Thatcher et al., 2020).

This paper aims to delve into the multifaceted perceptions of coaches regarding the integration and impact of technology within sports, exploring the preliminary results. By drawing on empirical studies, questionnaires, and scholarly discussions, it seeks to illuminate the diverse viewpoints, apprehensions, and strategies employed by coaches in leveraging technology to optimize athlete development and competitive success, because technology enhances coaching (Cushion & Townsend, 2019), and help sports, when integrated in science (Kos et al., 2018).

Through a comprehensive exploration of these perspectives, this paper endeavours to offer insights into the evolving role of technology in coaching, its implications on athlete-coach dynamics, and the ever-evolving nature of sports performance enhancement.

Method

To elucidate the complex relationship between coaches and technology in the realm of sports, a methodical approach was undertaken. Between July and September, a structured questionnaire was meticulously designed and administered to coaches across various sporting disciplines. The utilization of the scientific method within this survey aimed to systematically uncover insights into coaches' perceptions, practices, and engagements with technology and technological advancements in sports and coaching.

Data

The questionnaire was thoughtfully crafted, comprising three distinct sections: 1) socio-demographic characterization: these questions focused on obtaining background information about the coaches, such as their coaching experience, sport specialization, and demographic data. This served as foundational knowledge to contextualize subsequent responses); 2) Coach Activity and Technology Use: this section delved into the practical application of technology in the coaches' daily activities. It probed their current utilization of technological tools, challenges faced, and the perceived impact of technology on their coaching methodologies; and 3) focus on technology: The crux of the questionnaire revolved around this section, concentrating solely on technological aspects. It encompassed inquiries spanning diverse technological domains, such as wearable tech, data analytics, virtual reality, and artificial intelligence. These questions aimed to unravel the depth of coaches' familiarity, comfort, and willingness to embrace various technological innovations.

The implementation of the scientific method within this questionnaire facilitated a structured and systematic exploration of coaches' perceptions concerning technology in sports coaching. By meticulously organizing the questionnaire into distinct sections and rigorously analysing the obtained data, this approach aimed to unearth comprehensive insights into the intricate interplay between coaches, technology, and the evolving landscape of sports performance enhancement.

Participants

The cohort of respondents to the technology in coaching questionnaire provides a diverse yet insightful glimpse into the landscape of coaches engaging with technological tools and methodologies. Among the 101 participants, notable demographics emerge, shedding light on the composition of coaches involved in the survey applied between July and September.

The sex distribution within the sample reveals a marked imbalance, with 17.8% of respondents being women coaches, highlighting an underrepresentation of female coaches within this study. Conversely, male coaches represent the predominant demographic, comprising 82.2% of the sample.

Educational attainment among the respondents is noteworthy, with 43.6% holding a higher education degree and 25.7% having achieved a master's degree. This emphasizes a substantial portion of coaches possessing advanced academic qualifications within the surveyed population.

Regarding professional background, 32.7% of respondents held a TPTD3, indicating elevated coaching credentials. Additionally, a predominant 80.2% of respondents were affiliated with Clubs, Associations, or entrepreneurial ventures, suggesting a professional engagement within established sports entities. Geographically, 30.7% of respondents originated from Lisbon, potentially signifying a regional concentration of coaches within the surveyed population.

An overwhelming majority of 80.2% of respondents reported actively utilizing technology in their coaching practices, underscoring the widespread integration of technological tools among coaches. Conversely, 19.8% indicated a lack of engagement or utilization of technological advancements within their coaching methodologies.

Results and Discussion

Wearable Technology

The survey probed coaches' familiarity and utilization of wearable technology, revealing intriguing insights into their engagement with these innovative tools. Among the respondents, 51% indicated familiarity with wearable technology, while an equivalent 51% reported actively using such devices within their coaching activities.

The parity between familiarity and utilization demonstrates a noteworthy trend within the coaching community. While the overall familiarity with wearable technology is consistent with its usage, it also suggests that a significant portion of coaches who are aware of these tools actively integrate them into their coaching methodologies.

The survey identified several prominent types of wearable technology prevalent among coaches:

Smartwatches: Emerging as the most recognized and utilized wearable technology, smartwatches garnered considerable attention within the coaching cohort. A substantial 30% of respondents reported actively employing smartwatches in their coaching activities, leveraging their diverse functionalities for real-time data monitoring and activity tracking.

Smart bracelets: Following smartwatches, smart bracelets were recognized as another prevalent form of wearable technology among coaches. Approximately 15% of respondents reported utilizing smart bracelets, harnessing their fitness tracking capabilities and health monitoring features to augment coaching strategies.

Virtual Digital Training Platforms: Virtual digital training platforms also stood out as significant tools adopted by coaches. Approximately 16% of respondents incorporated these platforms into their coaching methodologies. These platforms, often integrated with wearable sensors, facilitate immersive and interactive training environments, aiming to enhance athlete engagement and skill development.

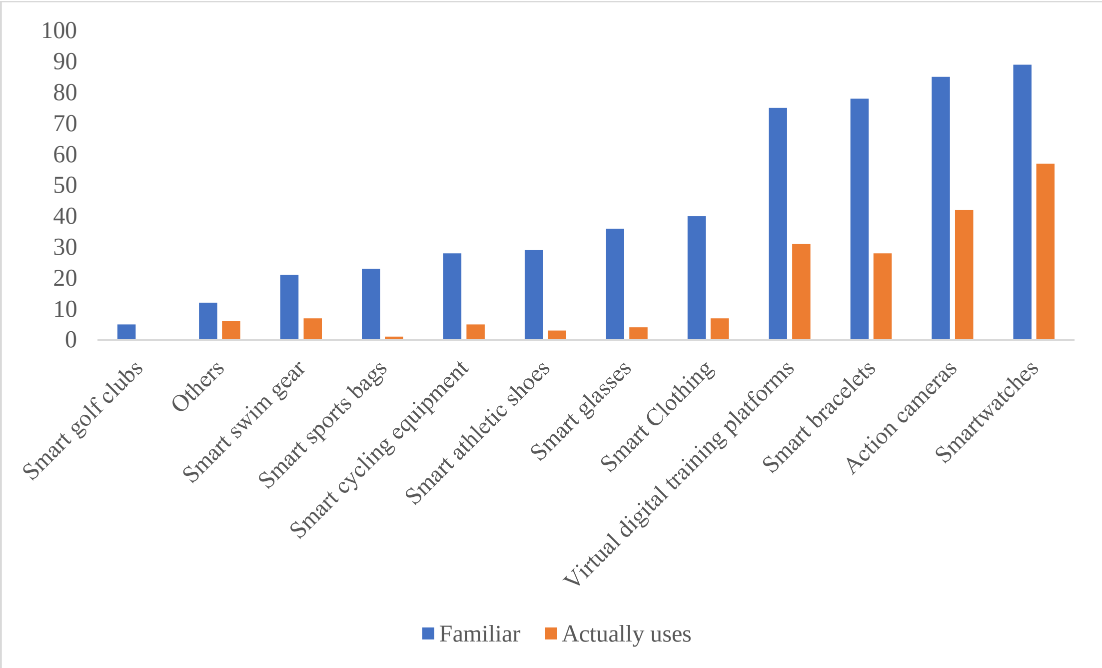

Figure 1. The figure shows which wearable technology coaches are more prom to know and use.

Video Analysis Software in Coaching

The investigation into coaches' engagement with video analysis software unearthed intriguing patterns regarding their familiarity and practical utilization within coaching contexts. Among the surveyed coaches, 37.6% expressed familiarity with video analysis software, while a smaller subset of 14% reported actively using these tools in their coaching activities.

Among the array of video analysis software recognized by coaches, two platforms stood out as the most known and utilized:

A significant 33% of coaches identified VO Sport/Video Observer as a familiar video analysis software. Furthermore, among those employing video analysis tools, 31% specifically utilized VO Sport/Video Observer, marking it as the foremost choice among the coaches actively leveraging video analysis in their coaching practices.

Following closely behind, XPS Sideline emerged as another prominent video analysis software, recognized by 20% of coaches. Among the subset of coaches using video analysis software, 28% reported employing XPS Sideline, positioning it as a significant platform utilized within coaching activities.

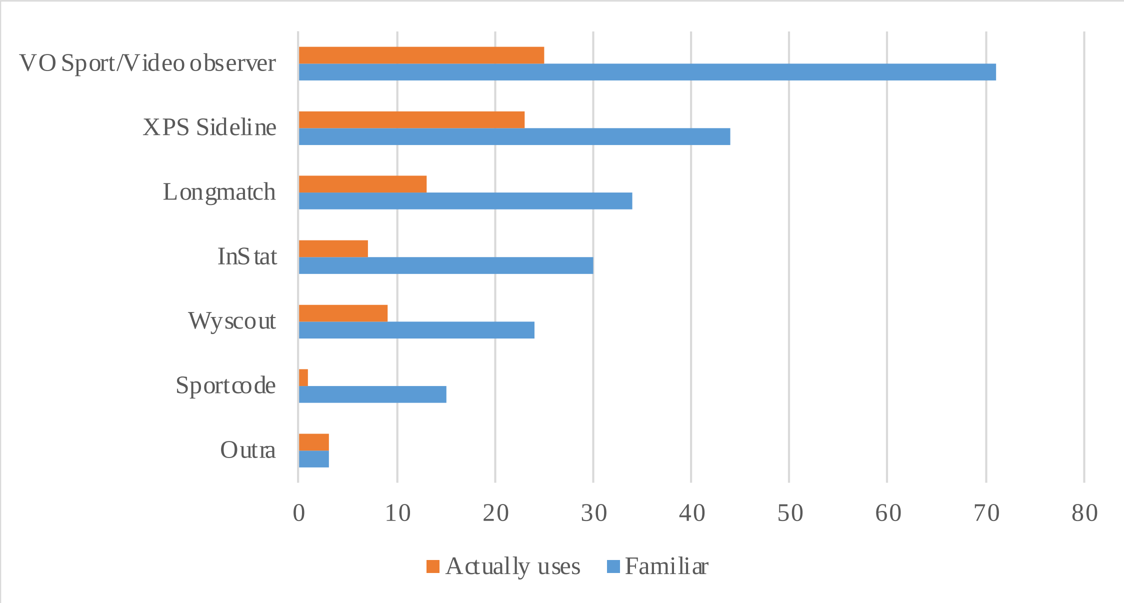

Figure 2. The figure shows which video analysis software are coaches more prom to know and use in training.

Virtual Reality Training

The exploration into the utilization of virtual reality (VR) training among Portuguese coaches revealed limited engagement and adoption within this technological domain. The survey responses indicated minimal involvement in VR training methodologies, with sparse instances of its implementation among the surveyed coaches. Among the respondents, only a handful demonstrated engagement with VR training tools: merely two respondents reported utilizing FIFA VR within their coaching practices. This platform, known for its immersive virtual reality experiences, found minimal traction among the surveyed coaches. Similarly, only one coach acknowledged employing Intel True VR as part of their training regimen, highlighting a sparse adoption of this technology within coaching environments. A solitary respondent mentioned using Box VR, representing a nominal presence of VR-based training tools among Portuguese coaches.

The scarcity of responses indicating utilization of VR training tools suggests a notable absence or underutilization of this technology within Portuguese coaching circles. The limited instances of VR engagement among the surveyed coaches indicate a prevailing lack of widespread integration or exploration of VR-based training methodologies within coaching practices.

Performance Analysis Software

The survey conducted to assess coaches' engagement with performance analysis software unveiled nuanced insights into the familiarity, utilization, and specific preferences within this technological domain. Among the respondents, 12% expressed familiarity with performance analysis software, while a smaller subset of 5.6% reported having used such software, with a mere 2.1% actively utilizing it within their coaching activities.

The disparity between familiarity, usage, and active utilization rates signifies a notable gap between awareness and practical integration of performance analysis software among the surveyed coaches. While a modest portion acknowledged awareness, a smaller fraction actively incorporated these tools into their coaching methodologies.

Several performance analysis software platforms emerged as the most recognized and utilized among coaches:

Kinovea: Garnering the highest recognition among coaches, Kinovea was familiar to 25% of respondents. Among those who had used performance analysis software, 31% reported utilizing Kinovea, and a substantial 37% continued to actively use it, signifying its sustained prominence.

Catapult Sport: Notably recognized by 16% of coaches, Catapult Sport held a significant presence within the surveyed population. Among users of performance analysis software, 15% reported utilizing Catapult Sport, with a consistent 16% still actively employing it in their coaching activities.

Coach’s Eye: Equally recognized by 16% of coaches, Coach's Eye also held a notable position. Among those who had used performance analysis software, 12% utilized Coach's Eye, and an enduring 16% continued to actively utilize this platform.

Dartfish: Acknowledged by 13% of coaches, Dartfish held a recognizable yet slightly lower position. Among users, 13% reported using Dartfish, with 11% continuing to actively incorporate it into coaching methodologies.

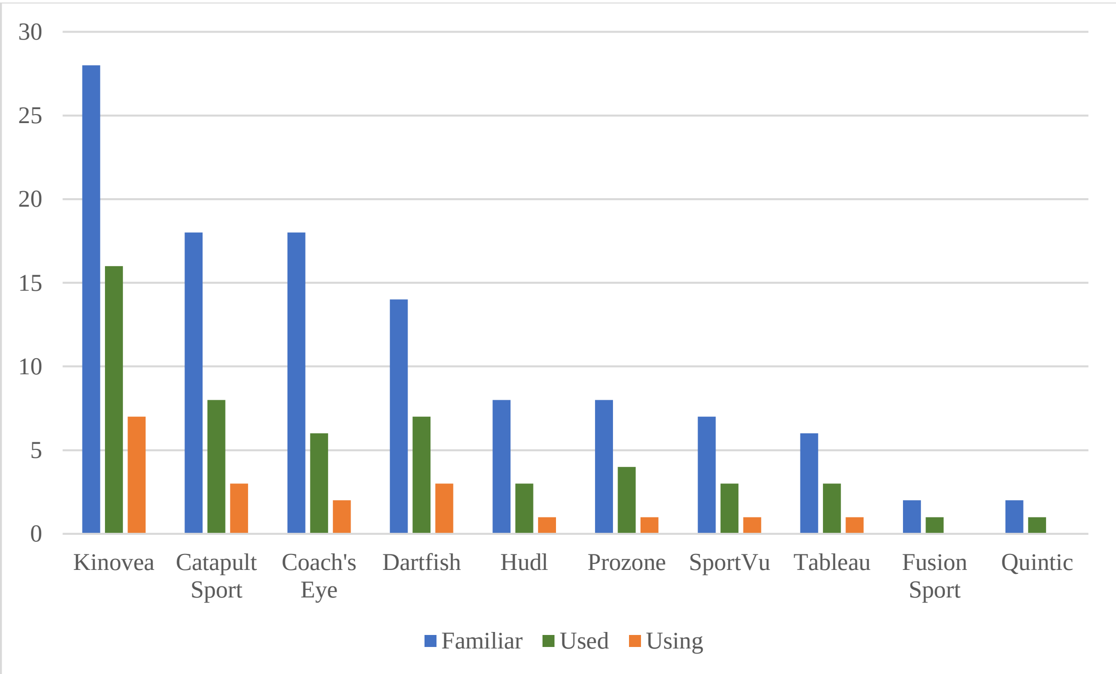

Figure 3. The figure shows which performance analysis software coaches are more prom to know, have used or are using in training.

Utility Assessment of Taxonomy Technological Tools in Coaching Practice

The evaluation of taxonomy technological tools within coaching practices unveils nuanced insights into their perceived utility and application among coaches. The assessment, based on a scale of 1 to 5, illustrates coaches' perspectives on the effectiveness and relevance of various technological tools within their coaching methodologies.

Video Analysis Software received the higher mean rating (3,61), indicating its perceived effectiveness in aiding coaches with in-depth video analysis, tactical assessment, and performance review. It was followed by Performance Analysis Software (M = 3,35), signifying its recognized effectiveness in aiding coaches with detailed performance assessments, video analysis, and tactical review. The high score of these two elements indicates its pivotal role and widespread acceptance within coaching methodologies.

Coaches attribute a moderate utility level to Wearable Technology (M = 3,12), indicating its relevance in monitoring athlete metrics and enhancing performance. Also, with a moderate rating the Smart Equipment garnered a moderate rating (M = 2,98), indicating coaches' acknowledgment of its utility in enhancing training and performance. In both cases its value suggests potential avenues for improvement or wider utilization within coaching practices.

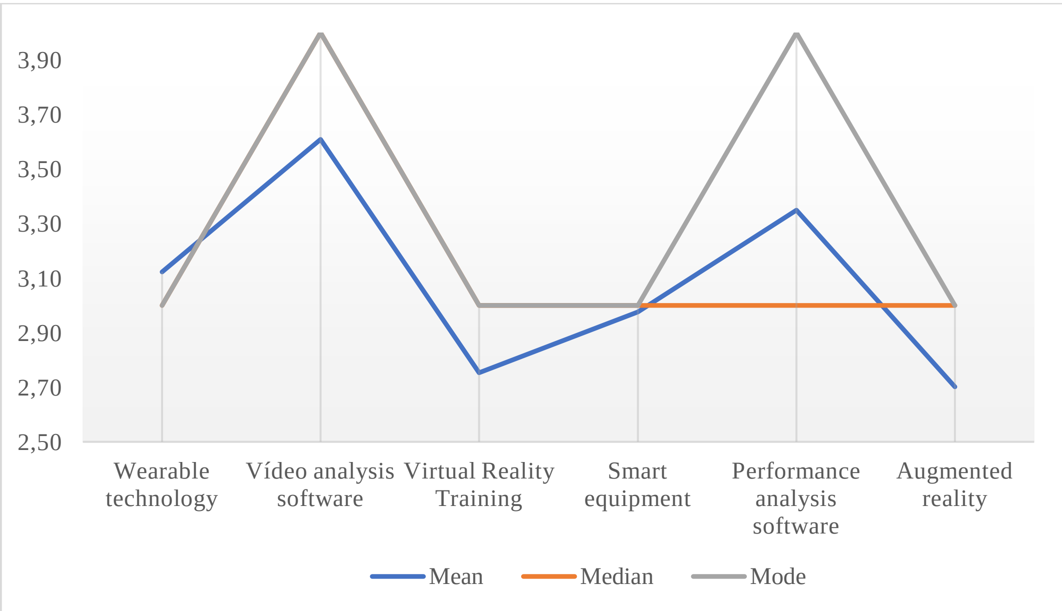

Figure 4. The figure shows the scores for tools utility.

Concerning Virtual Reality Training coaches rated it a lower score (M=2,75), indicating a perceived but somewhat limited utility within coaching practices. Alongside the Augmented Reality tools received the same score (M=2,70), implying a perceived but relatively limited utility within coaching practices. The score suggests potential need for further development or enhancement to augment its effectiveness within coaching contexts.

Conclusion

The integration of technology into coaching promises a revolution in sports training, showcasing the potential of wearable tech, video analysis software, VR tools, and performance analysis software. This landscape signals a shift in the way coaches optimize athlete development. Yet, there's a significant gap between awareness and seamless implementation of these tools. The consensus emphasizes the urgent need for tailored technology-focused training modules to equip coaches with the skills needed to maximize athletic performance effectively.

The rise of artificial intelligence (AI) in coaching brings forth transformative possibilities and concerns. AI's potential to reshape training methods prompts debates on its impact—will it revolutionize traditional coaching or pose challenges? Amid this transformative phase, it's critical to prepare sports professionals to harness technology effectively. Striking a balance between embracing innovation and preserving coaching's core principles will shape the future of sports training, ensuring that technology acts as a driving force for progress without compromising coaching's fundamental essence.

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THE INFLUENCE OF TECHNICAL EXECUTION OF SINGLE LEG LONG JUMP ON JUMPING PERFORMANCE IN TEAM HANDBALL

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Summary

In Team handball explosive unilateral movements are essential and highly correlate with sports performance. The aim of the study was to discover the influence of technical performance of Single Leg Long Jump (SLLJ) on jump length of top-level Team handball players. We found out that in case of SLLJ the positioning of the knee joint and shin angle in lateral plane during take-off phase had the biggest effect on jump length.

Keywords

Team handball, Single leg long jump, Technical performance, Jump kinematics

Introduction

In Team handball explosive unilateral movements are essential and highly correlate with sports performance. A movement analysis enables to detect deficiencies in the performance of basic movement tasks or technical elements. It can help us to find risk factors for potential injuries or to improve the technical performance of the movement. Movement patterns that represent a deviation from the optimal technical performance of a movement task or a technical element in sports cause unfavourable redistribution of forces on muscles, tendons and joint structures, which increases the risk of injury (Moore, 2016).

The single leg long jump (SLLJ) is a test used to determine power of leg muscles and the ability to generate force in the horizontal plane (Madruga-Parera et al., 2020). The performance of the SLLJ is determined by the length of the jump, which is measured from the marked point of push-off phase to the point where the first contact with the ground occurs. Test consists of a simple protocol, is time efficient, does not require expensive equipment and is therefore an excellent choice for measuring power of the lower extremities. It represents a good connection with the athlete's speed abilities, such as acceleration and maximum speed (Lin et al., 2023). Standing long jump (SLLJ) performance strongly correlates with sports performance (McErlain-Naylor et all., 2014). Current available research shows that jumping performance is positively influenced by power (Aragón-Vargas & Gross, 1997), coordination (Bobbert, 2002) and mobility (Godinho et al., 2019), while asymmetries in physical abilities negatively affect to jumping performance (Bishop idr., 2016).

Kinematic variables are often used for analysing jumping performance, but there is a lack of evidence examining the relationship between kinematic variables and SLLJ performance. In previous published research papers, the take-off angle has been highlighted as the most important kinematic variable for SLJ performance (Wakai and Linthorne, 2005). The main aim of the present study was to demonstrate a simple testing procedure for evaluating the technical execution of the SLLJ and to determine whether the technical execution of the SLLJ effects on the length of the jump.

Methods

Eighty top level Slovenian handball players participated in the study (age 22 ± 4; body mass 90,8 ± 10 kg; height 189,8 ± 5,6 cm; training experiences 12 ± 4 years). Testing procedure was explained to each participant and the entire course of the experiment was carried out in accordance with the Helsinki-Tokyo Declaration and approved by the Committee for Ethical Issues in the Field of Sport at the University of Ljubljana, Faculty of Sports (No. 14:2023).

Participants attended one testing session that took place at the Faculty of Sports in Ljubljana. Prior to the testing session a standardized warm-up was performed. The measurement protocol consisted of six SLLJ jumps (three jumps per leg). The jump distance was measured from the push-off point to the landing point (the back of the footwear). The test subject performed a jump, which consisted of a short and fast eccentric descent, followed by a fast-concentric part and a jump. The dominant leg was determined based on the better jumping score.

At the testing station, self-adhesive markers were placed on the participants, on the following anatomical points: in the lateral plane on I) the middle of the deltoid muscle, II) the greater trochanter, III) the lateral epicondyle and IV) the lateral malleolus, and in the frontal plane on I) the lowest part of sternum, II) on the anterior upper edge of the iliac spine, III) the middle of the femur (half the distance from the middle of the patella to the ASIS), IV) the centre of the patella, and V) the middle of the instep.

All repetitions were recorded in the lateral and frontal plane. We used Panasonic DMC-FZ200 cameras with a recording frequency of 100 Hz (Panasonic Corporation, Kadoma, Osaka, Japan). Video analysis was then performed in Kinovea program. The reliability and validity of the software for obtaining kinematic parameters was excellent (ICC < 0.80). The space was calibrated with the longer side of the marked rectangle on the floor. Markers were manually placed in Kinovea program at certain time frames of the video and thereby obtained values in space. The selected time frames were: i) moment before the start of decent, ii) moment of the lowest amplitude of the decent and iii) the moment of push-off (only in lateral plane for determining take-off angle).

All obtained values in 2D space were exported to Excel (Microsoft Office Excel 2019, Microsoft, Washington, USA), where we calculated (using pre-prepared equations) slopes and angles between body segments in the lateral (shin, thigh, torso) and frontal (shin, thigh, pelvis, and torso) planes. The direction coefficients of the individual lines of the segments were obtained using the following equation (see Formula 1).

$$k = \frac{(y_2 - y_1)}{(x_2 - x_1)} \quad (1)$$

At the selected time points, we calculated the slopes of individual elements relative to the vertical line (k = 0). They were all calculated in degrees as the arcus tangent (arctan) of the slope of the line of the previously mentioned body segments (see Formula 2).

$$slope\ of\ body\ segment = |\arctan k| \quad (2)$$

Lastly, we calculated the angles in the knee, hip, and vertical push-off amplitude in the lateral plane, as well as the angles in the knee, pelvis and trunk in the frontal plane - individually for each jump and leg. They were calculated as the arcus tangent of the absolute values of the differences in the direction coefficients between nearby body segments, more precisely in the frontal plane pelvis-trunk, thigh-pelvis, tibia-thigh and in the lateral plane thigh-trunk and tibia-thigh (see Formula 3).

$$joint\ angle\ (k_{segment\ 1}\ and\ k_{segment\ 2}) = \arctan |k_{segment\ 2} - k_{segment\ 1}| \quad (3)$$

Before carrying out the statistical analysis, we checked the relevant assumptions for the selected statistical analyses. To improve the reliability of the results, we entered the statistical analysis with the average of three repetitions of all tests. The reliability of the results was checked before statistical analysis using the interclass correlation coefficient (ICC) and the coefficient of variance (CV).

Differences between legs in results and technical execution of jumps in the lateral and frontal planes were analysed with a t-test for dependent samples. Pearson's correlation coefficient (r) was used to assess the strength of the linear association between the variables. To determine the strength of the effect of the test statistic, we used Cohen's d coefficient. The influence of the technical execution of jumps on the length was determined for each jump separately using multiple regression. Using the same method, we also determined the influence of differences between the legs in the technical execution of the jump on the length, and finally, we also determined the predictive values of the kinematic variables on the length of the jump. The differences between the legs were previously calculated using the index of symmetry between the legs (Bishop et al., 2016).

We also checked the assumptions of normality of distribution, homoscedasticity, and the absence of multicollinearity. The predicted number of variables in each model was determined using the forward selection method. The statistical characteristics of the predictive values were verified by analysis of variance (ANOVA). In the task, we only list the results of variables whose predictive values statistically significantly predict the results of jumps ($p < 0.05$). The random influence of the explained variance of the model was excluded with the values of the corrected R2 coefficient, which was used to compare the fit of the regression models. The values of the asymmetries between the legs of all kinematic variables were calculated based on the following equation (see Formula 4).

$$asymmetry = \frac{(dominant\ leg - non-dominant\ leg)}{dominant\ leg}\ x\ 100 \quad (4)$$

Results

Table 1: Reliability of push-off performance of a dominant and non-dominant leg

Leg	Variable (cm)	rep1	rep2	rep3	CV (%)	ANOVA	*p*	ICC
		M(SD)	M(SD)	M(SD)		F		(95 % CI)
DOM	Jump length	198,93 (18,71)	204,87 (16,33)	207,29 (16,16)	3,99	23,15	<0,05	0,72 (0,60; 0,81)
NDOM		188,82 (19,29)	193,82 (19,61)	195,24 (22,15)	5,18	9,93	<0,05	0,74 (0,65; 0,81)

Key: rep. 1 *- first repetition;* rep. 2 *- second repetition;* rep. 3 *- third repetition;* M *- arithmetic mean;* SD *-standard deviation;* CV *- variance coefficient;* ICC *= intra-class correlation coefficient;* CI *= confidence interval;* DOM *– dominant leg,* NDOM *– non-dominant leg.*

In the Table 1 we can see the reliability analysis of the jump length between three jump repetitions of dominant and non-dominant leg. Results show a good reliability for jump length with both legs (ICC = 0.72 and 0.74). We found out acceptable CV values (CV < 10%) and statistically significantly differences were found between all jump repetitions (ANOVA; p > 0.05).

Table 2: Differences between dominant and non-dominant leg in jump length

Variable (cm)	Repetition average			*r* (95% CI)	*r (p)*	*t*	*t (p)*	*d*
	DOM	NDOM	Difference					
	M(SD)	M(SD)	M(SD)					
Jump length	203,28 (15,65)	191,96 (18,76)	10,72 (11,75)	0,78 (0,67; 0,86)	<0,05	7,95	<0,05	0,91

Key: All results are obtained on the average of three results. DOM = dominant leg; NDOM = non-dominant leg; M = arithmetic mean; SD = standard deviation; CI = confidence interval; d = Cohen's d coefficient.

Table 2 shows the differences in jumps between the dominant and non-dominant leg. We found out statistically significant differences between the legs in the jump length results (p < 0.05). Differences between legs were large (d > 0.9). Based on the Pearson correlation coefficient, we found a very high correlation between the results of the dominant and non-dominant leg for the length of the jump (r = 0.78; p < 0.05).

Table 3. The influence of kinematic variables on the length of jumps with dominant and non-dominant leg

Leg	Best prediction variables	*R*	R^2	*R* adj.	*SE*	*βs*
DOM	lateral – take-off angle*	,51	0,26	0,24	13,37	– 0,45
	lateral – hip angle*					– 0,24
NDOM	lateral – take-off angle**	,53	0,28	0,24	16,79	– 0,28
	frontal – trunk inclination*					0,30
	lateral – shin inclination*					0,25

*Key: DOM = dominant leg; NDOM = non-dominant leg; R adj. = adjusted R2; SE = standard error; βs = beta standardized coefficient. * p < 0,05. ** p < 0,001.*

In the Table 3 we can see results of the multiple regression analysis, which was used to analyse the influence of kinematic variables on the length of one-legged jumps. We found that the length of the SLJ with the dominant leg at the key moment of processing is statistically significantly negatively influenced by the take-off angle and the hip angle in the lateral plane (R2 = 26%). The non-dominant leg jump result is at the key moment of processing, statistically significantly negatively influenced by the take-off angle, and statistically significantly positively influenced by the inclination of the trunk in the frontal plane and the inclination of the shin in the lateral plane (R2 = 27.6%).

Discussion

The main finding of our research is that in our sample of subjects, statistically significant differences exist between the dominant and non-dominant leg in long jump results. The differences in long jumps between legs can be partly attributed to the different technical execution of the SLLJ.

Statistically significant differences in kinematic variables were confirmed in the following variables: in the lateral plane for I) knee angle, II) take-off angle and III) shin inclination, and in the frontal plane for IV) pelvis-trunk angle.

Using regression analysis, we found that a smaller take-off angle meant a longer jump. Wakai and Linthorne (2005) also came to similar results. The next observation, which applied to both legs, was that a smaller hip angle means a longer jump. In addition, we can add that a greater inclination of the trunk has the same effect, since the two variables are similar. The findings coincide with previous research (Kariyama and Zushi, 2013; Kariyama et al., 2017; Nagano et al., 2007) where was highlighted that during the long jump performance the hip joint is extremely important for generating horizontal explosive force and helps to efficiently move the centre of body mass in a horizontal direction.

In the case of the non-dominant leg, we found that a greater inclination of the shin in the lateral plane is associated with a forward shift of the centre of body mass and a longer jump, and is directly associated with a lower take-off angle as well. This allowed the jumpers to transfer the centre of body mass forward and create a good predisposition for jumping performance (Kariyama, 2017 et al.; Nagano et al., 2007). We also found that a greater inclination of the trunk in the frontal plane affects to a jump length. We conclude that this occurs due to easier maintenance of balance, since the jumper stands on one leg (Kariyama and Zushi, 2013). An additional reason may also be that the proper stretch of the trunk and hip joint muscles (for purpose of rotation), providing a longer path for the force development (Kariyama et al., 2017). Although we found variables that can partially explain the result, we must be careful, because the predicted value is “always less” than 30%, which means that there are other variables that affect jump performance with varying strength levels.

Conclusions

In the sport practice we would suggest practicing the technical execution with an emphasis on lowering the take-off angle and explosive use of the hip joint in the horizontal direction, which is achieved with a deep forward bend of the trunk and an inclination in the horizontal direction. Additional attention would also be advised in eliminating I) differences between the dominant and non-dominant leg in terms of ankle mobility and II) asymmetries of the hip and trunk muscles. SLLJ is a complex movement task, and its performance is dictated by many different factors, so further research is needed. Based on our findings, it would be reasonable to analyse other factors, such as muscle strength and their predictive values of SLLJ together with kinematic variables.

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DIFFERENCES IN SOME PHYSIOLOGICAL PARAMETERS OBTAINED IN THE 30–15 INTERMITTENT FITNESS TEST AMONG ELITE HANDBALL PLAYERS ON DIFFERENT PLAYING POSITION GROUPS

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Summary

The purpose of the study was to assess differences in some physiological parameters obtained in the specific field endurance test among groups of elite handball players in different team playing positions at Lactate threshold (LT), at Onset of Blood Lactate Accumulation (OBLA) and at peak velocity at the test (v30-15IFT). The results suggest that very few differences occurred in the selected physiological parameters between wings (W), backs (B) and pivots (P).

Keywords

handball, playing positions, aerobic field-test, physiological parameters

Introduction

The intensity and volume of work-rate or loading intensity and volume of the load in handball are highly heterogeneous. During play, work-rate or loading, which may vary in intensity and volume, alternates continuously with periods of relative rest, i.e. standing or slow walking (Sibila et al., 2004). A well-developed aerobic system allows handball players to tolerate the high intensities and physiological load of the daily training, in addition to enhancing recovery between training sessions and competitions (Dello Iacono et al., 2018). Competitive handball involves position-specific differences in the physiological demands (Povoas et al., 2014a). It can be argued that activity profiles in handball are modulated by playing position and playing time (Büchel et al., 2019).

According to previous results repeated shuttle run performance and measured functional abilities during the test, play an important role among several factors of playing performance in team sports (Mohr et al., 2003; Thomas et al., 2006; Castagna et al., 2007; Castagna et al., 2008; Sirotic and Couts, 2007; Covic et al., 2016).

For the purpose of resolving training intensity prescription issues in intermittent team sports, the 30–15 Intermittent Fitness Test (30–15IFT) was developed (Buchheit, 2008a; Haydar et al., 2011). The 30–15IFT estimates aerobic capacity (VO2max), determines maximal heart rate (HRmax) and anaerobic and intermittent HR capacity (Buchheit and Rabbani, 2014; Thomas et al., 2015). The primary outcome measure of the 30–15IFT is running velocity (v30–15IFT) for the last completed stage (Buchheit, 2010), a suitable alternative to running velocity at maximal oxygen uptake (vVO2max) and HR_{peak} (Rabbani and Buchheit, 2015).

The aim of this study was to determine differences in some physiological parameters obtained during the 30-15IFT between W, B and P in elite male handball. Due to positionally generated differences in morphological and physiological profile and because of the different activity profiles of the players in the game, we assumed that differences would occur among groups of players in some physiological parameters obtained at lactate threshold (LT), onset of blood lactate accumulation (OBLA) and peak velocity in the 30–15IFT as well.

Methods

The participants of this study were 24 elite men handball players – members of senior national team of Slovenia (age = 23.17±5.1 yrs., body height = 187.8±6.7 cm, body mass = 89.0±9.3 kg and body mass index = 25.23±1.99). According to their playing positions participated 8 B (age = 20.65±2.0 yrs., height = 189.4±4.5 cm, body mass = 86.6±3.1 kg, BMI = 24.14±1.99), 8 W (age = 25.7±5.9 yrs., height = 183.5±6.3 cm, body mass = 83.6±7.5 kg, BMI = 24.82±1.50) and 8 P (age = 23.2±5.7 yrs., height = 190.5±7.6 cm, body mass = 96.7±10.5 kg, BMI = 26.64±1.34).

Basic anthropometric parameters (stature and body mass) were registered in the study protocol. After shuttle run performance was tested using 30–15IFT (Buchheit, 2008a).

To obtain physiological parameters we used a portable gas analyser K4 *b2* (COSMED, S.r.l. Italy) which provides values of oxygen uptake (VO_{2max}), carbon dioxide production (VCO_2), pulmonary ventilation (VE) breath by breath respiratory exchange ratio (RER), oxygen pulse (OP), VO_2 versus HR ratio (volume of oxygen consumed by the body per heartbeat).

Arterialised blood samples (20 μl) were collected from the earlobe after each third running interval during the test (ecery 2 min 15 seconds) and in 1st and in 3rd minute of recovery after last performed run stage and analysed for blood lactate concentration ($[LA^-]$) using a Kodak Ektachrome analyser. Heart rates were measured using Polar S-610 heart rate frequency meters (Polar Electro, Kempele, Finland).

The statistical Package for Social Sciences SPSS (v22.0, SPSS Inc., Chicago, IL) was used for the statistical analysis. Descriptive statistics were calculated for all experimental data. The Kolmogorov-Smirnov test was used to test if the data was normally distributed. Due to the fact that data was not normally distributed, we used non-parametric methods to determine the differences among team playing positions. The Kruskal – Wallis 1-way ANOVA and Mann – Whitney U test were used to determine the differences between playing positions. Data were presented as mean±SD, and the alpha level for significance was set at $p \leq 0.05$.

Results

Statistically significant differences between three playing positions were found in v30-15IFT (Tables 1 and 2), respiratory frequency (RF) (Table 6), heart rate (HR) (Tables 1, 2 and 3) and respiratory quotient (RQ) (Table 6) at LT, OBLA and peak velocity.

W achieved statistically significant higher v at OBLA as B (Table 2). W had statistically significant higher RF as B at peak velocity (Table 6). B had statistically significant higher RQ as P at peak velocity (Table 6). The statistically significant difference occurred in HR at LT, OBLA and peak velocity (Table 1).

No statistically significant differences between three playing positions were found for VT, VO_2, $VO_2 \cdot KG^{-1}$, VCO_2, VE, $HR \cdot VO_{2max}^{-1}$ at LT, OBLA and peak velocity and LA_{max} (Tables 4, 5 and 6).

Table 1

Obtained velocities and heart rates during the $30–15_{IFT}$ test at LT

	All	Back players	Pivot players	Wing players
Velocity ($km.h^{-1}$)	13.04±0.85	12.65±0.78	12.90±1.02	13.58±0.46
Heart rate ($b.min^{-1}$)	154.58±10.33	146.13±8.41*†	155.88±7.55†	161.75±8.96*

Note. * – statistically significant difference ($p≤0.05$) – B vs W

† – statistically significant difference ($p≤0.05$) – B vs P

Table 2

Obtained velocities and heart rates during the $30–15_{IFT}$ test at OBLA

	All	Back players	Pivot players	Wing players
Velocity ($km.h^{-1}$)	16.63±1.14	16.26±0.70*	16.39±1.58	17.24±0.81*
Heart rate ($b.min^{-1}$)	176.25±9.15	171.75±9.18*	174.75±6.04	182.25±9.36*

Note. * – statistically significant difference ($p≤0.05$) – B vs W

Table 3

Obtained velocities. heart rates and lactate [LA^-] during the $30–15_{IFT}$ test at peak velocity

	All	Back players	Pivot players	Wing players
Velocity ($km.h^{-1}$)	19.46±1.16	19.19±1.33	19.13±0.99	20.06±1.02
Heart rate ($b.min^{-1}$)	182.88±7.40	181.88±2.75	178.13±5.11‡	188.63±9.02‡
[LA^-] ($mmol.L^{-1}$)	9.22±3.21	9.35±4.12	9.13±2.72	9.19±3.08

Note. ‡– statistically significant difference ($p≤0.05$) – P vs W

Table 4

Obtained respiratory parameters of the subjects according to team positions during the 30–15_{IFT} test at LT

	All	Back players	Pivot players	Wing players
LT_Rf (b.min^{-1})	35.82±6.94	33.19±4.87	34.99±7.48	39.29±7.49
LT_VT (L)	2.36±0.34	2.36±0.28	2.41±0.46	2.31±0.29
LT _VE (L.min^{-1})	83.45±14.03	78.68±16.22	81.96±9.96	89.70±14.53
LT _VO_2 (mL.min^{-1})	3324±499	3162±457	3412±618	3397±429
LT _VCO_2 (mL.min^{-1})	2676±521	2689±559	2636±593	2703±475
LT _VO2•kg^{-1} (mL.min^{-1}.kg)	36.80±5.08	34.42±3.74	37.32±5.35	38.67±5.61
LT _RQ	0.80±0.08	0.85±0.08	0.77±0.08	0.80±0.08
LT _VO_2·HR^{-1} (mL.bmp^{-1})	21.52±3.12	21.61±2.57	21.98±4.50	20.98±2.11

Note. LT_RF – respiratory frequency at LT; LT_VT – tidal volume at LT; LT_VE – pulmonary ventilation at LT; LT_VO_2 – oxygen uptake at LT; LT_VCO_2 - minute volume of exhaled carbon dioxide at LT; LT_VO2•kg^{-1} – relative oxygen uptake at LT; LT_RQ - respiratory quotient at LT; LT_VO_2·HR^{-1}– oxygen pulse at LT;

Table 5

Obtained respiratory parameters of the subjects according to team positions during the 30–15_{IFT} test at OBLA

	All	Back players	Pivot players	Wing players
OBLA_Rf (b.min^{-1})	46.89±6.49	44.64±4.74	45.82±5.90	50.21±7.84
OBLA _VT (L)	2.74±0.38	2.79±0.44	2.76±0.43	2.67±0.30
OBLA _VE (L.min^{-1})	127.61±19.97	124.87±25.46	125.28±18.12	132.69±17.02
OBLA _VO_2 (mL.min^{-1})	4183±522	4150±624	4227±500	4171±503
OBLA _VCO_2 (mL.min^{-1})	3867±676	4049±789	3821±686	3730±589
OBLA _VO2•kg^{-1}(mL.min^{-1}.kg)	46.34±5.20	45.13±4.94	46.45±4.77	47.44±6.22
OBLA _RQ	0.92±0.10	0.97±0.09	0.90±0.10	0.89±0.09
OBLA _VO_2·HR^{-1}(mL.bmp^{-1})	23.76±2.96	24.13±3.14	24.23±3.18	22.91±2.76

Note. OBLA_RF – respiratory frequency at OBLA; OBLA_VT – tidal volume at OBLA; OBLA_VE – pulmonary ventilation at OBLA; OBLA_VO_2 – oxygen uptake at OBLA; OBLA_VCO_2 - minute volume of exhaled carbon dioxide at OBLA; OBLA_VO2•kg^{-1}– relative oxygen uptake at OBLA; OBLA_RQ - respiratory quotient at OBLA; OBLA_VO_2·HR^{-1}– oxygen pulse at OBLA;

Table 6

Obtained respiratory parameters of the subjects according to team positions at peak velocity

	All	Back players	Pivot players	Wing players
MAX_Rf ($b.min^{-1}$)	53.73±7.01	51.64±4.29*	52.08±8.89	57.46±6.33*
MAX_VT (L)	2.87±0.41	3.00±0.38	2.89±0.50	2.73±0.34
MAX_VE ($L.min^{-1}$)	152.35±15.55	154.64±19.36	146.91±9.83	155.52±16.48
MAX_VO_2 ($mL.min^{-1}$)	4646±565	4475±726	4782±561	4679±387
MAX_VCO_2 ($mL.min^{-1}$)	3421±700	4687±887	4407±682	4448±555
MAX_VO2·kg^{-1}($mL.min^{-1}.kg$)	51.54±5.98	48.97±8.22	52.43±3.49	53.22±5.13
MAX_RQ	0.98±0.13	1.08±0.15†	0.92±0.08†	0.95±0.08
MAX_VO_2·HR^{-1}($mL.bmp^{-1}$)	25.45±3.37	24.61±4.05	26.92±3.68	24.82±1.87

Note. * – statistically significant difference ($p \leq 0.05$) – B vs W

† – statistically significant difference ($p \leq 0.05$) – B vs P

MAX_RF – maximal respiratory frequency; MAX_VT – maximal tidal volume; MAX_VE – maximal pulmonary ventilation; MAX_VO_2 – maximal oxygen uptake; MAX_VCO_2 – maximal minute volume of exhaled carbon dioxide; MAX_VO2·kg^{-1}– maximal relative oxygen uptake; MAX_RQ – maximal respiratory quotient; MAX_VO_2·HR^{-1}– maximal oxygen pulse;

Discussion and conclusions

Relatively few statistically significant differences occurred among groups of players in the various physiological parameters monitored during the 30-15IFT test. Since handball as a start-stop sport is characterized by short, intensive to highly intensive activities, such as short sprints, changes of direction, duels or jumps, anaerobic endurance is considered to plays a key role (Groeger et al. 2019). Several studies (Bautista, et al., 2016; Massuca, et al., 2014) have suggested that anaerobic capacity and other functional abilities of handball players such as vertical jump, speed, agility, and acceleration are better predictors of success in handball compared to aerobic capacity. Notwithstanding all the above, some differences do occur. In terms of both statistically significant and not significant differences, we can say that W achieved slightly different results in comparison to B and P players. We find particularly interesting that W reached a statistically significant higher velocity at LA than players in other two groups and significant higher velocity than P at OBLA. In view of this, we could conclude that W are able to persist for a long time, or to achieve a higher velocity, within the aerobic range. In principle, this allows them to remain on the court unchanged for longer than is the case with B and P (Büchel et al., 2019). W also reached the highest average peak v30_15 IFT, but no significant difference was observed among groups. It is also interesting to note that W reached the highest values of HR at all observed levels. Upon more accurate analysis of the results, it becomes apparent that the W group players achieved their advantage in terms of a better end result in the peak velocity compared to the other two group players in the aerobic range - meaning they came to the anaerobic area (OBLA) at a higher speed as players of the other two groups (Table 1 and 2). In the range from OBLA to the end of the test (peak velocity), the differences in velocity between the groups remained almost the same. The largest difference in velocities occurred in the test range from the start to LT (Table 1). W reached LT at a velocity that was almost 0.9 km·h^{-1} higher than velocity of B and 0.6 km·h^{-1} higher than at P. In the range between LT and OBLA, the difference between W and P increased slightly and amounted to more than 0.8 km·h^{-1} on OBLA. However, between groups B and W, the difference in achieved velocities in OBLA remained almost unchanged with respect to the difference in LT, but the difference became statistically significant (Table 2). The difference, as already mentioned, in peak velocity remained practically unchanged between the groups compared to the difference achieved in LT and OBLA. W therefore reached the highest value of the achieved running velocity among all groups at all three measured points (LT, OBLA and peak velocity). We find it interesting, however, that the difference was achieved only in the area up to OBLA (mostly even in the area up to LT). A possible explanation is in the very nature of the test used, as the increase in velocity significantly increases the neuromuscular load as well. Namely, at higher velocities (especially after reaching a velocity of 18-19 km·h^{-1}), the subjects must make more changes in the direction of movement and use more neuromuscular potential than when performing a test task at a lower speed (Buccheit, 2020). Thus, even better prepared players are not able to withstand the load of the test, which with increasing velocity disproportionately includes the neuromuscular part (beside metabolic factors persistence in the test becomes very dependent on neuromuscular factors as well). At each new stage of the test there is ever less straight running at a constant speed and there are more stops and accelerations, which cause rapid increase of fatigue and the consequent completion of the test. The limitation for this kind of speculation is the lack of data on muscle lactate, which would give us a more solid basis for these speculations (Chwalbinska-Moneta et al., 1989). These findings enables different profiles of handball experts (physical trainers, coaches and scientists) to better understand the course of physiological events during the test 30-15IFsT for various groups of handball players. They must be careful and exact in interpreting the results in terms of consideration the specificities expressed by the players at the various playing positions. An important factor here is the morphological structure of the players, which is significantly different especially with the W. In principle, it is highly recommended to monitor the level of fitness of handball players with the help of the 30-15IFT test and to prepare an appropriate program to improve aerobic and anaerobic endurance (Buccheit, 2008b). Based on our results, coaches in practice can predict that, on average, better results (peak velocity) in the test will be achieved mainly by players in positions W compared to B and P. This can be the basis for individualizing preparation (or working in groups) in the field of endurance development as well. In this sense for a practical application, coaches can be advised that for their practice reinforce effort for designing high intensity, short-duration, and short-time recovery exercises such as repeated sprints, jumps, pulling/drift actions, and contacts during both conditioning and mixed (tactical and physical-based) training sessions, regardless of the fact that handball rules allow unlimited number of substitutions (Michalsik, 2018). Based on our results, however, we would suggest that players, especially in position B and P (players with higher body height and body mass) with the help of specific aerobic training of slightly lower intensity increase their abilities to the point that they will be able to operate in aerobic or aerobic-anaerobic range (below OBLA) at higher load intensities. This should be taken into account especially for the off-season period. In doing so, however, the neuromuscular aspect should not be neglected - e.g. exercises by changing the direction of movement and by incorporating braking and acceleration. Whilst it is a limitation of this study that anaerobic performance and other functional abilities (agility, jump ability, acceleration, explosivity, etc.) were not measured, this study has been the first to attempt to understand the physiological characteristics of handball players on different playing positions with the $30\text{–}15_{IFT}$ and as such has provided some interesting findings. However, these results suggest that very few differences occurred in the selected physiological parameters between W, B and P.

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DEVELOPMENT OF DATA MODEL FOR ATTACKING BEHAVIOR IN HANDBALL

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Summary

This study focused on using machine learning to evaluate organized attack behaviours in handball. The goal was to help inexperienced coaches understand the tactical attacking behaviours of players. The study used 20 match videos from the men's world handball championships to classify 24 different tactical attack patterns. They created an image dataset and achieved an 89.3% accuracy in classifying these attack patterns using machine learning. The study identified challenges in classifying more complex player behaviours and suggested the need for more data and model tuning for future research.

Introduction

In ball game sports, skilled coaches are able to understand how players are moving with what aim in tactical behaviour that consists of the movements of multiple players. However, it is difficult for inexperienced coaches to understand such things. In recent years, there has been progress in the development of methods to evaluate tactical behaviour and playermovement using machine learning in ball sports. In this type of research on sports analysis using machine learning, there are studies that propose a classification method for game situations and attempt to automatically detect team tactics in handball[1)]. Also, in soccer, there are studies that evaluate what tactics are being used by machine learning image classification of the drawings of the movement trajectory of multiple players[2)].

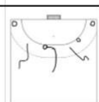
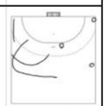
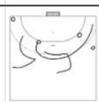
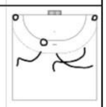
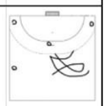
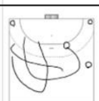
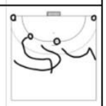
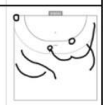
Therefore, we hypothesized that categorizing the movement trajectories of multiple players during each tactical behaviour would assist inexperienced coaches in understanding the quality of tactical behaviour in ball sports. The purpose of this study was to develop a data model for a method that uses machine learning to evaluate tactical behaviours such as "how" and "what" from players' location information and movement trajectories in order to promote a better understanding of tactical behaviour in handball.

The development of such a data model in handball will make it possible to have a computer make decisions on the part of the coaches, who used to recognize andjudge the players' tactical behaviour, and thus reduce the variability of results among analysts, which has been the biggest problem in qualitative game analysis.

Methods

The 20 match videos included in the study were randomly selected from the main leagues of the 2019 Handball Men’s World Championship and the 2021 Handball Championship. The extracted organized attack scenes were classified into 14 types of attack patterns. Three of the 14 classified attack patterns were a combination of two attack patterns or a sequence of two attack patterns in succession. Therefore, these three attack patterns were further subdivided and classified. As a result, the organized attack scenes were finally classified into 24 different attack patterns and labelled accordingly. Based on the classified attack pattern videos, an illustration creation application was used to draw the attack behaviour of multiple players in each of the 24 different attack patterns and save them as image data.

Table 1 Data set of organized tactical attacking

Class	Number of Data	Play pattarn	Class	Number of Data	Play pattarn	Class	Number of Data	Play pattarn
Back-Wing_Cross	22		PM_Transition	140		WingJugo	54	
Back-Back_Cross	98		Back_Transition	44		Jugo	54	
Back-PM_Cross	26		Back_Transition +Press	128		Jugo_Attack	54	
DoubleCross	48		WingTransition_PV1-2	408		Jugo_French	126	
PM-Wing_Cross +Return	64		WingTransition_PV1-2out	50		Jugo+PM-BackCross	114	
PM-Back_Cross	50		WingTransition_PV1-2 +PM-BackCross	88		Yugo+PM-BackCrossReturn	28	
PM-PV_Cross+PMAttack	342		WingTransition_PV1-2+Jugo	74		Jugo+PMTranstion	14	
PM-PV_Cross+BackAttack	168					Jugo +WingTransition	34	
PM-PV_Cross+BackAttack +Continue	38	  						

In creating a dataset for image classification by machine learning, three very similar attack patterns were defined as one attack pattern out of 24 different attack pattern image datasets. As a result, we finally created an image dataset classifiedinto 22 different attack patterns (Table 1). To improve training efficiency, all images were replicated with left-right flipping and data augmentation was performed (2344 images).

In each class, 85% of the data images were used for training to build supervised models. The remaining 15% of data images were used for model validation. Google's Teachable Machine (https://teachablemachine.withgoogle.com/) was used for machine training with these images. In the advanced settings of the Teachable Machine, the number of epochs was set to 50, the batch size to 16, andthe learning rate to 0.001.

Results & Discussion

We achieved 89.3% accuracy in classifying 24 different patterns of attack tactical behavior of organized attack in handball in this study. The model is shown at the following URL;

https://teachablemachine.withgoogle.com/models/Pn_MiDSv-/

Figure 1 shows the accuracy per epoch and the loss per epoch. These results

indicate the possibility of revealing the quality of tactical behavior of multiple players by using a machine learning image classification method based on a dataset of video images of attacking behavior of multiple players.

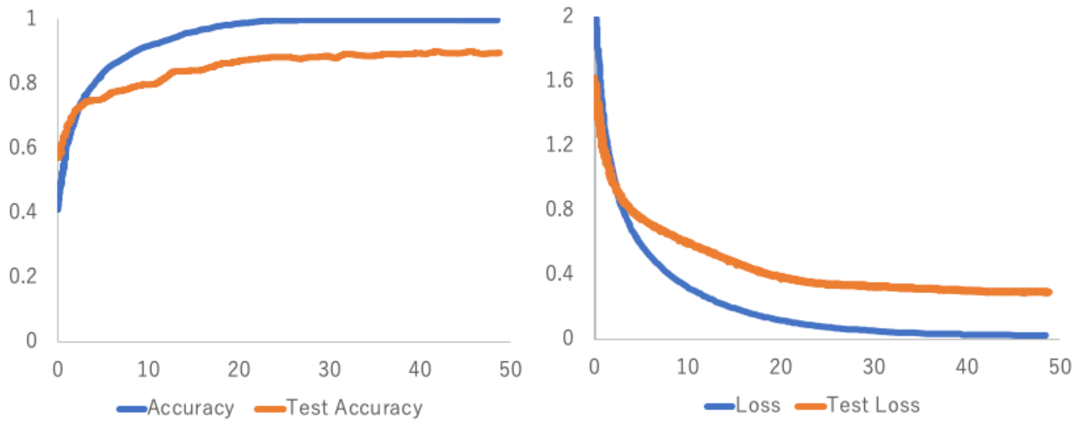


Fig. 1 The accuracy per epoch and the loss per epoch

Table 2 Accuracy each class

Class	NofData	Accuracy	Samples
Back-Wing_Cross	22	1	4
Back-Back_Cross	98	0.87	15
Back-PM_Cross	26	1	4
DoubleCross	48	0.88	8
PM-Wing_Cross+Return	64	0.9	10
PM-Back_Cross	50	0.88	8
PM-PV_Cross+PMAttack	342	0.96	52
PM-PV_Cross+BackAttack	168	0.73	26
PM-PV_Cross+BackAttack+Continue	38	0.83	6
PM_Transition	140	0.95	21
Back_Transition	44	1	7
Back_Transition+Press	128	0.95	20
WingTransition_PV1-2	408	0.97	62
WingTransition_PV1-2out	50	1	8
WingTransition_PV1-2+PM-BackCross	88	0.93	14
WingTransition_PV1-2+Jugo	74	0.83	12
WingJugo	108	1	17
Jugo	78	0.67	12
Jugo_Attack	54	0.67	9
Jugo_French	126	0.74	19
Jugo+PM-BackCross	114	0.83	18
Jugo+PM-BackCrossReturn	28	0.8	5
Jugo+PMTransition	14	1	3
Jugo+WingTransition	34	0.33	6

Table 2 shows the accuracy at the time of testing in each class. Figure 2 also shows the confusion matrix for this model. In many classes, the accuracy was above 80%, but the accuracy was low for Jugo. One possible reason for this is that Jugo, Jugo_attack and Jugo_French were very similar player behaviours, and that Jugo was not only used as a stand-alone attacking behaviour, but was often followed by Jugo and then other attacking behaviours such as Jugo+PM-BackCross, Jugo+ PM- BackCrossReturn, Jugo+PMTransition, Jugo+WingTransitoin, etc., and that other attacking behaviours were often added after Jugo (Table 2).

From these results, it was recognized that there is a challenge in this research method to classify more complex multiple players attacking behaviour with higher accuracy, such as a combination of two attacking patterns or a series of attacks.

	Back-Wing_Cross	Back-Back_Cross	Back-PM_Cross	DoubleCross	PM-Wing_Cross+Return	PM-Back_Cross	PM-PV_Cross+PMAttack	PM-PV_Cross+BackAttack	PM-PV_Cross+BackAttack+Continue	PM_Transition	Back_Transition	Back_Transition+Press	WingTransition_PV1-2	WingTransition_PV1-2out	WingTransition_PV1-2+PM-BackCross	WingTransition_PV1-2+Jugo	WingJugo	Jugo	Jugo_Attack	Jugo_French	Jugo+PM-BackCross	Jugo+PM-BackCrossReturn	Jugo+PMTransition	Jugo+WingTransition
Back-Wing_Cross	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Back-Back_Cross	0	12	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Back-PM_Cross	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DoubleCross	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PM-Wing_Cross+Return	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
PM-Back_Cross	0	0	0	0	0	7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
PM-PV_Cross+PMAttack	0	0	0	0	0	0	47	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
PM-PV_Cross+BackAttack	0	0	0	0	0	0	2	23	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
PM-PV_Cross+BackAttack+Continue	0	0	0	0	0	0	1	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PM_Transition	0	0	0	0	0	0	0	0	0	20	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Back_Transition	0	1	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Back_Transition+Press	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0
WingTransition_PV1-2	0	0	0	0	0	0	0	0	0	0	0	0	60	1	0	0	1	0	0	0	0	0	0	0
WingTransition_PV1-2out	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0
WingTransition_PV1-2+PM-BackCross	0	0	0	0	0	0	0	0	0	0	0	0	1	0	13	0	0	0	0	0	0	0	0	0
WingTransition_PV1-2+Jugo	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	1
WingJugo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0
Jugo	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	8	0	2	0	0	0	0
Jugo_Attack	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	1	0	0	0
Jugo_French	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2	14	0	0	1	0
Jugo+PM-BackCross	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0
Jugo+PM-BackCrossReturn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4	0	0
Jugo+PMTransition	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Jugo+WingTransition	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	0	2

Fig. 2 Class-specific confusion matrices in this model

Conclusion

Machine learning with supervised image classification using a dataset of hand-drawn tactical behaviour diagrams of the multiple-players attacking behaviour in organized attackhas resulted in highly accurate classification of tactical behaviour in handball.

However, the accuracy was lower when two or three tactical attacking actions were combined or performed in sequence. In order to increase the accuracy of the classificationof organized tactical attack behaviour in handball using this method, it is necessary to obtain a larger number of data, create more data sets, and tune the model, which is an issue for further study.

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THROWING VELOCITY AMONG FEMALE YOUNG HANDBALL PLAYERS: INFLUENCE OF TRUNK STRENGTH AND ANTHROPOMETRIC MEASUREMENT

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Summary

The aims were to study (i) the reliability of two trunk rotation strength tests in handball players with a functional electromechanical dynamometer, and (ii) the association with throwing velocity (TV). 24 young female players performed two exercises and handball TV. The reliability of the exercises was high and the TV could be explained by the arm span and mean force of the low cable woodchop in the 59%. Trunk rotation force plays a key role in throwing velocity in female young handball players.

Keywords: adolescents, FEDM, physical training, sport, athletic performance.

Introduction

The main purpose of coaches is to achieve an improvement in athletes' performance. In handball, the throwing velocity (TV) is considered a key factor to score a goal. Commonly, both general upper-body pushing strength exercises and throwing-specific exercises are used to improve TV (1). In evaluation, for decades, different tests have been used to assess TV, especially with general exercises such as the bench press (2). Currently, more specific exercises such as the unilateral standing pullover (3) are beginning to be used for evaluation and training.

In all sports, the performance assessment process is crucial to determine an athlete's fitness profile. Due to advances in technology, new specific reliable tests are being developed with handball players (4). Specifically, a functional electromechanical dynamometer (FEMD) allows the creation of a large number of different tests to evaluate handball players (5,6). In previous studies, sprint and TV performance has been correlated with specific strength measured with FEMD in adult players (3), however, to date, this technology has not been used to evaluate young players.

This study aimed to determine (i) the reliability of two trunk rotation strength tests (TRS): rotational trunk and low cable woodchop (LCW) with FEMD, and (ii) the association with TV in young female handball players.

Methods

Twenty-four young female handball players (15.92 ± 0.72 years, 59.77 ± 8.57 kg, 1.60 ± 0.05 m and 23.24 ± 2.49 kg/m^2) completed a repeated-measures design to evaluate TRS and TV with one familiarization session using elastic bands and three test session separated by one week. The exclusion criteria were (i) to have any musculoskeletal injury and (ii) to have less than 2 years' experience in handball. During the test period (after the competitive phase), players continued with a weekly frequency of 3 days of training on a handball court (1.5 hours per day). Players, coaches, and legal tutors were informed of the nature, aims, and risks associated with the experimental procedure before they provided written consent to participate. The study protocol was approved by the Biomedical Committee of the University of Granada (nº 2560/CEIH/2022) and was conducted following the Declaration of Helsinki.

First day

Anthropometric measurements and the maximal TV were recorded. Body mass (kg), height and arm span were measured using a digital bioimpedance scale (TANITA, model 331, Tokyo, Japan) and a SECA stadiometer (model 214, Hamburg, Germany). After that, a general (dynamic mobility and jogging) and specific warm-up (push strength exercises and submaximal throws) was completed and three repetitions of maximal TV were performed. For TV assessment, the participants were asked to throw as fast as possible from the 7-meter line to the radar (Stalker Pro II; Stalker Radar, Plano, TX) placed behind the goal at a height of 1.3 meters. TV was registered, however, if the throw was outside the goal the velocity was not recorded. Two ball sizes were used according to the specific category of each participant (size I of the International Handball Federation with 50 to 52 cm of circumference and 290 to 330 grams and size II of the International Handball Federation with 54 to 56 cm and 325 to 375 grams).

Second and third day

TRS was recorded with FEMD (Dynasystem, model research, Granada, Spain) (3,7). The players completed two incremental TRS tests until failure or not available to maintain the technique. After a general warm-up, the specific warm-up consisted of two sets of five repetitions of the testing tasks with elastic bands. Then, participants performed an isometric test of LCW to establish the 30% of isometric peak force and two incremental tests (rotational trunk and LCW) with 3 min of rest between trials (Figure 1).

A B

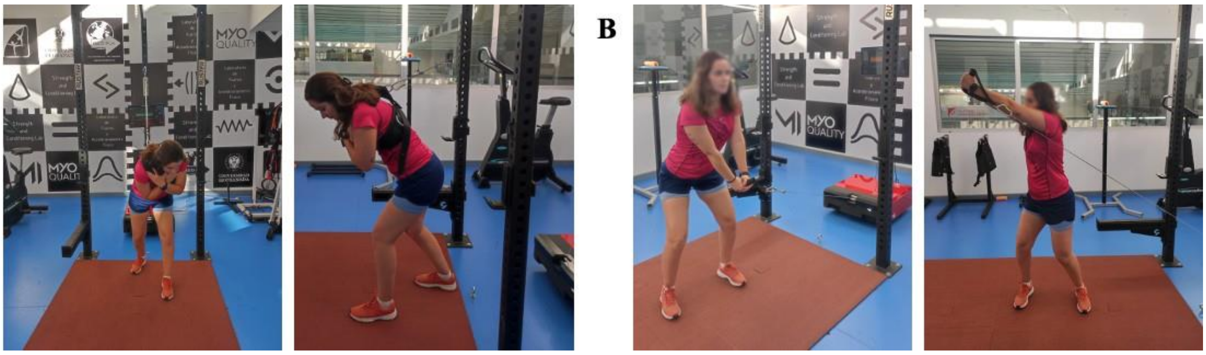

Figure 1. The initial and final position of (A) rotational trunk (B) low cable woodchop exercises.

Participants were allowed to use a self-selected length for each exercise. The LCW exercise was performed as indicated in the article by Rodriguez Perea et al., (2023) (8). LCW measurements were started with 30% of the isometric peak force and the load was increased to 2 kg between reps. Rotation of the trunk test started with the opposite foot forward. The task was to forcefully rotate the trunk to the opposite side and then slowly return to the starting position. Rotational trunk measurements started with 20% of body weight (BW) and the load was increased 1 kg between reps. The order of the tests was randomized using a computer program.

Statistical analyses

Descriptive data are presented as mean ± SD. Reliability was assessed using t-tests of paired samples with the ES, coefficient of variation (CV), and intraclass correlation coefficient (ICC), with 95% confidence intervals. Hopkins et al., (2009) classify through a qualitative scale the magnitude of the values of the ICC, the values close to 0.1 low reliability, 0.3 moderate, 0.5 high, 0.7 very high, and those close to 0.9 extremely high (9). Reliability analysis was performed using a customized spreadsheet (9). A Pearson's bivariate correlation was calculated to quantify the association between the specific handball strength tests with TV. The strength of the r coefficients was interpreted as follows: trivial (0.00–0.09), small (0.10–0.29), moderate (0.30–0.49), large (0.50–0.69), very large (0.70–0.89), nearly perfect (0.90–0.99) and perfect (1.00) (9). Finally, to develop a more precise equation for the sample, a multiple backward linear regression model was performed to assess which variable best predicted the TV. Statistical significance for all tests was accepted at the 5% level. All statistical analyses were conducted with the statistical software package SPSS v23.0 (SPSS Inc., Chicago, IL, USA).

Results

The reliability of the TRS exercises was high and very high for the peak and mean force (Table 1). The mean value of TV was 57.75±6.86 km/h. The highest correlation between TV was found with the mean force of LCW (r = 0.70; $p < 0.01$) (Table 2). The TV could be explained by arm span and mean force of the LCW in the 59%.

Table 1. Reliability of rotational trunk and LCW exercises.

		Test	Retest	ES	ICC (95% CV)	SEM	%CV (95% CI)
Rotational Trunk	Peak	9.0 ± 1.6	9.6 ± 1.8*	0.35	0.83 (0.65-0.92)	0.47	7.94 (6.14-11.24)
	Mean	5.5 ± 1.0	5.6 ± 0.9	0.14	0.51 (0.12-0.76)	1.01	12.28 (9.45-17.55)
Low Cable Woodchop	Peak	18.3 ± 3.2	18.7 ± 4.9	0.10	0.73 (0.47-0.87)	0.63	11.90 (9.25-16.70)
	Mean	10.6 ± 2.0	10.5 ± 2.4	-0.04	0.56 (0.22-0.78)	0.91	14.04 (10.91-19.75)

ES = effect size; ICC = intraclass correlation coefficients; CI = confident interval; %SEM = standard error of measurement; %CV =percentage coefficient of variation. * Significance difference between test and retest (p < 0.05).

ES = effect size; ICC = intraclass correlation coefficients; CI = confident interval; %SEM = standard error of measurement; %CV =percentage coefficient of variation. * Significance difference between test and retest (p < 0.05).

Table 2. Association between throwing velocity and descriptive and strength test variables.

		Throwing velocity
Descriptive Characteristics	Mean ± SD	*r*
Age (years)	15.92 ± 0.72	0.40
Experience (years)	5.96 ± 2.44	0.21
Weight (kg)	59.77 ± 8.57	0.41*
Heigth (m)	1.60 ± 0.05	0.41*
BMI (kg/m^2)	23.24 ± 2.49	0.28
Seated height (m)	58.12 ± 2.46	0.38
Arm Span (m)	82.27 ± 3.28	0.44*
Strength test	Mean ± SD	
F_{peak} Rotational Trunk	5.6 ± 0.9	0.26
F_{mean} Rotational Trunk	9.6 ± 1.8	0.64**
F_{peak} Low Cable Woodchop	10.5 ± 2.4	0.65**
F_{mean} Low Cable Woodchop	18.7 ± 4.9	0.70**

Significance level *p < 0.05 **p < 0.01. BMI = body mass index; SD = standard deviation.

Discussion

The main findings of the study were that both the LCW exercise and the trunk rotation exercise are reliable, with the peak force variable being more reliable than the mean force. These data can help coaches make decisions about which force variable to use when assessing TRS with FEMD in female handball players. In addition, a long correlation was found between the mean trunk rotator force and peak force of LCW exercise with TV, and a very long correlation between mean LCW force and TV. Moreover, the TV could be explained by arm span and the mean force of LCW in the 59%. Specific actions in young handball players have been explored reporting high reliability (10,11), with some of them being more reliable than general physical tests (12). Based on the findings of the current study, it appears that assessments closer to sport-specific tasks are reliable for evaluating and designing training programs for young handball players. According to the current data, evaluating and designing training programs for young handball players. According to the current data, Chirosa-Rios et al., (2022) reported a higher reliability with peak velocity in the two-step exercise with FEMD (6). The higher reliability with the peak variable could be explained because the mean is more sensitive to the variability in an open task. The physical contribution to performance parameters as TV has been explored before in elite handball players (3). The strength of the shoulder, unilateral pullover and step-forward exercises show a high correlation with TV (3,13). However, the correlation of the present study is higher than those performed with elite players (3). The long correlation between trunk rotation force with TV enhances the relevance of the kinetic chain in TV (14), demonstrating the necessity of incorporating multi- component strength training for enhancing handball performance. Furthermore, the relevance of arm span and throwing velocity has been demonstrated to discriminate between top elite and elite female handball players (15)In the present study, 59% of the throwing velocity could be explained by arm span and average force in LCW. Previous studies analysed the relationship between different anthropometric variables with throwing velocity in players under 15 years of age and did not find any relevant variable to predict handball performance. However, in this study, arm span was not measured and the only strength test performed was the manual grip test. Another study conducted on male handball players found that the only anthropometric variable that explained throwing velocity performance was height, although it should be noted that arm span was not included in the model because of the correlation with height (16). On the other hand, LCW force was the variable that most explained throwing velocity in handball, however, there are no previous studies that measure the TRS but have analysed the endurance strength of the trunk musculature, finding weak correlations between trunk extension and throwing velocity (17).

Conclusion

The high reliability of TRS exercises and the significant correlation with TV allow us to include these tests in handball evaluation and training. Moreover, the large influence of LCW and arm span on TV can discriminate the use of tests and training exercises to increase their efficiency in the protocols used.

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EXAMINATION OF SCORING EFFICIENCY IN MEN'S HANDBALL USING RANDOM FOREST

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Introduction

Research Background and Objectives

The outcome of a handball game is determined by the number of points scored within the designated game time. Therefore, shooting, which is the method of scoring, is considered to be the most important play that directly determines the outcome of the game (Enari, 1980). Shooting is an open skill that is performed under unpredictable conditions. It is believed that various factors, such as defensive actions by the defence (DF), shooting position, and plays leading up to the shot, are related and can impact the success or failure of the shot. Therefore, if players can understand the situations in which shooting is more likely to result in scoring, they can efficiently generate points. In a study that investigated game results and the types of shots taken, it was found that winning teams took more side shots and 6m shots, which are closer to the goal, and scored more goals compared to 9m shots. On the other hand, losing teams took more 9m shots and scored fewer points. This suggests that players on losing teams shoot without focusing on tactics and simply take shots that are available in the moment (Nikola, 2010). It is important to prioritize high-scoring shots, such as those taken from positions near the goal, in order to increase the chances of winning the game and creating scoring opportunities. Furthermore, it has been revealed that the final actions of the back player contribute to achieving higher probability shots and ultimately lead to the team's victory (Nikola, 2010). While the significance of situational judgment in ball games has been emphasized, there has been limited advancement in handball. One of the reasons for this is believed to be the absence of clear criteria for making situational judgments in handball. According to Yao (2007), recent handball games have experienced an increase in the pace of play as a result of rule changes. Players are now required to make quick judgments and take immediate action in complex game situations. They must also collaborate with their teammates to create advantageous situations in order to achieve their individual goals. Therefore, it is believed that understanding shooting situations and having high scoring efficiency can lead to making good judgments even in fast-paced play.

Therefore, this study aims to analyse the situations in each shooting scene for the backcourt players in handball and examine which positions and situations are more likely to result in high-scoring and efficient shots (scoring efficiency). By examining the various factors that influence the success or failure of shooting situations, this study aims to assist players in making informed decisions about shot selection. It is also believed to be useful in devising tactics, such as allowing opponents to take shots in situations where the probability of scoring is low, even when defending one's own team.

Study Limitations

This study is subject to certain limitations that must be taken into consideration when interpreting the findings. The limitations are as follows:

1) Limitations related to the analysis method:

The analysis in this study solely focused on the binary outcome of whether a goal was scored or not, without considering the tactical strategies employed by each team or the intentions of individual players. Consequently, it was not possible to identify strategic shots that were set up through coordination between the goalkeeper and defenders, or shots that were targeted at specific shooting styles or preferred areas. Additionally, the study relied on the shooter's take-off foot as the criterion for determining the shooting area, which may have resulted in inaccurately recording the actual shooting position. If a shooter took off from the long area but jumped forward to shoot in the middle area, or if a shooter took off from the centre area but jumped sideways to shoot in the left or right area, the shooting position would not have been accurately recorded. This limitation arose from the inability to accurately capture the shooting position through video observations.

2) Limitations related to the sample size and subjects:

To facilitate future research on the Japanese national team and international teams, this study focused on teams that had won at least one match in the All-Japan Student Handball Championship. This selection criteria ensured that the students chosen had a high level of athletic ability. Consequently, the sample size was limited to 15 matches. Furthermore, there was an imbalance in the number of right-handed and left-handed players among the teams and as a whole, resulting in a lack of data regarding left-handed players compared to their right-handed counterparts. Therefore, although the sample size of the analysed matches may not be sufficient, it is important to acknowledge that the analysis was conducted using actual matches that occurred.

Research Method

1. Sample Matches

The shooting scenes of the backcourt players (left back, right back, centre back) from a total of 15 matches, including the second round, quarterfinals, semifinals, and finals of the 2022 All Japan Student Handball Championship, were selected for analysis.

2. Analysis Items

Game footage available on YouTube was used to analyse each shooting scene by the backcourt players. The analysis encompassed eight items, namely the "dominant hand," "shooting area," "shooting type," "offensive situation," "defensive situation," "pre-shooting movement," "final direction of progress," and "result."

1) Dominant Hand

The hand with which the player executed the shot was considered their dominant hand. Players who threw the ball with their right hand were classified as right-handed, while those who used their left hand were classified as left-handed.

2) Shooting Range

The shooting area was divided into three sections based on the position of the goalposts. The area between the goalposts was designated as the "Centre" area. The area to the left, when viewed from the direction of offensive progress, was labelled the "Left" area. Similarly, the area to the right, when viewed from the offensive progress direction, was denoted as the "Right" area.

3) Shooting Type

The shooting types analysed in this study included the "Breakthrough Shot," "Middle Shot" (shots taken from a distance of 7-9m), and "Long Shot" (shots taken from a distance of 9m or more).

4) Attack Situation

It is divided into two categories: set attack and fast break. There is no differentiation based on the type of fast break.

5) Defensive Situation

Depending on the contact situation between the shooting player and the defender (DF), it is divided into two categories: with DF and without DF.

- With DF.

This refers to situations where the player shoots while being touched by the defender from the front, or situations where the player shoots while being affected by contact with the defender and their posture is disrupted. It also includes cases where the shot hits the defender's arm. Situations involving warnings or ejections are excluded.

- Without DF.

This refers to situations where the player is not touched by the defensive player, or situations where the player is touched by the defensive player but still able to swing their dominant hand freely with only minor contact.

6) Pre-Shooting Action

The pre-shooting play is divided into three categories.

- Shifting: Shifting refers to the strategy where the teammate in front of the shooter attracts the defensive player (DF), allowing the shooter to take a shot when there is no DF present or when the DF has shifted by more than half of their body (either through a parallel shift or a cross shift).

- Self-fake: When the shooter performs a fake move and then shoots themselves. There is no differentiation based on the type of fake move.

- No fakes: This refers to a situation where there are no deceptive or misleading movements, and the shooter shoots directly ahead.

7) Final Direction of Progression

Based on the dominant hand used for shooting, the direction in which the shooter takes their final approach before shooting or evading the defensive formation (DF) is divided into two categories: the dominant hand side and the non-dominant hand side.

8) Result

If it results in a goal, it is marked as "IN". If the ball is blocked by the opponent's goalkeeper or goes outside the goal frame, it is marked as out. Statistical Processing Method

3-1 Creation of a Prediction Model

In this study, the random forest method, which was developed by Breiman (2001) in the field of machine learning, is used. Random forest is an ensemble learning method that utilizes decision trees. Although individual decision trees do not have high discriminative power, it is possible to achieve high predictive performance by using multiple trees and complementing their results. It is also known for its efficiency and high computational speed.

In random forest, it is possible to calculate the importance of variables. Therefore, we ranked and examined the factors that influence shooting results.

When conducting machine learning, it is common to allocate 80% of the data for training and reserve the remaining 20% as test data to assess the level of error. In this study, the data was randomly divided into an 80% to 20% ratio for machine learning. For all the data, the variables other than the outcome were used as features, and the outcome was set as a binary value, with "IN" representing TRUE and "OUT" representing FALSE. A prediction model was constructed using random forest. For the data separated into right-handed and left-handed individuals, the features remained the same as the overall data, with the exception of the result and dominant hand. The target variable was also set to be the same as the overall data.

3-2 Validation Method for the Constructed Prediction Model

By comparing the predicted results of the shooting result prediction model with the actual results, we can verify the accuracy of the constructed prediction model. In random forest, the AUC (Area Under the Curve) is used as an index to validate the accuracy of predictions. To calculate the AUC (Area Under the Curve), the ROC (Receiver Operating Characteristic) curve is used. This graph represents the ratio of the false positive rate on the horizontal axis to the true positive rate on the vertical axis. The area under the Receiver Operating Characteristic (ROC) curve is known as the AUC. A higher AUC value, closer to 1, indicates higher accuracy, while a value closer to 0.5 suggests lower accuracy.

3-3 Chi-square test and residual analysis

We conducted a chi-square test and residual analysis to compare and evaluate the factors that influence shooting outcomes for each analysed item. IBM SPSS Statistics 29.0 was used for the statistical analysis, with a significance level of 5%. Examination of the reliability of the analysis records was conducted.

To assess the reliability of the records using the aforementioned method, we evaluated the agreement among three analysts. Specifically, two individuals with extensive experience and expertise in handball, along with the author, conducted the same analysis for two matches. They considered all factors such as area, defensive situations, final results, etc. and calculated the agreement rate using the formula: agreement rate = agreement count / (agreement count + disagreement count). The interpretation of the agreement rate value was based on Siedentop and Tannehill's (1999) study.

Results and Discussion

1. **Examination of the reliability of the analysis records**

The agreement rates of the analysis records conducted by the three analysts were all above 98%. Therefore, we considered that the reliability of the analysis records conducted by the lead author had been ensured.

2. **Analysis Using Random Forest**

2-1 Accuracy of the constructed shooting result prediction model

The area under the curve (AUC) for right-handed data was 78.4%, while the AUC for left-handed data was 78.6%.

2-2 Importance of Features

The significance of features was determined through the utilization of a random forest-based shoot result prediction model. Figure 1 displays the descending order of feature importance for each dominant hand.

For both right-handed and left-handed players, the most crucial aspect was the interaction with the defender (DF), which was followed by the type of shot and the preceding action. For right-handed players, the next important features were final progression direction, area, and situation. For left-handed players, the next important features were area, final progression direction, and situation.

Figure 1. The Significance of Features (Top: Right-Handed, Bottom: Left-Handed)

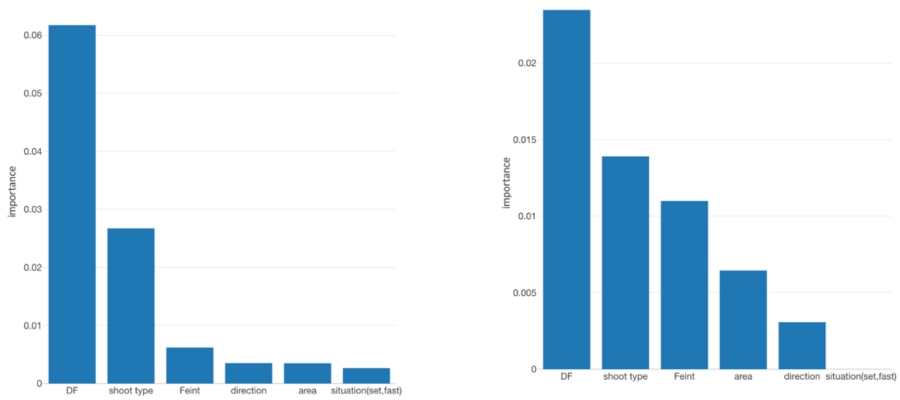

Figure 1. Feature Importance (The upward trend indicates an increase in right-handedness, while the downward trend indicates a decrease in left-handedness)

3. **Results of the Chi-square test**

3-1) Area

There was no statistically significant disparity observed in the area between right-handed and left-handed players.

3-2) Shot Type

There was a significant difference for right-handed players. The residual analysis showed that break-through shots were more likely to score than other shots, while long shots were less likely to score.

(Chi-square value = 47.067, $p < 0.01$, V = 0.260)

There was a notable disparity observed among left-handed players. The residual analysis showed that break-through shots were more likely to score than other shots.

The chi-square value was calculated to be 11.933, with a significance level of $p < 0.01$. The effect size, as measured by V, was found to be 0.210.

3-3) Situation

There was a significant difference for right-handed players. The residual analysis showed that fast breaks were more likely to score than set attacks.

(Chi-square value = 6.800, $p < 0.01$, $\varphi = 0.099$)

For left-handed players, there was no significant difference between fast breaks and set attacks. The chi-square value was calculated to be 0.304, with a corresponding phi coefficient of 0.034.

3-4) Contacting the Defender

There was a notable disparity observed among players, both right-handed and left-handed. The residual analysis showed that not having contact from the defender resulted in a higher chance of scoring.

(Right: Chi-square value = 97.876, $p < 0.01$, $\varphi = 0.376$) (Left: Chi-square value = 24.051, $p < 0.01$, $\varphi = 0.298$)

3-5) Previous Action

There was a significant difference for right-handed players. The residual analysis showed that shifting was more likely to score than self-fakes.

The chi-square value was calculated to be 8.047, indicating a statistically significant result ($p < 0.05$). The effect size, as measured by V, was found to be 0.108.

There was also a significant difference for left-handed players. The results of the residual analysis indicated that shifting had a higher likelihood of scoring compared to self-fakes, while both self-fakes and no self-fakes had a lower likelihood of scoring than shifting.

(Chi-square value = 9.866, $p < 0.01$, $V = 0.191$)

3-6) Final Progression Direction

There was no statistically significant disparity observed in the ultimate progression direction between players who wereright-handed and those who were left-handed.

Discussion

The purpose of this study was to use shooting scenes of backcourt players from the 2022 All Japan Student Handball Championship from the second round onwards, and to demonstrate the importance of factors influencing shooting results using machine learning. The study aimed to investigate the most efficient way to score goals from which positions and under what circumstances. The shoot result prediction model, employing the random forest algorithm, demonstrated a commendable accuracy rate of more than 78% for both right-handed and left-handed players. However, it is important to acknowledge that the model utilized in this study was derived solely from data collected from male university students. Consequently, additional research is imperative to ascertain the model's efficacy in accurately predicting outcomes across various age groups, skill levels, and genders. Additionally, augmenting the quantity of collected data has the potential to enhance the predictive precision of the model. Despite the substantial disparity in the quantity of data points between right-handed and left-handed players examined in this study, there was minimal variation observed in the precision of the prediction model. This suggests that there may be limitations to predicting outcomes in handball, which is an open-skill sport. In actual handball matches, there are often surprising plays that leave spectators in awe. For instance, a seemingly flawless and unchallenged shot can be thwarted by the goalkeeper, while a shot taken from a considerable distance may still result in a goal. These unforeseen results can be influenced by a multitude of factors, including the player's current physical condition, their psychological state when faced with pressure, the velocity of the shot, and their level of physical fitness. Therefore, predicting these outcomes based on the available data is extremely challenging, and the predictive accuracy of the constructed model in this study is considered reasonable. The analysis of feature importance revealed that both right-handed and left-handed players are primarily influenced by the contact situation with the defender (DF) when it comes to shooting results. The type of shot and immediate action also plays significant roles. On the other hand, the importance of the attacking situation and the final direction of play was found to be low, indicating less influence on the shooting results. A detailed discussion combining the results of the chi-square test and residual analysis is shown below. Looking at the numerical predictions of shooting results focusing on the four items that showed significant differences in the chi-square test, "DF situation," "shot type," "attacking situation," and "immediate action," the situation with the highest prediction when the probability of a shot being successful is 90.0% was a break-through shot without contact from the DF in a set attack with a shifting development. On the other hand, when the same development and shot type were considered but with contact from the DF, the predicted probability of a successful shot significantly dropped to 54.5%. In a shifting development, when there is no contact from the defence, the predicted probability of a successful middle shot is 81.3%. Conversely, the situation with the lowest prediction when the probability of a shot being successful is 11.4% was a long shot without self-fake in a set attack while being in contact with the DF. However, when avoiding contact from the DF in the same development and shot type, the probability of a successful shot increased to 63.1%. From these findings, it can be suggested that the contact situation with the DF is quite important, and while a break-through shot is ideal, even a middle shot has a high scoring probability if there is no contact from the DF. Considering that a winning team needs an attacking success rate of over 60% (2020, Hanajo), when looking at the predicted probability of a successful shot being 60.5%, it was achieved by performing a feint in a set attack and shooting a long shot without contact from the DF. On the other hand, a situation where the success rate does not exceed 60% was achieved by shooting a long shot without a feint but without contact from the DF, with a success rate of 59.9%. In other words, in order to efficiently score, it is considered effective to take advantage of the condition of not being in contact with the DF and shoot from an attack coordinated with teammates. Even when shooting a long shot, it is believed to be better to either draw the DF towards teammates or perform a feint oneself to confuse the goalkeeper and defenders before shooting.

Conclusion

In this study, we used the shooting scenes of backcourt players in 15 games from the second round onwards of the 2022 All Japan Student Handball Championship as samples. We aimed to determine the importance of factors influencing shooting results using machine learning and to examine the efficiency of shooting from which position and under what circumstances to increase the probability of scoring.

The main results showed that in order to score efficiently, the probability of making shots is higher in the order of break-through shots, middle shots, and long shots. Therefore, it is important to shoot from positions closer to the goal. It was also suggested that it is difficult to score when being contacted by the defence, so it is important to focus on creating a situation where the shot can be taken without being contacted by the defence and to actively aim for shots without being contacted by the defence in order to score efficiently.

Furthermore, it became clear that it is easier to score by receiving a pass from a teammate and shooting rather than using feints to evade the defence before shooting. At the university level of competition, there are differences in individual abilities, and strong movements and powerful shots often lead to scoring. However, at higher levels of competition, these plays may not work, so it is necessary to play with a focus on scoring efficiency even at the university level. Although the results of this study may not apply to every level of competition, it is believed that training with a focus on scoring efficiency in practical situations in all categories can improve the selectivity of players' plays and enable consistent development.

	ALL(n=964)	Right hand(n=694)					Left hand(=270)				
	result	IN		OUT		χ^2値			OUT		χ^2値
		n	%	n	%		n	%	n	%	
Area	Left	146	37.5	92	30.2	4.119	10	6.6	12	10.1	5.809
	Center	185	47.6	162	53.1		71	47.0	39	32.8	
	Right	58	14.9	51	16.7		70	46.4	68	57.1	
Shot Type	Breakthrough	191	49.1+	75	24.6	47.067**	60	39.7+	24	20.2	11.933**
	Middle	112	28.8	109	35.7		36	36.4	39	32.8	
	Long	86	22.1	121	39.7−		55	23.8	56	47.1	
Situation	Fastbreak	107	27.5+	58	19.0	6.800**	32	21.2	22	18.5	0.304
	Set	282	72.5	247	81.0		119	78.8	97	81.5	
DF	Yes	74	19.0	168	55.1	97.876**	33	21.9	60	50.4	24.051**
	No	315	81.0+	137	44.9		118	78.1+	59	49.6	
Action	Parallel	74	19+	35	11.5	8.047*	48	31.8+	20	168	9.866**
	Feint	188	48.3	152	49.8		63	41.7	51	42.9−	
	No-Feint	127	32.6	118	38.7		40	26.5	48	40.3−	
Direction	Dom	276	71	210	68.9	0.359	105	69.5	75	63.0	1.270
	Non-Dom	113	29	95	31.1		46	30.5	44	37.0	

**：p<0.01,*：p<0.05, :Significantly easier to score, -:Significantly harder to score

Figure 2. Results of the chi-square test

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INERTIAL DATA FROM KOREAN NATIONAL TEAM IN HANDBALL WORLD CUP 2023

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Summary: 20 Korean Top Handball Players (age 26.10 ± 3.32; heigth185.65 ±4.64 and weight 94.29±16.63), were monitored during the 7 games of Handball World Cup 2023 (16 per game) in order to obtain inertial data, using Catapult Vetor S7 devices. Player Load (PL), Player Load per Minute (PL/Min), Changing of direction (Cod), accelerations (Accel) and decelerations (Decel) were analysed by game and by position. The training unit should meet, at least this kind of demands presented, and the player selection for major competitions must be based on those who can handle and maintain them when they happen in short period of time, every 2 days.

Keywords: Handball, Player Load, Player Load/Min, High Band Jumps, Accelerations, Decelerations, Change of Direction

Introduction

Handball can be considered an intense activity for all players, especially because of the large number of repeated high-intensity actions occurring throughout the game (e.g., jumps, sprints, changes of direction, duels, contacts [9,12,13]. The performance of a Handball Team, is based on the sum of individual performances, and both are influenced by a huge number of factors [4, 7,

9]. This shows the importance about the role of the technical staff is to make sure that every individual athlete has the perfect conditions to perform well in the game [1, 2, 4,7, 10, 12,13]. Prior to every aspect that you may consider has a coach, if a player is not available (due to injury) or if he has a physical handicap and can't perform to the level that is needed for the game, the probabilityof a negative result grows exponentially. In the 21st century, the introduction of the accelerometers, gyroscopes and magnometers, allows the coaching staff to have access to inertial measurement data, that allows a precise quantification of both high intensity activity sports specific actions and external player load [1,2,3,4,5,7,8,9,10,11,12]. Although there is an incremental usage of this kind of devices, the usage of different scales (according to the brands and/or the date of production) is a barrier that not allows accurately the data [3,7]. With this kind of knowledge about collective and individual game demands, the evolution of training process getting more precise and individualized [6, 1, 7,8,12].

Methods

Subjects

The sample consisted in 20 Male Handball players thattook part in the final roaster of the Korean National Team that participated in the 7 games of the 2023 Handball World Cup (WC). The offensive playingpositions were used to divide the players: left wing (LW), left back (LB), centre back (CB), right back (RB), right wing (RW), pivot (PIV). Two defensive positions were considered: goalkeepers (GK), and defence specialist (DEF).

The average age is 26,25 ±3,40 years, height is 186,17 ±4,72 cm weight is 95,94 ±17,13 kg.

	n	Age (AVR±SD)	Heigth (AVR±SD)	Weigth (AVR±SD)
GK	3	22,67±3,21	190,77±1,17	125,17±24,66
LW	2	27,00±0,00	181,35±1,91	83,7±4,38
LB	1	30,00±0,00	185,00±0,00	93,10±0,00
CB	4	27,25±3,59	180.83±4.58	82,13±6.24
RB	2	30,00±1,41	186,60±4,67	91,5±7,50
RW	3	25,00±5,66	185,73±4,95	89,77±5,23
PIV	3	24,67±3,06	189,5±2,00	96,9±1,30
DEF	2	27,50±0,71	190,10±2,69	99,15±5,73
	20.00	26,25±3,40	186,17±4,72	95,40±17,13

For this sample characterization (except age and position), the data was obtained by a simultaneous multi-frequency bioelectrical impedance analysis using InBody770™.

Instruments and Procedures

The inertial data was obtained via Catapult™ Vetor S7 devices placed on the Catapult Vest™, 45 minutes before every game. All the data was live monitored for technical and tactical coach decisions, but all the data was only used after prior sync using the Catapult Dock, the game time cut from the data timeline and then downloaded from the open field cloud. The data was downloaded in .CSV file, and then transferred for Microsoft Excel™. Player Load (PL) is the sum of the accelerations across all axes of the internal tri-axial accelerometer during movement. It takes into account instantaneous rate of change of accelerationand divides it by a scaling factor (divided by 100). The scaling factor is used to reduce the total value of the Accumulated Player Load thereby making it easier to work with during analysis.

This PL formula was originally developed at the Australian Institute of Sport (AIS) as a proposed metric for measuring effort in a rugby union application. When you divide the PL for the time that occurs the movements you have the Player Load per Minute (PL/m).

$$\text{Player Load}=\sqrt{\frac{(fwd_{t1}-fwd_{t-1})^2+(side_{t1}-side_{t-1})^2+(up_{t1}-up_{t-1})^2}{100}}$$

Note: **fwd:** forward acceleration **side:** sideways acceleration **up:** upwards acceleration **t:** time

When we analyse the jumps, they are divided in 3 bands: low band (IMA low -under 20 cm), medium band (IMA med - 20-40 cm) and high band (IMA High - over 40 cm).

The accelerations and the deceleration are measured trough inertial sensors that gives us arbitrary units (AU), and divide both of parameters in tree bands, low, medium, and high. For this study weonly consider high band (over 3 AU) accelerations (IMA Acel High) and decelerations (IMA DeclHigh). The changes of direction (CoD) is accessed by the gyroscopes, and even that we can accesslow, medium and high, we only consider high Cod right (IMA CoD Right) and Cod Left (IMA CoD left).

Development

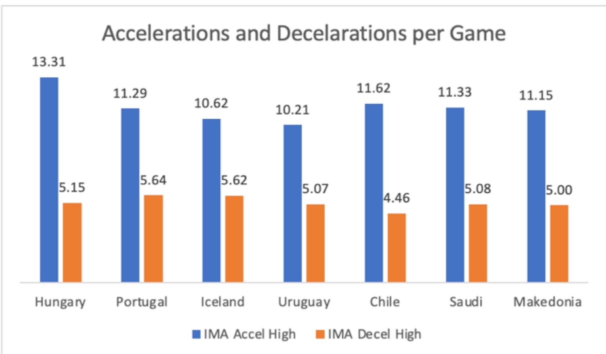
			HUNGARY		PORTUGAL		ICELAND		URUGUAY		SAUDI		CHILE		MACEDONIA	
	AVR PL ± SD	AVR PL/MIN ±SD	AVR PL ± SD	AVR PL/MIN ±SD	AVR PL ± SD	AVR PL/MIN ±SD	AVR PL ± SD	AVR PL/MIN ±SD	AVR PL ± SD	AVR PL/MIN ±SD	AVR PL ± SD	AVR PL/MIN ±SD	AVR PL ± SD	AVR PL/MIN ±SD	AVR PL ± SD	AVR PL/MIN ±SD
GK	153,37±7,04	3,57±7,04	150,94±112,99	3,97±0,26	149,04±101,71	3,47±0,41	156,01±35,08	3,68±0,71	148,17±131,71	3,99±0,28	270,64±0,00	3,58±0,00	160,68±74,77	3,55±0,11	163,96±77,38	2,61±1,02
LW	337,59±15,74	8,32±0,69	333,96±45,73	9,13±1,19	326,25±87,09	8,05±1,03	321,38±29,42	8,10±1,63	340,88±128,62	8,84±0,22	325,46±194,11	8,80±1,04	365,47±259,24	7,08±0,49	349,74±128,75	8,21±0,73
LB	359,55±102,99	7,80±0,88	350,34±0,00	8,11±0,00	472,72±0,00	9,21±0,00	399,64±0,00	7,39±0,00	296,87±0,00	8,19±0,00	443,98±0,00	6,84±0,00			193,78±0,00	7,06±0,00
CB	261,64±71,75	6,79±0,64	331,06±45,70	7,76±0,15	268,71±61,44	6,74±0,22	438,57±0,00	6,91±0,00	238,87±75,75	6,81±0,35	387,91±0,00	5,65±0,00	295,06±222,10	6,48±0,25	381,03±131,29	7,16±0,63
RB	268,99±51,22	8,10±1,24	257,10±125,33	10,16±1,05	303,06±237,86	9,02±2,24	259,95±71,15	8,09±1,43	233,98±46,65	6,90±0,84	272,64±237,64	7,15±0,37	358,57±120,43	6,83±0,99	197,63±109,86	8,53±1,48
RW	353,50±94,40	7,80±0,78	417,93±124,48	8,36±0,67	288,20±90,45	7,14±1,58	427,45±15,96	7,73±0,33	332,32±173,80	8,11±0,30	406,54±300,42	9,11±1,20	176,88±130,61	6,94±1,72	425,17±34,29	7,22±0,67
PIV	333,16±57,95	8,21±1,42	360,20±248,43	8,50±0,36	355,18±261,22	8,29±1,56	327,83±145,16	6,55±1,33	361,38±297,37	9,84±0,02	301,49±93,38	7,74±0,53	317,13±194,46	8,13±0,00	410,59±353,85	9,63±0,82
DEF	329,82±76,38	5,81±0,47	337,63±213,63	6,38±0,82	322,86±147,41	5,52±0,27	279,06±3,90	5,18±0,74	318,82±52,49	5,72±0,47	207,76±70,93	5,49±1,81	404,57±333,29	6,41±1,32	438,02±0,00	5,97±0,00
	AVR PL ± SD	AVR PL/MIN ±SD	AVR PL ± SD	AVR PL/MIN ±SD	AVR PL ± SD	AVR PL/MIN ±SD	AVR PL ± SD	AVR PL/MIN ±SD	AVR PL ± SD	AVR PL/MIN ±SD	AVR PL ± SD	AVR PL/MIN ±SD	AVR PL ± SD	AVR PL/MIN ±SD	AVR PL ± SD	AVR PL/MIN ±SD
AVR[1]	322,70±40,46	7,56±0,94	340,48±118,95	8,36±1,30	323,16±140,92	7,70±1,68	324,92±84	7,19±1,44	298,81±118,40	7,68±1,40	321,64±154,78	7,42±1,56	322,61±176,98	6,97±0,95	333,83±158,45	7,93±1,30

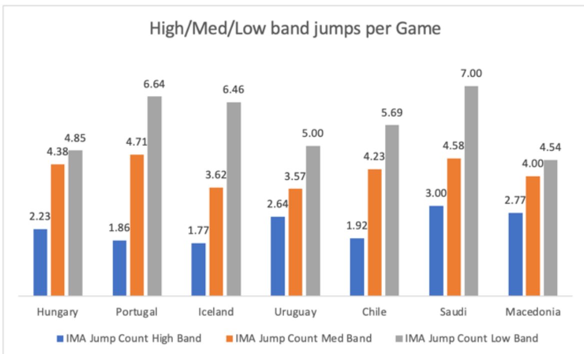
Observing the table above we can analyze the PL and the PL/Min for each position globally and for each position per game.

The positions that presented a PL over the team average- 322,70 ± 40,46 (excluding GK) were LW, LB, RW PIV and DEF, and over the average in PL/Min- 7,56±0,94 were LW, LB, RB, RW and PIV.

Not considering the GK PL and PL/Min: (i) vs Hungary the LB, RW and PIV where over the average in PL and LW, RB, RW and PIV are over the average in PL/Min; (ii) vs Portugal LW,LB,PIV and DEF where over the average in PL and LW, LB, RB and PIV where over the average in PL/Min; (iii) vs Iceland LB, CB, RW and PIV were over the average in PL and LW, LB, RB andRW where over the average in PL/Min; (iv) vs Uruguay LW, RW, PIV and DEF where over the average in PL and LW, LB, RW and PIV where over the average in PL/Min; (v) vs Saudi ArabiaLW, LB, CB and RW where over the average in PL and LW, RW and PIV where over the averagein PL/Min; (vi) vs Chile LW, RB and DEF where over the average in PL, and LW and PIV whereover the average in PL/Min; (vi) vs Macedonia LW, CB, RW, PIV and DEF where over the average in PL, and LW, RB and PIV where over the average in PL/Min.

The game with the highest in Average PL (340,48 ± 118,95) and in Average PL/Min (8,36 ± 1,30)was played against Hungary. The game with lowest Average PL was against Uruguay (298,81 ± 118,40) and with lowest Average PL/Min was against Chile (6,97 ±0,95).





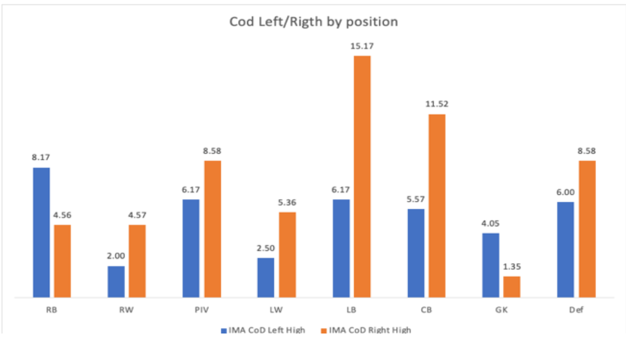
Observing the PL/Min, the average is 7.61±0,46. Over this value it was presented in the games against Hungary, Portugal, Uruguay and Macedonia, and values under the average were observedin the games against Iceland, Chile and Saudi Arabia.

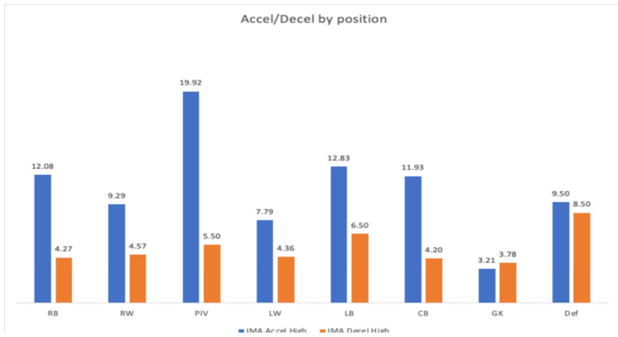
From this point forward, the goalkeepers are taken in consideration for this study.

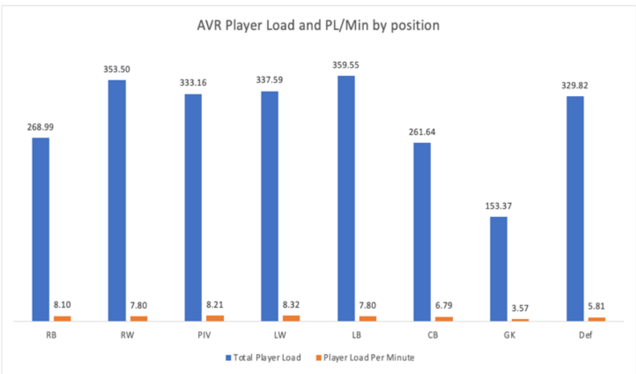
In what concerns to the number of accelerations the average number is 11,36±0,98 and we can observe a lower average in the games against Portugal, Iceland, Uruguay, Saudi Arabia and Macedonia, a higher average can be observed in the games against Hungary and Chile.

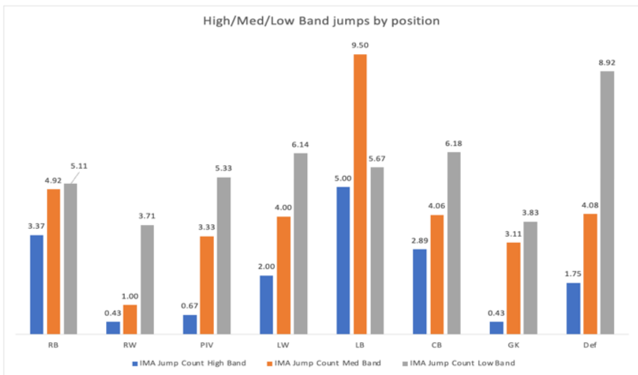
Observing the different bands of jumping, the high band average is 2,31±0,49 (over this average the game against Uruguay, Saudi Arabia and Macedonia, and under this average in the game against Hungary, Portugal, Iceland and Chile. The medium band jumps average is 4,16± 0,45, andvalues over the average were observed in the games with Hungary, Portugal, Chile and Saudi Arabia and values under the average in the games with Iceland, Uruguay and N. Macedonia.

Let's now analyse all these parameters regarding the different playing position.









The position that presents higher average PL is the LB 359,55±102,99 followed by the RW 353,50±94, 90, PIV 347,83±34,20, LW 337,59±7,58, DEF 332,74±142,46, RB 310,44±86,18, the CB 265,80±100,02 and the GK 187,26±29,51.

About the PL/Min, the position that has higher values is the LW 8,32±0,69, PIV 8,21±1,42, RB 8,10±1,24, RW (7,80±0,78) and LB (7,80±0,88), CB (6,79±0,64), DEF (5,81±0,47) and GK

(3,57±7,04).

About the jump bands, the position that has higher number of high band jumps (5,00±2,96) and medium band jumps (9,50±5,08) per game is the LB. Concerning low band jumps, DEF is the position that has more occurrences (8,92±3,53).

Observing the Cod Left, the position that presents the higher number is the RB 8,17 ±3,37, followed by the PV 6,17±2,12 and LB 6,17±3,19, the DEF 6,00±2,55, the CB 5,57±2,30, the GK4,05±0,93, the LW 2,50±1,31 and the RW 2,00±1,15.

In the values of the Cod Right, the position that clearly has more is the LB 15,17±6,34, the CB 11,52±6,80, DEF 8,58±5,05 and PIV 8,58±4,60, the LW 5,36±0,51, the RW4,57±2,51 and the RB

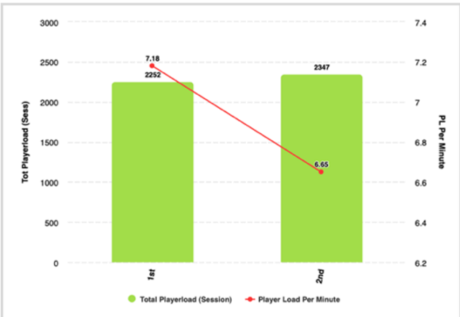
4,56±1,71 and GK 1,35±1,35.

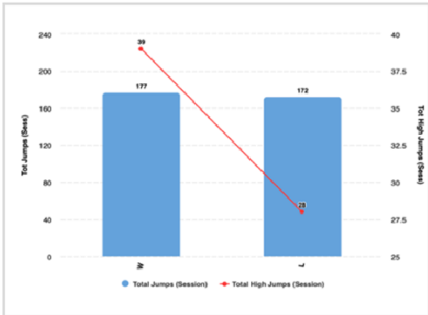
Observing the accelerations, the position with clearly more accelerations is PIV 19,92±2,24, followed by the LB (12,83±5,34), RB (12,08±2,60), CB (11,93±2,69), DEF (9,5±4,72), RW

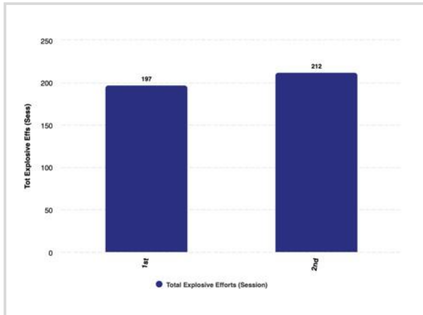
(9,29±4,46), LW (7,79±0,10) and the GK (3,21±3,29).

Concerning to decelerations, the DEF are the ones with higher number during the game (8,5±3,53), followed by the LB (6,50±4,76), the PIV (5,5±0,71), RW 4,57±2,51), LW (4,36±2,12), RB

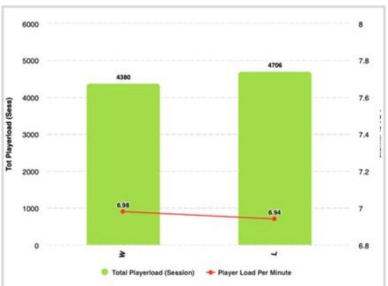
(4,27±1,53), CB (4,20±2,43) and GK (3,78±1,07).

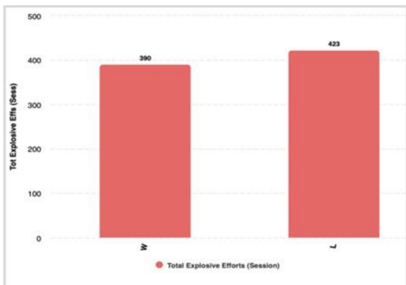






If we divide the game in two periods (1st and 2nd half), we observe that the Total PL in the 1st halfis lower (2252) compared to the 2nd half (2347), but the PL/Min is higher (7,18 vs 6,65). Analysing the number of jumps, in the 1st half the players jump more times (89 vs 85), but less frequently high band jumps. The total explosive efforts (Accelerations + Decelerations+ CoD Left + CoD Right) happen more in the game second half (212 vs 197).





Analysing the game only by the final result (Win-W or Lose-L), we observe that in the games ended with victory the team had lower player load (4380 vs 4706) with a higher player load/min,(6,98 vs 6,94), that the team jumped more times (177vs172) and from those much high band jumps(39 vs 28), performing less total of explosive efforts (390 vs 423).

Discussion and conclusions

The technological development (small wearable inertial measurement devices) allows coaches and sports scientist to access new data[10] that will, for sure, open new research areas that will help the players to enhance their individual performance and consequently the team performance. The trend in every sport suggests a better selection and better conditioning of the game participants [1], therefore a better understanding of game demands must lead to a more precise training prescription.From what we have searched we only found one paper[11] that made a study of this nature in a Men's Handball World Cup (Qatar 2015). There are no significant differences between top and low ranked teams[3,11] when we compare running data (distance and types of running), but we cannot affirm that the same happens in the variables analysed in this study, because the devices that we used couldn't collect distance and types of running in Indoor Sports, due to lack of indoor antennas. The playing position have high influence on game demands [4,6] and this was clear in our study in all the analysed variables. The PL was only significantly different between the GK and the other playing positions. The PL by itself, it is very important to analyse the individual load that a player has, but in a team with a large roaster, the intensity of the team can be very high (PL/Min) with low values of individual PL. Analysing PL/Min we could find significant differences between playing positions: GK and DEF have values clearly lower that other positions. CB have the lowest values comparing to other attacking players what does not corroborate other studies [3,10] where in CB presents big values of sprints and high-speed running. The values of PL and PL/Min presented by the Korean National Team in the 2023 Handball WC show that the rotation of the players during the games was made to achieve higher game intensity (except GK, all other positions have a low standard deviation), and no player was overloaded during any match (PL) even taking in account a pre competition injury that embezzled the team of one LB and force some players to adapt to a not common playing position. The body contacts, and isometric forces produced for example by the defenders and by the pivots are not measurable and most likely they affect the neuromuscular load [9] and consequently to the PL and the PL/Min should be taken into consideration.

Analysing the distribution of the jumps we assume that the Korean National Team does not use the jumping height has a *weapon* in the attack (maybe due to the players height), because we can check that in all games the low band jumps were the most commonly used, and only the LB playersuse more medium jumps that other jump bands (and has the higher number of high band jump compared to other positions). We may infer that this situation is due to the speed that the team putsin every aspect of the game to overcome the genetic height/weight disadvantage.

The changing of direction in handball is fundamental in a lot of game situations, both offensive and defensive. If the data obtained for the LW, LB, CB, PIV (show a clear tendence to go to the right side) and RB (show clear tendence to go to the left side), is considered *normal* because of theadvantage situation to put the body between the ball and the defender, further attention must be taken and maybe a video analysis should be done to explain why RW and GK change more timesdirection to the unadvantaged side. If naturally the Human body is not symmetric, this overuse ofone side to change direction (games+practice) probably will compromise more the body stability and planning is needed to balance this kind of situations, reducing the risk of injury.

The accelerations and decelerations in a high intensity game like handball, can provide a team the change of pace needed to overcome defensive systems or to anticipate offensive actions. In all games (except vs Chile), the number of high band accelerations almost doubled the number of high band decelerations, and if we look by position the GK are the only players in the court who have more decelerations than accelerations, even that the DEF have almost the same number of events. The Korean National Team PIV show a huge difference between accelerations and decelerations (19,92 vs 5,50), what shows that, the defensive role, the role in offensive transition,and in the attack system can clearly influence this kind of data. More studies are needed to validatea clear tendency in these parameters. According to the Total Explosive Efforts, that were found more in the game second half, we do not corroborate previous studies that reported less high intensity activities in the game second half [5].

The evolution of the GK role in a handball team has evolved a lot in the recent years. Besides the goalkeeping skills that are becoming more precise, the GK recently became *runners* (in the 7x6 in attack, and 6x6 empty goal), became *shooters* (can shoot goal to goal in 6x7 situations) and, even with less PL and PL/Min that the court players the values obtained are relevant and must be takenin consideration by the GK coaches in the full preparation for competitions, according to the team tactical approach.

For further notice, the games won by Korean National Team (compared to the one the team lost) had lower PL, higher PL/Min, more jumps, more high jumps, and less explosive efforts.

The training loads are often higher that game loads[6], and the data collected must help the coaching staff to better prescribe training unit and be used has a *natural* injury prevention plan [2]. Besides this, the team must be able to maintain high performance during all the game (tactical, technical and rotation between players) to be closer to win the game [11]. The number of players, and the spaceused in each drill, are two factors that the easily coaches control and have great influencethe %HRmax [13], and maybe have the same effect in the other variables here presented.

The data presented in this study should be taken in consideration when the coaching staff is planning a concentrated competition (like World Cup, Continental Championships/Games, Olympic games, etc). The selected players must be able to handle of all these variables loaded in a short period of time, added to the clubs' season load, with minimum risk of injury. Is becoming more and more important to combine the training sessions with monitored nutrition,supplementation, recovery processes, injury prevention protocols and rest to maximize the probability of winning a game/competition.

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REALTIME KINEMATIC DATA IN HANDBALL – WHAT TO DO WITH IT?

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SUMMARY

In this short communication, we elaborate on the procedures to extract some indicative information from kinematics data obtained from high-frequency locators and MEMS accelerometers as indicators of alactic anaerobic, lactic, and aerobic exertion. We also address the estimates of recovery dynamics for these *loads*. The data used was collected during the European Men's U-20 Handball Championship (13th edition).

INTRODUCTION

Physiology has developed methods to quantify exertion, be it energy expenditure or some other form of acute capability degradation.

The Ultra-Wideband Indoor Local Positioning System (UWB/LPS), microcontroller, and MEMS (*micro-electro-mechanical systems)* revolutions eventually opened the area of kinematic data (positional data and accelerometery) as a workload measuring tool in intermittent sports.

But this has been both an exciting and a deceptive journey, as the average demands approach most likely underestimates the real player workload (West *et al.,* 2020), and current activity metrics just add some kinematic quantities:

Add running distance (m), time and distance run at different speeds, running pace (m/min) (whatever direction and interval between them), and worst-case scenarios (within 5-min. periods);

Add accelerations, such as (n) of high-intensity accelerations, decelerations, and changes of direction (whatever direction and interval between them).

Monitoring load and the player's physiological response in handball is complex and challenging. Still, even with a lack of objective, reliable information about the actual load and its impact on each player, coaches subjectively measure it and make decisions. They "measure" and react mainly to performance changes, which are very dependent on volitive aspects. Also, they do some load balancing (such as resting players with many matches in the eve of a major event or rotating players during the match, etc.).

Therefore, coaches seem eager to know how much *effort* their players have made, although most often they seem to prefer lesser-quality, but immediate information rather than higher-quality data obtained with invasive, expensive, and very slow laboratory methods. Thus, this information might be important for training design, load management (including recovery), developing tactical strategies for performance optimization (including players' rotation during a match), and mitigating injury risk. So, there is a role for exertion data in team management decisions.

In this short communication, we elaborate on the procedures to extract some indicative information from wearable sensors targeted to the indoor sports market. We focus exclusively on kinematics data as obtained from high frequency locators (UWB/LPS, etc.) and MEMS accelerometers as indicators of alactic anaerobic, lactic, and aerobic exertion. We also address the estimates of recovery dynamics for these *loads*.

However, regressions established for other sports – *e.g.*, between displacement velocity and energy expenditure or lactate production - are not valid in handball. There are many side and backward displacements, many jumps and receptions in very inappropriate biomechanical conditions and a good amount of *almost static fight*. Also, the changes in the type of activity and main metabolic pathway are so frequent and unpredictable that we can only expect to estimate these *on average*. This is very much a work in progress, therefore here only a preliminary approach is presented.

METHODS

Methodological approach to the problem

We are developing handball-specific regressions between displacement velocity and aerobic energy expenditure as measured by oximetry. Recovery dynamics should be established with biochemical methods. These regressions are subject-specific and only valid on average although some more generic, position-specific equations are also being developed.

This form of exertion mainly produces energy depletion, some dehydration, and loss of salts. However, this is very easily and quickly recoverable (a few hours), so this is rather irrelevant except maybe for teams subject to multiple matches or multiple training sessions per day and extreme weather conditions.

For the lactic activity, the same considerations apply. In handball, these efforts very seldom have a duration exceeding ten seconds, and its recovery is even faster than in the previous case (a few minutes), so this information is also probably irrelevant for coaches.

Anyway, we present here the importance of considering the recovery as well as the load: it is the only way to understand the difference between a trivial high-intensity interval training of 7x200m with 5' intervals and a super-human world record of 1x1400m at the same pace. If we just add *efforts*, these two are equal (as represented in figures 1 and 2).

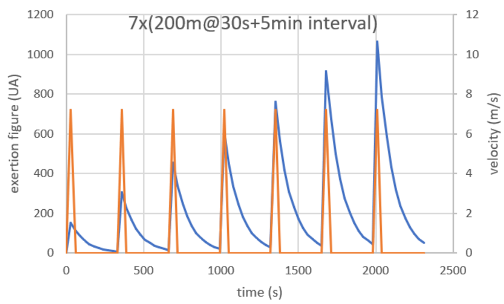

Figure 1. A very mundane 200m interval training, such as 7x(30'' at 26km/h) with 5' pause. Orange line represents the effort, and the blue line the estimated lactate production/recovery.

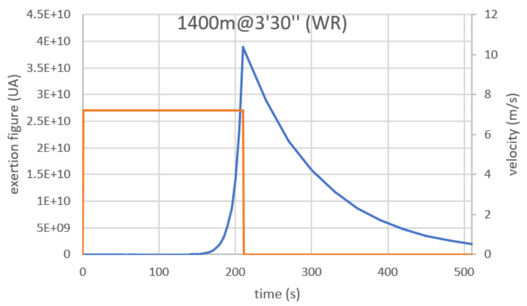

Figure 2. 1x1400m world record (3'30''). Orange line represents the effort and the blue line the estimated lactate production/recovery.

Finally, the high-intensity eccentric activity (mainly alactic anaerobic) is the most significant indicator. It is linked to muscle damage, possibly to injury risk and it takes days to fully recover from (Proske et al. 2001, Khan et al. 2016). It is also hard to properly calibrate as it depends on expensive biochemical indicators. For now, we are using the popular DSL function (dynamic stress load, Beato *et al.* 2019) as an indicator of exertion and a simple capped exponential as a recovery indicator.

Contextualization

This is an exploratory and preliminary study about different workload types and estimated recovery using data collected during the European Men's U-20 Handball Championship held in Portugal, where a team plays seven matches in 11 days (from the preliminary round until the final).

Like many other contemporary international handball tournaments, the studied tournament was characterized by a high number of matches condensed into a short period, with one day of rest between matches or even in two consecutive days (table 1 provides an example of a team match schedule from the preliminary round until the final).

Table 1. A typical matches' schedule of a team that went until the final

EURO	Preliminary round				Rest	Main Round		Rest	Semi-final	Rest	Final
Day	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11
	M 1	M 2	--	M 3	--	M 4	M 5	--	M 6	--	M 7

Instruments

Each player's 2D position data (x, y coordinates; 20 Hz) and 3-axis acceleration (100 Hz) were obtained via a wearable sensor (Wimu) that was embedded in a vest worn under their jersey (located at the posterior side of the upper torso). The Ultra-Wideband (UWB) Indoor Local Positioning System operates by means of triangulations between 8 antennae located around the handball court and connected to a server. Immediately after the warmup, players were asked to place the sensor and to remove it at the end of the match. A total of 711 player samples were obtained, as only some court had the necessary equipment.

Table 2. A typical matches' schedule of a team that went until the final

	TEAMS	Preliminary Round	Main/Intermediate Round	Cross Matches	Placement matches	Semi-Finals/ Finals
TOTAL	N=16	24 matches	16 matches	6 matches	6 matches	4 matches
Monitored	N=11	12 matches	8 matches	1 match	2 matches	4 matches

DEVELOPMENT – Results

Once these regressions are established, we can simply apply them to kinematic data and see the exertion dynamics. We present here just a pair of each, from an official European Men's U-20 Handball Championship, produced with our preliminary regressions, as an illustration.

Exploiting kinematic-derived metrics

Based on the measured "impacts" (i.e., high acceleration events) we computed and integrated the DSL using the following equation:

DSL= $\alpha \cdot IMPACT_i^k$

Alpha is an irrelevant scaling factor; k is 3 and $IMPACT_i = \|\vec{a}\|_i$ if $\|\vec{a}\|_i > 2\ G$ or zero otherwise.

One match - sample

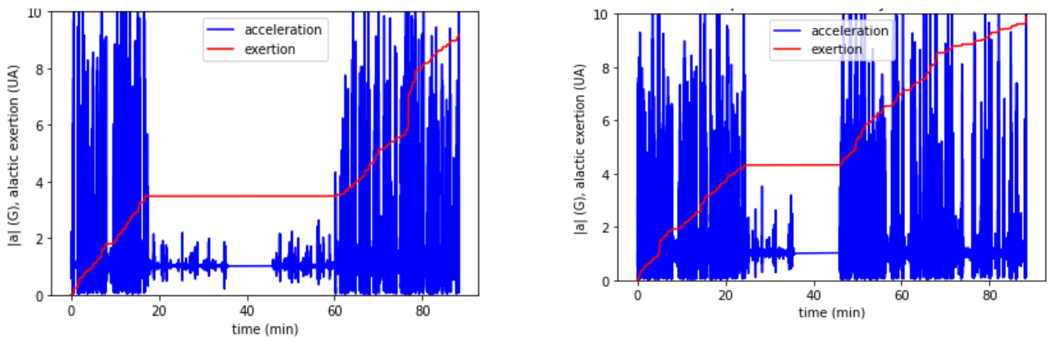

Figure 3. The two presented graphic are from two players of the same team and match where the observed muscle load follows a different path as they played different time and where the load intermittency is quite noticeable.

Multiple matches - sample

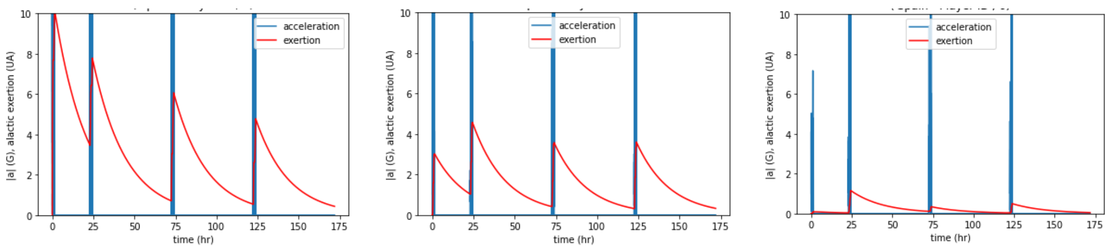

Figure 4. In each graph the estimated recovering time from the assessed muscle load is presented, considering four consecutive matches, from the first main round match (0-hour time), until the final (125-hour time). The 'left graph' is from a right-back player, the 'middle graph' is from a right wing and the 'right graph' is from a goalkeeper.

Exploiting lactate dynamics

To address this problem, we propose a new method – biology-based – that is sensitive to intensity and recovery time. For future analysis, a few athlete-specific parameters (*e.g.*, v4, $vO_{2\ max}$, t_{10m}) might be incorporated to provide more realist analysis.

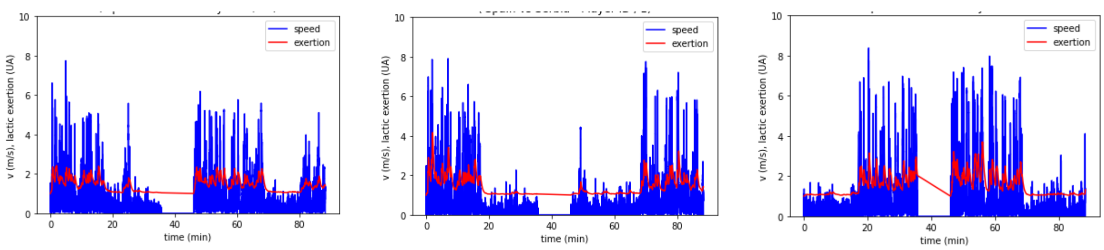

Figure 5. Data presented in each graph was computed from different court players, from the same team, and during the same match. The red line represents the estimated rate of lactate production and removal for each player during the match, considering standard (theoretical) values.

Exploiting total energy expenditure - mostly aerobics

This is the less complicated workload types to measure from velocity and speed data. Nevertheless, some oximetry experiments have already been done (we have done it during a match with referees). Most importantly is has a fast recovery, and it seem irrelevant to handball.

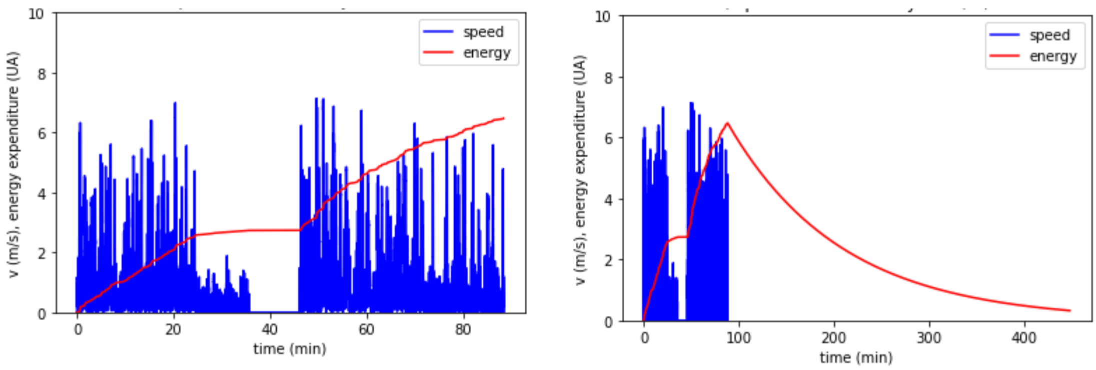

Figure 6. Both graphs are from the same court players. The 'left graph' shows the computed aerobic effort and the estimated energy expenditure during a selected match. The 'right graph' shows the estimated recovery in time (min.)

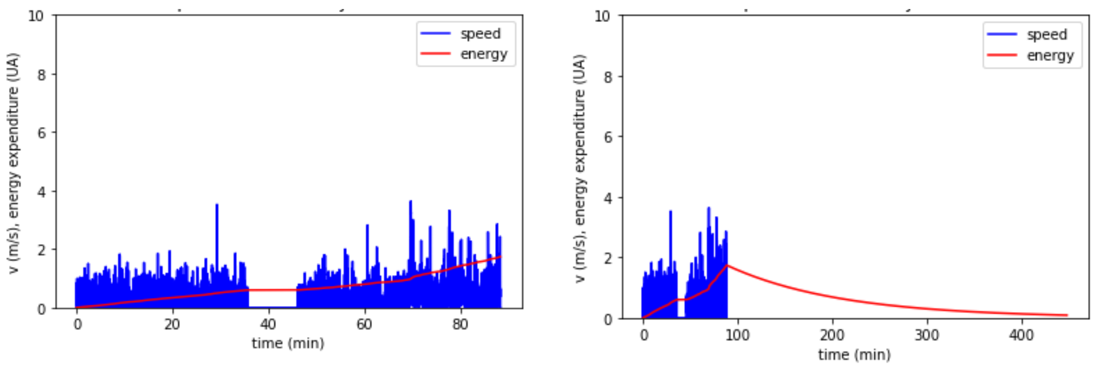

Figure 7. Both graphs are from a goalkeeper. The 'left graph' shows the computed aerobic effort and the estimated energy expenditure during a match. The 'right graph' shows the estimated recovery in time (min.)

As a summary, we can see that only the eccentric exertion should be a performance-diminishing and fatiguing factor in these kinds of tournaments.

FINAL REMARKS

We have produced some preliminary regressions between kinematic data and exertion quantification. These are just *rough indicators* of load but are easy to obtain.

The *load dynamics*, i.e., the understanding of *recovery*, is one more tool for some optimization of the training process, as well as better team and player management, reduced risk of player underperformance, and possibly reduced risk of injury. This is challenging but essential to avoid saturating coaches with useless data.

Acknowledgments

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ANALYSIS OF THE EMPTY GOAL AT THE WOMEN'S HANDBALL WORLD CHAMPIONSHIP 2021

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Abstract

The aim of this study was to analyse the use of the empty goal tactical resource and its influence on the game during the XXV Women's Handball World Championship 2021. The official match report and Play By Play documents of all the matches were used as source of data. The 1201 empty goal situations that occurred in the 105 matches played were analysed. The results showedthat the use of empty goal had a positive balance for most teams, and that they chose to replace the goalkeeper by an outfield player after 2-minute suspensions, rather than to attack 7 vs. 6.

Keywords: Handball, empty goal, offensive numerical inferiority, 7 vs. 6, World Handball Championship

Introduction

The tactical resource known as empty goal has been used both in situations of numerical equality to generate an offensive numerical superiority of 7 vs. 6 outfield players, and during periods of offensive numerical inferiority due to 2-minute suspensions, to attack with numerical equality, even at the risk of leaving the goal empty. The use of this tactical resource has been used for years, but it is from 1st July 2016 when some modifications to the rules of the game came into force, resulting in a greater frequency in its use.

Studies on championships where the rules of the game were applied prior to 1st July 2016, such as that of Antón-García (2010), suggest that the use of the "false goalkeeper" or "goalkeeper-player" did not entail a competitive advantage for the teams that used it. However, other studies, such as that of Beiztegui-Casado, Oliver-Coronado and Sosa-González (2019) showed favourable results in the use of this resource in situations of offensive numerical inferiority. Studies subsequent to the entry into force on 1st July 2016 of modifications to rule 4, where goalkeepers can be replaced by an outfield player without the need for the player who enters for the goalkeeper to wear an outfit of the goalkeeper's colour, nor for the goalkeeper to be the only one who can leave the field for the "real" goalkeeper, affirm that its use in numerical inferiority has had an enormous increase (Flores-Rodríguez and Ramírez-Macías, 2021), although theresults on its effectiveness are not homogeneous.

Most recent studies on rule change (Marczinka & Gál, 2018; Krahenbühl et al., 2019; Gümüș & Gençoğlu, 2020; Flores-Rodríguez & Ramírez-Macías, 2021) focus on the study of male competition. The existing differences between men's and women's competition make it necessary to also study this empty goal tactical resource in women's competition.

For all these reasons, this study was undertaken with the intention of providing data on this important and controversial research topic, on its use and effectiveness in the XXV Women's Handball World Championship 2021, held in Spain, with the objective of identifying and analysing the use of the tactical resource empty goal in this women's handball championship, differentiating its use in situations of offensive numerical inferiority, and in 7vs6 situations, determining whether these situations had a positive, neutral or negative influence on the development of the game, through a content analysis, and establishing a final balance of them during the championship, distinguishing their use in each of the 32 participating national teams.

Methods

This is a descriptive study based on the technique of content analysis of official documents obtained from the website of the International Handball Federation (IHF, 2021), such as the Match Report and the Play By Play or description of the game, play by play, of each of the 105 matches played by the 32 teams participating in the championship. It should be noted that not all 108 matches were played, as the national team of the People's Republic of China did not play their last 3 matches because they had cases of Covid-19 in their ranks, so they had to withdraw from the championship. The 1201 empty goal situations that occurred during the championship were identified and analysed. For this purpose, an ad hoc data recording instrument (recordsheet) was designed with the following variables: teams, number of 2-minute suspensions,number of empty goal situations, influence of the use of the empty goal and final score.

The variable influence of the use of the empty goal was defined as the result of each attacking situation when the empty goal was used, being specified in three categories of analysis, mutually exclusive:

- Positive influence: If the attacking team scores a goal, get a 7-meter throw, or a 2-minute suspension and/or disqualification of an opposing player.
- Negative influence: If the attacking team concedes a goal against while the use of empty goal, by means of an opposing counterattack (fast-break), or causes a 7-meter throw against them, 2- minute suspension and/or disqualification of one of their own players.
- Neutral influence: When none of the situations described above occur.

The final balance variable was defined as the difference between positive and negative results, being positive if the difference is greater than 0, negative if it is less than 0, and neutral if it is equal to 0.

Results

Table 1 shows the results of the empty goal situations in offensive numerical inferiority. The datais presented in order of the final ranking of the teams in the championship. The results of the use of the empty goal according to its influence or result in the game are detailed in Positive, Neutraland Negative, as well as the Total and the Final Balance of the use of empty goal in numerical inferiority. This final balance reflects the difference between the positive and negative results, being considered Positive if the difference is greater than 0, Negative if it is less than 0, and Neutral if it is equal to 0.

Table 1.

Results of the use of empty goal in situations of offensive numerical inferiority during the XXV Women's Handball World Championship, held in Spain in 2021.

Teams Classification	**Empty goal situations in offensive numerical inferiority**				
	Positive Result *n*	Neutral Result *n*	Negative Result *n*	Total Situations *n*	Final Balance
1º NOR	13	7	3	23	Positive (+10)
2º FRA	20	15	7	42	Positive (+13)
3º DEN	29	23	9	61	Positive (+20)
4º ESP	14	24	3	41	Positive (+11)
5º SWE	8	10	1	19	Positive (+7)
6º BRA	14	24	4	42	Positive (+10)
7º GER	13	20	4	37	Positive (+9)
8º RHF	14	16	2	32	Positive (+12)
9º NED	7	9	2	18	Positive (+5)
10º HNG	10	19	3	32	Positive (+7)
11º JPN	14	23	3	40	Positive (+11)
12º SRB	7	18	2	27	Positive (+5)
13º ROU	15	13	2	30	Positive (+13)
14º KOR	11	11	2	24	Positive (+9)
15º POL	11	13	2	26	Positive (+9)
16º AUT	21	24	6	51	Positive (+15)
17º SLO	11	22	12	45	Negative (-1)
18º CRO	*Does not use*				
19º CZE	7	24	2	33	Positive (+5)
20º PUR	2	5	5	12	Negative (-3)
21º ARG	8	12	3	23	Positive (+5)
22º MNE	6	20	4	30	Positive (+2)
23º CGO	18	13	6	37	Positive (+12)
24º KAZ	*Does not use*				
25º ANG	14	18	7	39	Positive (+7)
26º SVK	5	3	0	8	Positive (+5)
27º TUN	9	10	2	21	Positive (+7)
28º CMR	1	0	0	1	Positive (+1)
29º PAR	0	1	0	1	Neutral
30º UZB	*Does not use*				
31º IRI	*Does not use*				
32º CHN	20	19	4	43	Positive (+16)

Table 2 presents the results of the empty goal situations in 7 vs. 6. As in Table 1, the data are presented in order of the final ranking of the teams in the championship. The results of the use of

the empty goal according to its influence or result in the game are detailed in Positive, Neutral and Negative, as well as the Total and the Final Balance of the use of empty goal in 7 vs. 6. This final balance reflects the difference between the positive and negative results, being considered Positive if the difference is greater than 0, Negative if it is less than 0, and Neutral if it is equal to0.

Table 2.

Results of the use of empty in 7 vs. 6 situations during the XXV Women's Handball World Championship, held in Spain in 2021.

Teams Classification	**Empty goal situations in 7 vs. 6**				
	Positive Result *n*	Neutral Result *n*	Negative Result *n*	Total Situations *n*	Final Balance
1º NOR	3	1	0	4	Positive (+3)
2º FRA	2	2	2	6	Neutral
3º DEN	11	12	4	27	Positive (+7)
4º ESP	*Does not use*				
5º SWE	25	12	3	40	Positive (+22)
6º BRA	0	1	0	1	Neutral
7º GER	12	6	3	21	Positive (+9)
8º RHF	1	0	1	2	Neutral
9º NED	3	1	4	8	Negative (-1)
10º HNG	0	2	0	2	Neutral
11º JPN	21	13	6	40	Positive (+15)
12º SRB	0	1	0	1	Neutral
13º ROU	14	10	3	27	Positive (+11)
14º KOR	*Does not use*				
15º POL	3	3	0	6	Positive (+3)
16º AUT	19	20	11	50	Positive (+8)
17º SLO	*Does not use*				
18º CRO	*Does not use*				
19º CZE	0	1	0	1	Neutral
20º PUR	2	0	0	2	Positive (+2)
21º ARG	0	0	1	1	Negative (-1)
22º MNE	11	9	5	25	Positive (+6)
23º CGO	1	6	0	7	Positive (+1)
24º KAZ	*Does not use*				
25º ANG	28	24	5	57	Positive (+23)
26º SVK	1	0	0	1	Positive (+1)
27º TUN	11	10	2	23	Positive (+9)
28º CMR	3	0	0	3	Positive (+3)
29º PAR	*Does not use*				
30º UZB	*Does not use*				
31º IRI	0				
32º CHN	2	3	1	6	Positive (+1)

As the tables show, only 4 of the 32 teams did not use the tactical resource of the empty goal in situations of offensive numerical inferiority on any occasion, and 7 of the 32 teams did not use it to create 7 vs. 6 situations.

Only three teams, Croatia (18th), Kazakhstan (24th) and Uzbekistan (30th) did not use the empty goal tactic in any context. Cases such as the comparison between Spain (4th) and Angola (25th) stand out. The former did not use empty goal in 7 vs. 6 situations and was ranked as the fourth best team in the tournament, while the latter, despite a very positive balance (+23) in 7 vs. 6 situations, failed to qualify for the Main Round, but did win the first place in the President's Cup.

The team that made most use of empty goal was Austria (16th) with 101 situations, 51 in attacking numerical disadvantage and 50 in 7 vs. 6 situations, obtaining a positive balance in both contexts. Another fact to highlight is that only 2 national teams, Slovenia (17th) and Puerto Rico (20th) obtained a negative balance in empty goal situations in offensive numerical inferiority. The use in 7 vs. 6 situations left only 3 national teams with a negative balance: Netherlands (9th), Argentina (21st) and Islamic Republic of Iran (31st).

Figure 1.

Percentage of situations of use of empty goal in offensive numerical inferiority and in 7 vs. 6

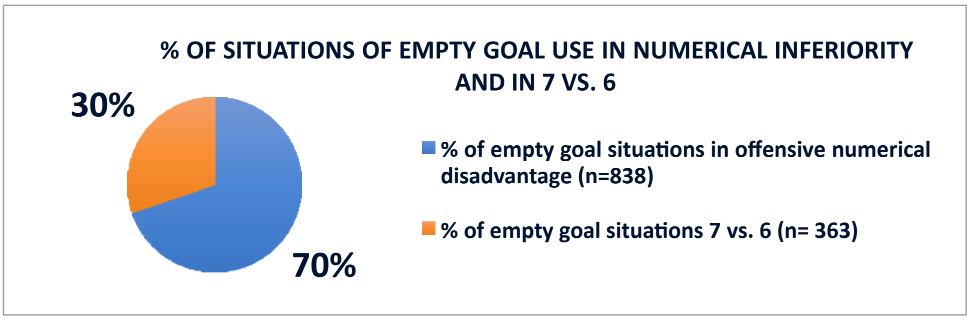

Figure 1 shows the % of situations in which the empty goal was used (1201) differentiating between the 838 situations in which it was used in offensive numerical inferiority, 70%; and the 363 situations in which it was used in numerical superiority of 7 vs. 6, 30%. In other words, it was used 2.3 times more for situations of offensive numerical inferiority than for 7 vs. 6.

Figure 2.

Influence of the tactical resource empty goal in situations of offensive numerical inferiority.

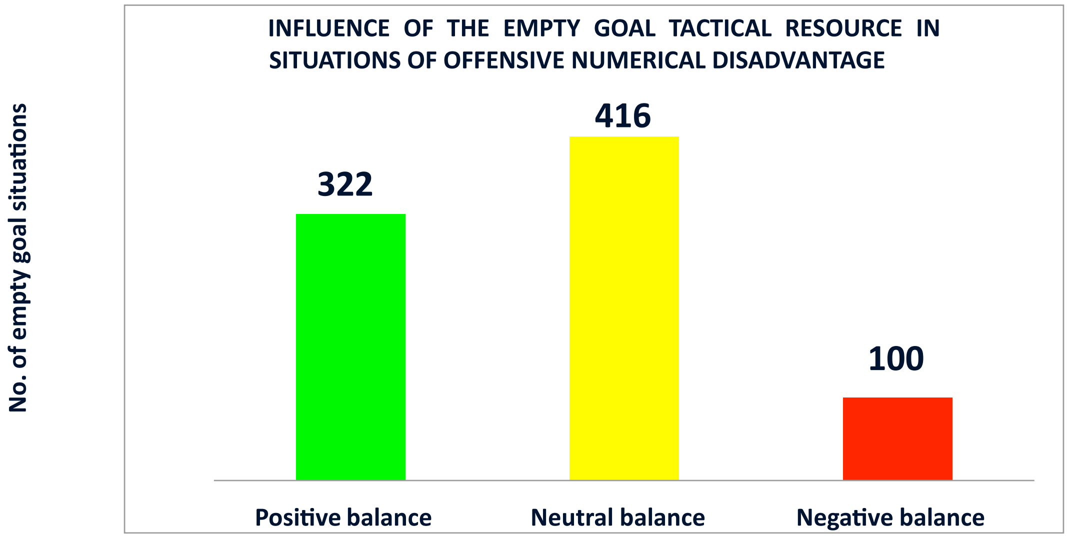

Figure 2 shows the influence of the tactical resource empty goal in the situations of offensive numerical inferiority in which it was used, obtaining a positive balance in 322, which means 38.43% of the total, a negative balance in 100 of them, 11.93%, and a neutral balance in 416, 49.64%, out of the 838 total situations in which it was used.

Figure 3.

Influence of the tactical resource empty goal in situations of 7 vs. 6 numerical superiority.

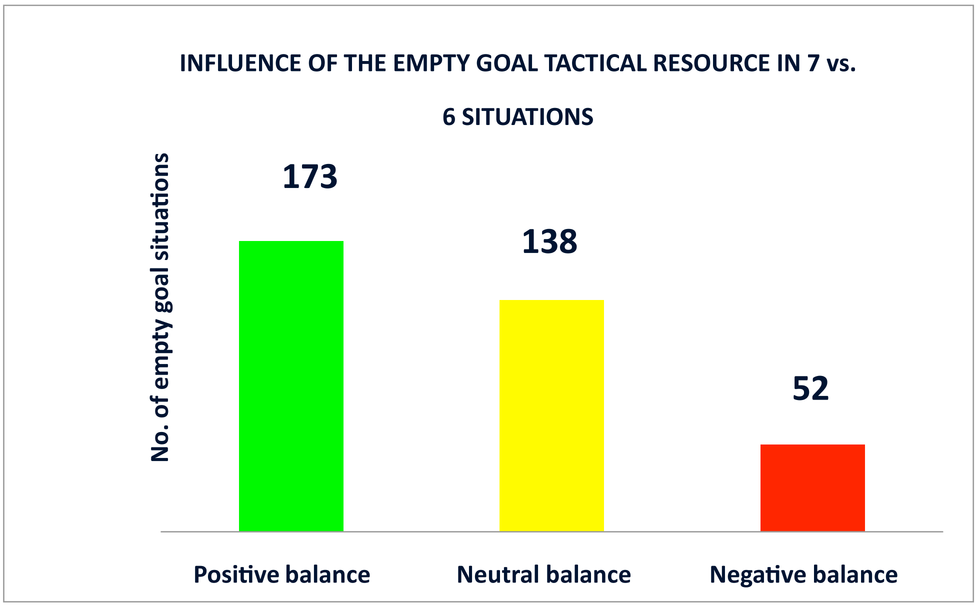

Figure 3 shows the influence of the tactical resource empty goal in the 7 vs. 6 situations in whichit was used, obtaining a positive balance in 173 (47.66%) of the total, a negative balance in 52 (14.32%) and a neutral balance in 138 (38.02%) of the 363 total situations in which it was used.

Discussion

The XXV Women's Handball World Championship in 2021 involved 32 teams instead of the traditional 24, so the sample of matches is larger, and the data is treated proportionally to other studies. In this study, the tactical resource empty goal benefited the teams that used it, especially in situations of offensive numerical inferiority. This contrasts with the study by Krahenbühl et al. (2019), where they concluded that its use did not bring significant changes in match resolution. Marczinka and Gál (2018) determined that teams used the tactical resource empty goal in offensive numerical inferiority twice as often as in 7 vs. 6 situations, which is similar to what was obtained in our study (2.3 times more), and is close to the findings of Bonjour et al. (2021) and the conclusions of Flores-Rodríguez and Ramírez-Macías (2021), where the empty goal was used to a greater extent in situations of offensive numerical inferiority. In the latter, moreover, it was found that all teams resorted to the empty goal in all situations of offensive numerical inferiority, while in our study 28 out of 32 teams did so (87.5%). Gümüș and Gençoğlu (2020) determined that the situations of offensive numerical inferiority were more effective than the 7 vs. 6 situations, a fact that is somewhat opposed to those of our study, as the final balance was more positive for the 7 vs. 6 situations.

Conclusions

- Almost all the teams used empty goal tactics, and their overall balance in the championship is positive.
- Most of the empty goal situations (69.78%) took place in numerically inferior attacking situations to compensate for the exclusion of a player, while situations of numerical superiority 7 vs. 6 accounted for only 30.22% of the total. In other words, the tacticalresource of empty goal was used more than twice as often (2.3 times) in numerically inferior offensive situations than in 7 vs. 6.
- Positives (38.43%) and neutrals (49.64%) predominated over negatives (11.93%) when using the empty goal tactical resource in situations of offensive numerical inferiority, making it an effective resource in such situations.
- The same occurred in the use of the empty goal in situations of 7 vs. 6, where positives (47.66%) and neutrals (38.02%) predominated over negatives (14.32%).
- The use of the tactical resource empty goal proves to be very effective in the two situations analysed.

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EFFECT OF CORE STRENGTH TRAINING ON VERTICAL JUMP HEIGHT, SPRINT AND THROWING VELOCITY IN UNDER 15 MALE HANDBALL PLAYERS

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Summary: This study aimed to determine the effects of CORE stability and strength on sprinting, jumping and throwing in under 15 handball players (14-15 years). Twenty-six male handball players (mean age 14.90±0.44 years) participated in this study. All the participants were playing in two under 15 handball teams, one team was the control group (n=13) and another team was the experimental group (n=13). The control group continued with their handball session, and the experimental group, in addition to the handball sessions, performed a circuit of six CORE exercises (3 sets with one-minute rest between sets), before each training session, with a duration of 15-20 minutes. The circuits to be performed were changed every two weeks. Jumping (CMJ), sprint (20 m) and throwing speed were evaluated before and after the six weeks of the intervention (18 sessions). No significant improvements were found in any of the variables analysed ($p>0.05$). The results of the research show that a six-week intervention focused on core strength training in under 15 handball players did not achieve improvements in jumping, sprinting, and throwing speed. This could be due to the difficulty of CORE training, which requires a great deal of corporal control, coupled with a short period, which may be the reason why no significant improvements in results were found.

Keywords: Adolescents, trunk muscle strength, exercise progression, athletic performance.

Introduction

Handball is a situational game where co-players and adversaries are involved in a changing environment with an infinite number of different muscle activation patterns, executed through different muscles. If muscle pattern can be anticipated, the central nervous system can plan previous strategies, but when the pattern is unpredictable, as happens in this type of sport, it is necessary to elaborate a proper response in a very short time. Hence, it is essential to have accurate proprioceptive information regarding position and the movement of the spine and pelvis to adjust motor response.

The main factor to be considered is the specificity of the sport since it could be determinant in achieving the positive adaptations that are going to be transferred to the players, depending on the stabilization demands that the sport has by itself. Those sports with strong decelerations and changes of direction cause destabilizing loads of the trunk that must be compensated by the stabilizing muscles of the core. This situation forces the central nervous system to generate stabilization strategies that are specific to each situation (Da Silva-Grigoletto et al., 2014).

Consequently, it is important to be aware of the adaptations in CORE stabilization processes, according to our work group when tasks and sessions are going to be designed. Therefore, it seems clear that it is not appropriate to propose CORE strengthening work without considering the specific demands of each sports activity (Shinkle et al, 2012). Taking this into account, under 15 handball players are a very interesting group to carry out CORE training. Firstly, because of age, since it is a perfect age for the development of different abilities in coordinative abilities, and secondly because of the influence that the CORE has in real handball situations. A handball match is a succession of changes of direction, high-intensity races, jump shots or imbalances, pushes, contacts with the opponent, etc. Working on strength and stability will not directly influence the improvement of performance in the different actions, but it will help us in an auxiliary way in each of these movements. A strong and stable CORE is the ideal complement to develop offensive and defensive actions efficiently and effectively. For all the above, this study aimed to determine the effects of CORE stability and strength on sprinting, jumping, and throwing in under 15 handball players (14-15 years).

Methods

26 male handball players of the under 15 category participated in this study, aged between 14 and 16 years. They were divided into two groups, 13 players in a control group (CG) and 13 players in an experimental group (EG). They are in the last mesocycle of the competitive period. The EG, in addition to the corresponding sessions, will carry out a CORE strength and stability exercise program before each of the training sessions. Both groups train 3 times a week. There have been casualties in both groups before the end of the sessions. In the experimental group, 2 injuries and 1 illness, and in the control group, 6 players had not completed the last training sessions and the post-test. The procedure was carried out via informed consent from their parents. The study complies with the Helsinki Declaration for working with human subjects.

Measures:

To measure the results of said exercise program on CORE strength, a series of variable tests have been carried out, in which CORE stability and strength have a determining role.

Assessment of physical condition

Sprint of 10 and 20 meters: Race in a straight line with a start indicated by acoustic stimulation.

Squat Jump (SJ): Vertical jump starting from a half-squat position (knees bent at 90 degrees), with the trunk upright and with the hands placed on the waist. The best of three attempts was recorded, with a three-minute rest between attempts.

Counter Movement Jump (CMJ): Vertical jump starting from an upright position and with hands on hips. A jump is performed by flexion followed as quickly as possible by an extension of the knees.

For both jumps (SJ and CMJ) the OptojumpNetx contact system was used, connecting the system's temporary controller to a computer, and two contact devices linked to it via infrared.

Throwing velocity: Players were asked to throw at maximum speed and without fainting. The test consisted of three different shooting situations: 1) from a penalty (7 m) (L7MSP and L7MCP); 2) support throw from 9 m with previous run (L9ASP and L9ACP); and 3) from 9 m in suspension with previous stroke (L9SSP and L9SCP). Each shot was made with the intervention of the goalkeeper (CP) and without his intervention (SP). All shots were made with the regulation ball. After each throw, the speed reached was reported to increase the players' motivation. The throwing speed was recorded with a radar gun (StalkerPro Inc., Plano, TX. USA) that had a recording frequency of 100 Hz and a sensitivity of 0.045 m/sec-1, placed behind the goal. The radar was placed at a distance of 3 meters and a height of 1.20 meters (Zapardiel Cortés et al., 2017).

Anthropometric Assessment: Anthropometric measurements were taken following International Working Group of Kinanthropometry protocols (ISAK) (Ross and Marfell-Jones, 1995). Weight was measured using the Tanita TBF300 with a precision of 0.1 kg. Height was measured using the Handac stadiometer with a precision of 1.00 mm. Body fat percentage was calculated using the body mass index (BMI) formula: weight/height^2 (kg/m^2).

Development

Before the conditional assessment, an anthropometric assessment was conducted. A specific warm-up for explosive strength tests and throwing speed was then performed under the coach's guidance.

Training:

The training consisted of 18 sessions conducted during the last mesocycle of the season, performed before each regular training session. Each session included 6 exercises highly involving the CORE muscles. The circuit lasted approximately 20 minutes. The sessions were conducted over 6 weeks. There were three different circuits, one for each two weeks. The intensity remained constant within each week but increased during the second week of each circuit. The difficulty of exercises in the circuits also progressively increased, with exercises in weeks 5 and 6 being more challenging than those in weeks 3 and 4, and so on. Each circuit consisted of 3 sets, with no rest between exercises and a 1-minute rest between sets.

Statistical analysis

All statistical analyses were performed using IBM-Statistical Package for the Social Sciences, version 24.0 (IBM-SPSS Inc., Chicago, IL, USA). A descriptive analysis of the sample was conducted using mean and standard deviation for the analyzed variables. Shapiro-Wilk test was used for normality, and Levene's test was used for homoscedasticity for pre and post-intervention moments. Paired t-tests were applied for intra-group pre-post intervention effects, and to determine the effect size for each group. Significance was considered for $p<0.05$.

Results and Discussion

The descriptive characteristics of the sample are shown in Table 1.

Table 1. Mean ± standard deviation of the test results in the pretest and posttest of the control group and experimental group.

	Experimental Group		Control Grup	
	Pre test (n=13)	**Post test (n=10)**	**Pre test (n=13)**	**Post test (n=7)**
Sprint 10 m. (sec)	2,5 ± 0,16	2,46 ± 0,10	2,16 ± 0,29	2,09 ± 0,47
Sprint 20 m. (sec)	3,78 ± 0,26	3,86 ± 0,17	3,46 ± 0,12	3,57 ± 0,21
SJ (cm)	29,43 ± 4,31	28,47 ± 5,41	32,80 ± 4,72	31,63 ± 1,86
CMJ (cm)	33,12 ± 5,83	30,84 ± 5,59	35,27 ± 7,13	36,45 ± 7,54
L7MSP (m/sec)	20,06 ± 1,04	19,69 ± 1,08	21,86 ± 2,11	20,18 ± 1,67
L7MCP (m/sec)	19,43 ± 1,01	19,68 ± 0,70	19,22 ± 2,44	20,21 ± 1,49
L3PASP (m/sec)	22,26 ± 1,84	21,94 ± 1,43	22,78 ± 2,22	23,22 ± 1,22
L3PACP (m/sec)	22,24 ± 1,44	21,90 ± 1,14	22,20 ± 1,96	22,52 ± 1,48
L3PSSP (m/sec)	20,60 ± 1,28	21,90 ± 1,14	22,07 ± 2,42	22,25 ± 2,17
L3PSCP (m/sec)	20,78 ± 1,16	20,14 ± 1,08	21,17 ± 2,35	21,44 ± 1,59

Leyend: SJ= Squat Jump. CMJ= Counter Movement Jump. Throw from 7 meters statically without a goalkeeper (L7MSP) and with a goalkeeper (L7MCP). Throw from 9 meters in support with 3 steps without the goalkeeper (L3PASP) and with the goalkeeper (L3PACP). Throw from 9 meters in a 3-step jump without a goalkeeper (L3PSSP) and with a goalkeeper (L3PSCP).

Our results showed a lack of significant improvements in the variables analyzed, such as sprints, jumps, and throws, among the experimental group (EG) participants. These results are in line with those published by Kunh et al. (2018) concerning throwing speed and correspond with the results of Ozmen et al. (2020) regarding jumps and speed. However, our results do not match with those reported by Saeterbakken et al. (2011), Manchado et al. (2017), and Gilmer et al. (2018). Several factors could be behind these unexpected results, hence a careful analysis for future interventions will be necessary.

One potential factor could be the timing of the intervention within the season. Conducting the training during a different mesocycle, when players are not as fatigued late in the season, might have yielded different outcomes. The duration of the training, despite comprising 18 sessions over 6 weeks, might have been insufficient for significant improvements. Although similar time frames have been used in other studies (Saeterbakken et al., 2011; Kuhn et al., 2019), it's possible that a more extended training period could have been more effective.

An essential aspect to consider is the players' inexperience with core training tasks. Core training demands a strong proprioceptive sense and a learning process to ensure that exercises are precisely targeted to the desired muscle groups. The lack of experience of our players could have affected the effectiveness of the training program. A potential solution for future interventions could involve a structured learning process, ensuring that participants have a solid understanding of the exercises before engaging in the full training program.

Furthermore, the study's approach to exercise variation could have affected the results. The frequent change of exercises every two weeks (using 30 different exercises) could have hindered the players' ability to master specific techniques thoroughly. Instead, maintaining a consistent base of exercises and making subtle modifications in difficulty could provide a more stable platform for skill development and improvement.

Conclusion and Recommendations:

In summary, the lack of significant improvements in the experimental group suggests that various factors, including the timing within the season, the training duration, the participants' inexperience in CORE training, and the approach to exercise variation, might have contributed to the observed outcomes. For future interventions, would be necessary to consider conducting training during a different season period, ensuring a more extended training duration, implementing a structured learning process for participants, and maintaining a stable base of exercises with slight modifications in difficulty. These adjustments could potentially lead to more effective core strength training programs for young handball players.

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ANALYSIS OF TECHNICAL ELEMENTS IN DEFENCE

Focusing on the differences between positions and genders

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SUMMARY

The aim of my research was to define the number of technical elements in defence based on the analysis of Hungarian first league handball matches and to compare the results between positions and genders. The results provided valuable insights for the design of optimal training plans and draw attention to the importance of position and gender specific training in handball.

Key words: handball, analysis, defence positions, gender,

INTRODUCTION

When coaching a team and training individual players, it is a legitimate expectation that the professional work should be adapted to the movement of handball and the demands of the game. Therefore, in coaching planning work, it is necessary to have metrics and benchmarks to predict match performance and the physical, technical and tactical demands of a position in attack and defence.

Most of the studies on the subject emphasise the importance of physical attributes as decisive factors of performance. However, in professional handball, success is influenced by several factors. The relationship between body composition and sport performance was demonstrated decades ago (Leedy et al., 1965, Bayios, et al., 2006). Then researchers (Urban et al., 2008, 2010; Vila et al., 2011; Visnapuu et al., 2011) found a strong relationship between body composition and playing position. When comparing genders, Sibila, Bon, Mohorič (2011, 2013) concluded that there are definite differences in anthropometry and body composition of female handball players at different levels related to position. Michalsik et al., (2011, 2013, 2015) addressed the dynamics and physical demands of matches, while Roglan (2006) studied the recovery time of Norwegian handball players. Platen & Manchado (2011) went a step further by analysing sprint acceleration profiles versus corresponding heart rate.

When looking for ways to improve performance in terms of handball technique, most research has focused on ball dexterity and ball speed in particular (Laffaye & Debanne, 2011), throwing motion of overarm and jump shots (Wagner et al., 2011) or the effect of different body parts on the velocity of the ball (Van den Tillaar & Etterma 2007).

For position-by-position comparisons, I have also found research mostly focusing on physiological and physical ability measurements: circulatory/metabolic workload (Karcher & Buchheit, 2014), locomotor load per position (Póvoas et al., 2014, Cardinale et al., 2017), the match load of men and women (Michalsik et al., 2015). More recently Bilge et al., (2020) compared the indicators of men's and women's national team top players in some points of the official statistics of the Tokyo Olympic handball.

In reviewing the research dealing with the topic, I found that, first and foremost, researchers approach the subject from a physical perspective. Over the past decade, I have made several attempts to assess the match demand of an attacking or defensive position. During the European Men's and Women's Championships, I assessed the attacking technical elements of the national teams (passes, goal shots, faking, dribbling) by positions and by gender. Throughout this pilot project, the statistical survey sheet has been refined, the way the data is entered and processed has been refined, and the experience gained has provided a good basis for the current survey work.

In my research I was looking for answers to the questions:

- How many technical and tactical actions executed by players in each defensive position?

- What are the differences between the different defensive positions?

- Are there differences in the number of executions between male and female players in these areas?

The outcome of this survey was to establish a baseline standard that is not yet available in the literature. And in analysing the data, I hoped to draw conclusions that could help handball coaches in the future in the individual coaching of their teams and players.

METHODS

In order to collate the adequate data, 5 men's and 5 women's matches were selected. Both the home and away team were analysed, hence the total number of teams analysed is 20, which is 71, 42% of the 14-14 team Hungarian First League. For this study I used post-match observation, which is a qualitative method based on purposeful, planned, systematic, objective facts (Wolcott, 1990). Match observations were conducted by qualified coaches (average 6 match/observer) with years of handball experience. The A4 statistical sheet, developed and tested on the pilot-project sample, (Bako et al., 2022) contains horizontal and vertical fields. The observation criteria include measurable, technical parameters of the defence *(Table 1)*

Defence activity	Variable observed	
Tackle	Diverting	on the ground or in the air
	Halting	
Blocking goal shooting	Overarm shot	individually or with a teammate
	Underarm shot	
	Curved shot	
	Jump shot	
Stealing the ball	Intercepting a pass	
	Knocking the ball away	

Table 1. Variables observed

In the data collection, only the settled defensive play against the settled attack was analysed because, unlike the offensive play during fast break, it is possible to define the positions in defence well. Players were analysed in the following six positions: Right1, Right2, Right3, Left3, Left2, Left1. The abbreviations of the official nomenclature of the International Handball Federation were used for the marking (Marczinka, 2016). To summarize the results, I used mathematical addition and rounding in some areas and the average result for one match was determined by percentage calculation.

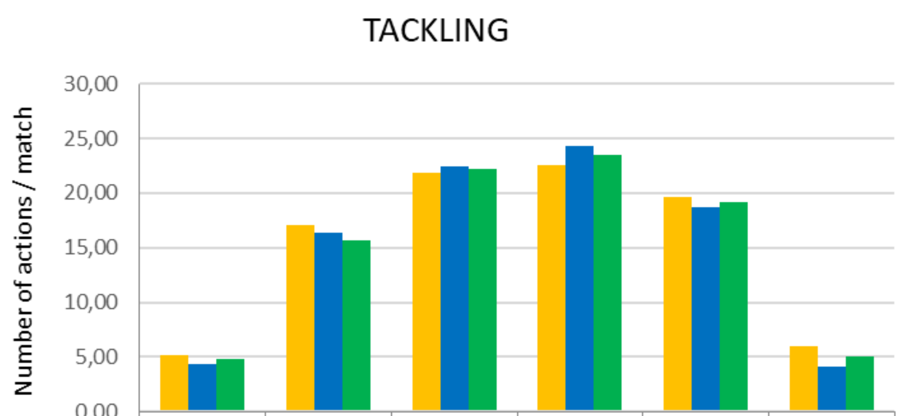
The overall average results of all the teams in all the matches, broken down by position and gender, are summarised in a table. This aggregation allows for the following analyses: *horizontal analysis* shows the differences between the defensive positions in main and sub-categories, averaged for female and male. At the end of the row, the total number of elements and their average score calculated. While *vertical analysis* can be used to determine the total load on the positions and the difference between the actions of male and female players. At the bottom of the columns, I aggregated the number of items per post, broken down by men and women, and averaged per match. These indicators can be used to compare the share of positions and gender in the total team activity.

RESULTS

Tackling - the combined execution rate of diverting and halting tackles on the ground and in the air was highest for No. 3 defenders (45.7), more than 10 times higher per match than No. 2 defenders (34.9) and more than four times higher than No. 1 defenders (9.9). In contrast to the difference between the sides of the No. 2 defenders (left No.2: 19.2 and right No.2: 15.7), the number of tackles on the left and right No.3 positions (23.5 and 22.2) was almost identical. If we divide the defensive activity into two sides, we find that the left side (42.7) had slightly fewer tackles than the right side (47.75).

The total average number of diverting tackles (D: 71.7) was more than 3 times higher than the number of halting tackles (H: 20.4) and in both cases they were significantly more often performed on the ground (D: 63.3 and H:17.85) than in the air (D:7.8 and H:2.55).

In terms of gender, it can be observed that in the right No.2 (F:17.1 and M:16.4) and left No.2 (F:19.6 and M:18.7), women tackled almost equally and more often than men. Although teams in the left No.2 position (19.2) on average made almost 4 more tackles than on the other side (15.7), by gender (36.7 and 35.1 respectively) women only slightly outperformed their male counterparts. And in the middle defensive position, there was no significant difference between men's and women's scores by sub-area, but also overall (F:22.4, M:24.3 and F:21.9 and M:22.6) between the right No.3 and left No.3 positions. *(Figure 1)*



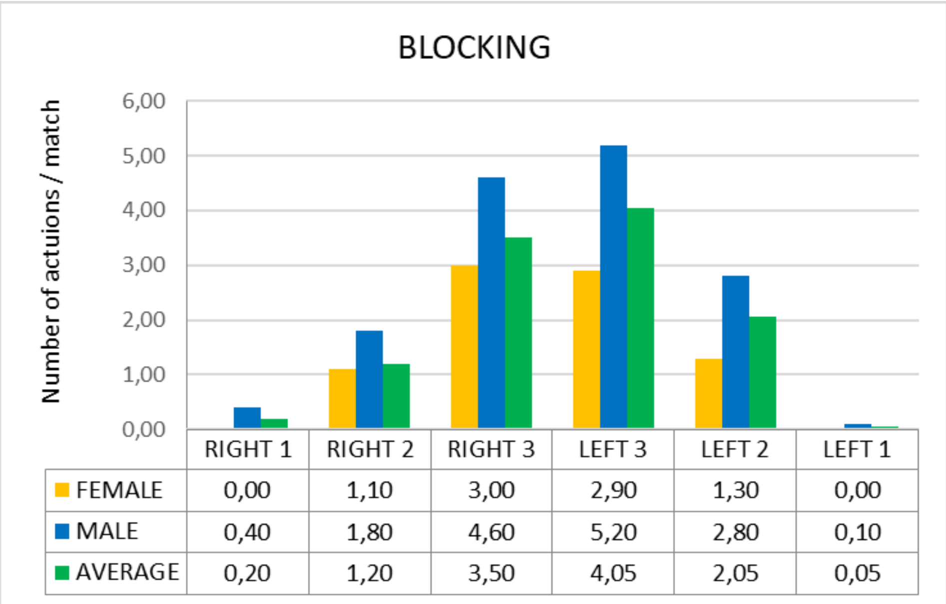
	RIGHT 1	RIGHT 2	RIGHT 3	LEFT 3	LEFT 2	LEFT 1
FEMALE	5,20	17,10	21,90	22,60	19,60	6,00
MALE	4,40	16,40	22,40	24,30	18,70	4,10
AVERAGE	4,80	15,70	22,20	23,50	19,20	5,05

Figure 1. Aggregated statistics of tackling (based on the results of 20 teams in 10 matches)

Blocking - given the way the handball game is played and the attacking players' shooting habits, it is not surprising that the number of blocking attempts was not significant in the No.1 positions (0.2 and 0.05 respectively) and that their frequency increased gradually towards the longitudinal axes of the court, in the inner defensive areas. According to the surveys, the blocking activity of the defenders in position No.3 (total: 7.55) was more than twice that of the defenders in position No.2 (total: 3.25) A comparison of the sides shows that there was no significant difference between the right No.3 (3.5) and its left post counterpart (4.05). However, the defender on the left (2.05) was twice as active in blocking shots on goal as his counterpart on the right (1.2), mainly due to the difference of blocking jump shots (1.5 and 0.6 respectively).

Due to the latitude of the long-range shooting zone, the horizontal shooting angle in the inner 4 defensive areas offers the attacker a variety of technical possibilities for attempting through shots on the ground or from the air. The quick shots from the ground (overarm, underarm, curved shots) were mostly taken individually (I:2.25, T:1.5), while the shots from the air (jump shots), which require longer preparation time and are therefore more easily anticipated, gave the defenders more opportunities to pair with their partner (I:3.45, T:4.25).

A comparison by gender reveals that male players in all positions implement blocking significantly more, and this results in a significant difference in the overall average score per match (F: 8.4 and M: 14.9). This is particularly striking in the most exposed area for goal shots, the middle area, where the number of male blockings in the two 3 defender positions was almost twice as high as the female element (5.9 and 9.8). *(Figure 2)*

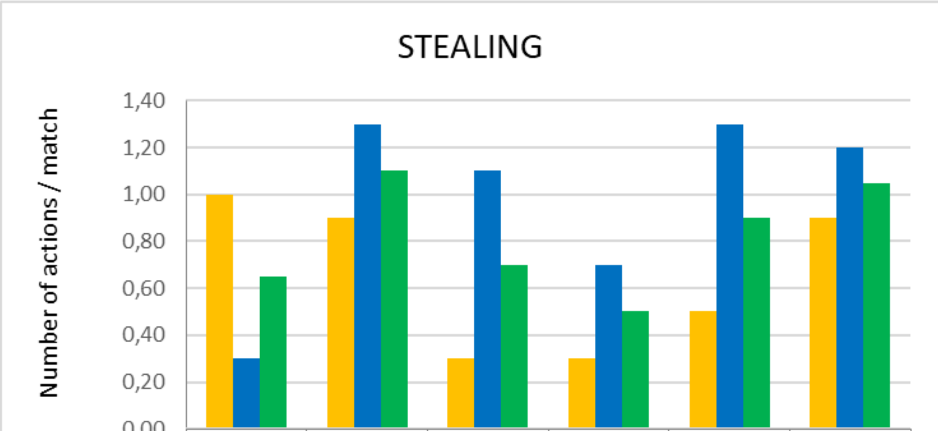


	RIGHT 1	RIGHT 2	RIGHT 3	LEFT 3	LEFT 2	LEFT 1
FEMALE	0,00	1,10	3,00	2,90	1,30	0,00
MALE	0,40	1,80	4,60	5,20	2,80	0,10
AVERAGE	0,20	1,20	3,50	4,05	2,05	0,05

Figure 2. Aggregated statistics of blocking (based on the results of 20 teams in 10 matches)

Stealing the ball - due to its location, No.2 defensive position provides an excellent opportunity for gaining possession. It is therefore no coincidence that, collectively, No.2 defenders (avg.: 2.0) made more attempts than No.1 defenders (avg.: 1.7), albeit by a small margin, and outperformed No.3 defenders (avg.: 1.2). At the same time, this is the survey category with the smallest difference between positions (max: 0.8, min: 0.15) and successful ball possession in all defensive positions. If we divide the assessed ball stealing techniques into two, we can see that intercepting a pass has a higher (3/match) and knocking the ball away a lower (1.9/match) share of the balls stolen (4.9/match)

When analysing the statistics by gender, it is striking that men (5.9) gained almost twice as many balls per match as women (3.9) and that this ratio increased even further in favour of men in the inner four defensive positions (F:2, M:4.4). *(Figure 3)*



	RIGHT 1	RIGHT 2	RIGHT 3	LEFT 3	LEFT 2	LEFT 1
FEMALE	1,00	0,90	0,30	0,30	0,50	0,90
MALE	0,30	1,30	1,10	0,70	1,30	1,20
AVERAGE	0,65	1,10	0,70	0,50	0,90	1,05

Figure 3. Aggregated statistics of stealing (based on the results of 20 teams in 10 matches)

CONCLUSIONS

A general examination of *tackles* revealed that diverting tackles were used more than three times more often in matches than halting tackles and were performed significantly more often on the ground than in the air. A significant difference in the number of tackles in the air was found in favour of men. When examining the diverting and halting tackles on the ground and in the air, a significant and in some places highly significant difference between the average execution numbers per position was observed: the highest for No.3 defenders, which decreased less for No.2 defenders and more significantly for No.1 defenders. However, when comparing the sides, it can be observed that there was no significant difference between the values of the positions in the central (Right 3 and Left 3) and the peripheral defensive areas (Right 1 and Left 1).

By knowing the way the game of handball is played and the habit with which attacking players shoot at the goal, it is not surprising that the number of goal shooting attempts and the attempt to stop them was not significant on the wings and that the frequency of these towards the longitudinal axes of the playing court, in the inner defensive areas gradually increased. Therefore, a position-by-position comparison of *blocking* was not relevant due to the small number of elements. When comparing between genders, I found that females were significantly more active than males when blocking close-range, lower positioned shots with a teammate. At the same time, men performed significantly more blocking in the air, both individually and with a teammate.

In the case of *stealing* the ball, I found that on average, intercepting a pass took a larger share of stealing the ball, while knocking it away takes a smaller portion. When analysing the statistical data by gender, no significant difference was found. This implies that there should be no gender differentiation in the content of training and that technical exercises to develop ball handling skills should be of equal importance in the training of male and female players. The fact that, due to the way the ball is handled, players have almost the same chance of attempting to steal the ball in each defensive position explains why there is no significant difference in the number of attempts in the different defensive areas.

As can be seen from the survey results, there were significant differences in the prevalence of technical elements when analysing defence by position and gender. These elements also caused physical stress to the body, therefore, it is clear that the physical demands of technical training must be taken into account in order to ensure accurate load distribution. Through this research, I have succeeded in establishing some standards that will help to achieve a more accurate load distribution according to the demands placed on the players. The results also demonstrate the need for differentiated training by position and by gender not just in conditioning but also in technical workout.

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SIX WEEKS OF ECCENTRIC TRAINING: CHANGES IN THE SHOULDER STRENGTH RATIOS IN JUNIOR MALE HANDBALL PLAYERS

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Introduction

Shoulder injuries account for 9% of all injuries in overhead sports (Petrie et al., 2019). The prevalence of shoulder injuries is as high as 36% (Clarsen et al., 2014) and in baseball the return to play rate is dramatically low at 7% (Fedoriw et al., 2014). One of the main reasons for this is the demands of throwing and the subsequent adaptations in the shoulder joint. Repeated throwing performance lead to an increase in strength and range of motion in the internal rotators, which is important for improving throwing performance. However, these adaptations do not occur in the antagonistic and stabilising external rotators, which have relatively low strength and range of motion values compared to the improved internal rotators (Astolfi et al., 2015; Burkhart et al., 2003; Johnson et al., 2018). In the long term, this leads to imbalances that chronically produce high stretching loads within the entire shoulder complex leading to tissue damage (Burkhart et al., 2003; Doyscher et al., 2014). Furthermore, as throwing always involves a massive eccentric load in a chronically reduced joint range of motion (Köhler et al., 2022), the acute stretching stress is increased with each throwing performance.

Similar shoulder demands (Van Den Tillaar & Ettema, 2007) and adaptations (Asker et al., 2020) apply to team handball. The consequences are performance-reducing shoulder complaints such as internal impingement syndromes or even acute rotator cuff injuries (Lubiatowski et al., 2018). As current prevention programmes do not show a significant effect in reducing shoulder overuse injuries (Achenbach et al., 2022), there is a need for effective prevention in handball. In order to primary prevent overuse injuries, it seems important to increase the strength ratio between antagonistic and agonistic shoulder muscles (Edouard et al., 2015), to reduce strength imbalances, to have a higher energy absorption capacity and to support the stabilisation of the shoulder complex. While eccentric resistance training for the lower limbs has been shown to be beneficial in improving injury risk factors such as a weakness in concentric and eccentric strength, a lowered ROM, and muscle fascicle length compared to conventional concentric-focused resistance training (Vetter et al., 2022), it is unknown how it improves shoulder function and the strength ratio for the external and internal rotator muscles. Therefore, the present study aims to find out how eccentric strength training improves the conventional strength ratio (CON/CON ratio, concentric external/internal rotator) or even the functional ratio (ECC/CON ratio, eccentric external/concentric internal rotator) promoted by Agaard et al. (1998).

Materials and methods

Sample and training regime

The study is based on a dataset of a randomized-controlled trial (Vetter et al., 2023). For this study, a total of 29 male junior handball players were recruited from a local elite handball club (18.0 ± 1.6 years; 186.8 ± 6.3 cm body height; 84.8 ± 11.3 kg body mass). 15 subjects were randomly assigned to the eccentric training group and performed five sets and ten repetitions of isokinetic eccentric training (BTE Primus RS, Hanover, MD, USA) twice a week for six weeks as part of the regular club strength training regime. 14 subjects were assigned to the active control group and exercised regularly by strengthening the shoulder with conventional free-weight strength training. Inclusion criteria for the present study were a healthy throwing shoulder, no medication that might affect adaptability, no history of musculoskeletal disorders, and no discomfort or pain in the shoulder complex.

Testing procedure

Before (pre) and after (post) the intervention phase, both groups underwent functional testing on an isokinetic device (ISOMED 2000, D & R Ferstl GmbH, Hemau, Germany). According to the pre- and post-testing procedure, all tests were performed in the order they are described and with a 60s rest in-between each test. The maximal strength tests were performed separately for concentric and eccentric rotation, alternating between internal and external rotation. Three repetitions were performed over an amplitude of 150° (60° internal rotation and 90° external rotation) at an isokinetic speed of 60°/s and then 30°/s. Each subjects position and dynamometer arm gravity correction value and settings were individualized at baseline and used for post-tests. A 10-minute warm-up on the rowing machine was performed at the beginning of the isokinetic tests. The data were recorded on the isokinetic dynamometer with a recording frequency of 200Hz.

Data processing and statistics

In terms of data processing and statistics, the data from the functional isokinetic tests were filtered using a fifth order, zero-lag Butterworth low-pass filter at a cut-off frequency of 6 Hz. Afterwards, the torque and angle data were cut according to repetition number and movement direction (internal or external rotation). From each repetition the acceleration and deceleration phase were cut leaving only the range with the desired isokinetic velocity. For statistics, the mean of three consecutive repetitions were used to calculate mean and peak torque using SPSS v.27 (IBM. Armonk. New York. USA). Descriptive results were based on mean values and the standard deviation (±). Univariate analysis of variance (ANOVA) and t-tests were performed to calculate pre-post and group differences. The significance level was set at $p = 0.05$.

Results

Four participants dropped-out of the trial due to previous shoulder discomfort and or a transfer to another handball club. Therefore, 14 subjects from the intervention group (17.9 ±

1.1 years; 188.6 ± 6.8 cm body height; 89.2 ± 11.6 kg body mass) and 11 from the control group (17.5 ± 1.3 years; 183.3 ± 5.2 cm body height; 78.3 ± 8.8 kg body mass) could be included in analyses. These participants successfully completed 12 training sessions within six weeks.

No changes were found for the intervention group in the CON/CON ratio (e.g. 60°/s peak torque (t(13) = .551, p = .295; d = .147), whereas significant negative changes were found for the control group for 60°/s peak torque (t(10) = 2.219, p = .025; d = .667). However, this change did not differ between groups (F(1,23) = .13, p = .722; ηp^2 = .006). All other parameters showed no change. In the 30°/s peak torque condition, the ECC/CON ratio improved in the intervention group (t(13) = -2.460, p = .014; d = .657) but not in the control group (t(10) = -.853, p = .207; d = .257). However, this change in the intervention group was not different from that in the control group (F(1,23) = 1.207, p = .283; ηp^2 = .050). No other changes were found. More details can be found in Table 1.

Table 1: Results for classical and functional strength ratio. Δ, change over time; p, significance; ER, external rotator; IR, internal rotator; ECC, eccentric; CON, concentric.

Ratio (ER/IR)	**Parameter**	**Control**				**Intervention**				**Group Difference**
		Pre	Post	Δ	*p*	Pre	Post	Δ	*p*	*p*
CON/ CON	Peak torque 30/°s	0.71 (0.11)	0.73 (0.09)	4%	.274	0.68 (0.10)	0.70 (0.08)	5%	.109	.814
	Peak torque 60/°s	0.73 (0.10)	0.71 (0.09)	-3%	.025	0.72 (0.13)	0.71 (0.08)	0%	.295	.722
	Mean torque 30/°s	0.75 (0.12)	0.80 (0.12)	7%	.106	0.74 (0.11)	0.76 (0.12)	4%	.238	.659
	Mean torque 60/°s	0.76 (0.09)	0.75 (0.10)	0%	.450	0.76 (0.13)	0.76 (0.10)	1%	.480	.965
ECC/ CON	Peak torque 30/°s	0.92 (0.13)	0.96 (0.16)	4%	.207	0.86 (0.14)	0.97 (0.16)	11%	.014	.283
	Peak torque 60/°s	0.93 (0.18)	0.98 (0.13)	4%	.092	0.93 (0.14)	0.97 (0.20)	4%	.212	.940
	Mean torque 30/°s	0.98 (0.21)	1.01 (0.22)	3%	.309	0.98 (0.20)	1.08 (0.25)	10%	.056	.382
	Mean torque 60/°s	0.96 (0.20)	0.97 (0.15)	1%	.428	1.01 (0.18)	1.04 (0.15)	3%	.242	.720

Discussion

The aim of this study was to figure out if isokinetic eccentric training of the external rotator can alter the strength ratio of the throwing shoulder in junior handball players. The present study found an 11% significant improvement (from 0.86 to 0.97) in the ECC/CON ratio after six weeks of eccentric training, while no changes were found in the control group. Interestingly, the conventional CON/CON ratio showed a 3% significant decrease in the control group and no change in the intervention group.

Compared to the literature, CON/CON ratios are widely applied (Achenbach et al., 2020; Hoppe et al., 2022). In adolescent male handball players, an isometric strength ratio of 0.78 for the external rotators was associated with shoulder overuse injury (Achenbach et al., 2020). In the present study, baseline CON/CON ratios ranged from 0.68 to 0.76 and did not change above 0.80. This means that in terms of the CON/CON ratio we can interpret that these shoulders are not far from an increased risk of overuse injury. But, looking at other injury risk factors that may be promoted by eccentric training, another study of this sample (Vetter et al., 2023) showed significant changes in eccentric strength (+15%) and muscle fascicle length in the supraspinatus and infraspinatus muscles (+13% and +8%, respectively). It can therefore be concluded that the CON/CON ratio may not reflect the full preventive potential of eccentric training. As Köhler et al (2023) quantified the massive eccentric load before and after a throwing performance, the ECC/CON ratio (Aagaard et al, 1998) may be a better way to understand the function and condition of the shoulder, which improved significantly in the present study.

However, it must be acknowledged that the shoulder joint presents a challenge to any intervention strategy, as it is a muscle-driven joint with five joints and small and curved structures. Therefore, not only the stabilising muscles but also passive structures such as the capsule determine the function of the shoulder complex (Culham & Peat, 1993). Due to the anatomical and physiological complexity of the shoulder, some scientists explain that it may be difficult to induce training stimulus to specific muscle-tendon-units to force effective structural adaptations and to improve disbalances and function in the throwing shoulder (Camargo et al., 2014; Zandt et al., 2010), On the other hand, Butterfield et al (2010) explain a better adaptability for small structures as the descending limb is reached earlier compared to the lower limb muscles, which indicates a greater stretching of the tissue and may lead to an effective hypertrophic response.

However, although we expected greater changes in some parameters, the results of the present study still show that eccentric training can improve the ECC/CON ratio and other functional and structural measures (Vetter et al., 2023). In addition, the handball players who consistently performed eccentric training as part of their regular strength training routine subjectively reported greater shoulder stability, less discomfort, and a better ability for shoulder warm-up during training and competition (Vetter et al., 2023), suggesting that eccentric shoulder training may be an important way to improve shoulder function and the shoulders' health condition in team handball.

Regarding the limitations, a few points are worth mentioning. Firstly, the sample size limited the statistical power, so that some variables, although showing some trends, failed to reach significance regardless of the analytical procedures employed. Second, the intervention group and control group showed different anthropometric characteristics, probably resulting in different adaptations. Therefore, the group-comparisons have to be interpreted with caution. Third, some handball players seemed to experience difficulties with the eccentric training and testing and were found to be outlier (excluded from analyses). However, after the intervention they explained chronic shoulder problems. Finally, the eccentric external rotation exercise used in this study does not fully address the entire functionality and adaptive potential of the external rotator muscles, as abduction exercises were not part of the training regime, which has been described as important for improving external rotator function (Camargo et al., 2014). However, the idea was to focus on rotational movements on the basis of the widely known glenohumeral internal rotation deficit in the throwers shoulder, which is a major risk factor for injury (Johnson et al., 2018).

Conclusion

In conclusion, the ECC/CON ratio showed improvements that are important from a biomechanical and preventive perspective. Therefore, eccentric training can be interpreted as superior to conventional preventive exercises (active control group). Furthermore, this study showed excellent compliance rates, which is a good sign that eccentric training could be incorporated and become an obligatory part of athletic training in handball and other throwing sports. However, future research with larger sample sizes is needed to clarify the feasibility and effects of eccentric exercises without the use of an isokinetic machine, and to correlate functional and structural measures.

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ANALYSIS OF GAME PACE AND PERFORMANCE METRICS OF ELITE TEAMS IN THE PORTUGUESA HANDBALL LEAGUE: A COMPARATIVE STUDY WITH THE EHF CHAMPIONS LEAGUE

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Summary

This study compared handball teams' game pace and performance metrics between the Portuguese League and EHF Champions League, analyzing 30 matches from each. While no significant differences were found in game pace and goalkeeper efficiency, variations occurred in goals scored, attack and defense efficiency, fast break efficiency, positional attack efficiency, and defensive recovery efficiency. The findings provide insights for coaches and stakeholders aiming to enhance collective performance in handball.

Keywords: Game Pace, Performance Metrics, Portuguese League, EHF Champions League.

Introduction

Handball is one of the most popular team sports in the world, as it is Olympic and played by around 19 million athletes (Ferrari et al., 2019). This sport is characterized by short high-intensity activity periods interspersed with variable recovery periods (McGarry et al., 2013). handball is a team sport considered an invasion, played by two opposing teams, with intermittent periods of effort and recovery, comprising submaximal stimuli with incomplete rest periods, where the intensity of effort varies depending on the player's position on the field (Póvoas et al., 2014). The game is defined by four phases: i) defence; ii) defence-attack transition; iii) organized attack; and iv) attack-defence transition. The defence-attack transition or offensive transition can include the fast break's first, second, and third waves. It is important to understand that analysing performance in different phases can contribute to the evolution and development of a team's performance and define success (Debanne & Laffaye, 2017). Post-match analysis helps assess performance in that specific game, while an overall analysis of the season, championship, or competition can contribute to classifying and assessing the success or failure of participating teams in general (Bilge, 2012). In recent years, many coaches, athletes, sports agents, and other stakeholders have perceived an increase in the technical, tactical, and physical demands of the game. Considering the aforementioned considerations, this study aimed to quantify the game pace among the top 6 teams in the Portuguese 1st Division Championship of the 2022/23 season and compare it with the EHF Champions League of the 2022/23 season. Understanding these evolving patterns can be useful for various applications, such as predicting future game and training demands, identifying talent, and assisting coaches in managing training loads, among many others, to better prepare for the future of handball. Thus, the objective of this research is to evaluate the game pace in the Portuguese league and identify the most relevant metrics for achieving better collective performance, providing insights and recommendations for coaches, athletes, and other sports stakeholders. The aim is also to assess the game pace and compare it with the EHF Champions League.

Methods

The cross-sectional study included the analysis of 30 matches from the Portuguese 1st Division Handball League (Liga Placard) of the 2022/2023 season, specifically focusing on the top 6 ranked teams playing against each other. Only matches played in the Portuguese league were analysed, excluding all matches played in other competitions such as the Portuguese Cup, Portuguese Super Cup, Iberian Super Cup, and EHF European League. Additionally, we had access to the analysis of the 128 matches from the 2022/2023 EHF Champions League conducted by Sevilla and Ruiz (2023). The EHF Champions League is the most prestigious club competition in Europe.

Game Phases: i) Positional Attack - The positional attack occurs when the attacking team has the opportunity to score a goal against an already structured defence. It involves organizing and coordinating the actions of all players involved in the attack to effectively occupy all areas of the field and ensure a well-structured offensive play; **ii) Counterattack -** The counterattack is considered the first phase of the attack, which occurs when the defending team recovers ball possession through a successful play or an opponent's mistake. It involves a quick transition from defence to attack before the opponent can organize their defence. There are different types of counterattacks, such as direct and sustained. In this study, only direct and sustained counterattack situations were standardized, representing the first and second waves, respectively.

Variables: i) Performance - The performance variable consists of the number of points obtained per match, in the Portuguese handball championship, the winning team receives three points, the losing team receives one point, and in the case of a draw, both teams receive two points; **ii) Pace -** Pace is the game pace and corresponds to the number of ball possessions each team has per game; **iii) G. Attack -** The G. Attack variable is the ratio of goals scored to the number of ball possessions, representing the overall efficiency of the attack. It includes both positional and counterattack phases; **iv) G. Defence -** The G. Defence variable is the ratio of goals conceded to the number of opponent's ball possessions, representing the overall efficiency of the defence. It includes both positional defence and the opponent's counterattacks; **v) Adv -** The Adv variable evaluates the attack performance of the defensive performance; **vi) Positional At. -** The Positional At. variable is the ratio of goals scored to the number of ball possessions in a positional attack, representing the effectiveness of the positional attack; **vii) Positional Df. -** The Positional Df. variable is the ratio of defensive successes, where the opponent did not score a goal, to the opponent's ball possessions in a positional attack, representing the effectiveness of the positional defence; **viii) Counterattack -** The Counterattack variable is the ratio of goals scored in a counterattack to the number of counterattacks, providing the efficiency of the counterattack; **ix) Retrait -** The Retrait variable evaluates the efficiency of the team's defensive recoveries; **x) Saves -** The Saves variable represents the goalkeeper's save efficiency; **xi) OT -** The OT variable represents the proportion of shots on target faced by the opposing goalkeeper that resulted in a goal. This provides shooting effectiveness.

Procedures

Data collection involved the analysis of all matches between the top six teams in the Portuguese League during the 2022/2023 season. The data were sourced from Andebol TV, the official broadcasting platform of the Portuguese Handball Federation. The MultiCounter+ application on an Android device facilitated data collection, with subsequent processing conducted using Microsoft Excel and Python. Variables collected for each match included game pace, number of goals, number of ball possessions, efficiency of attacks resulting in goals, efficiency of defences allowing goals, efficiency of positional attacks, number of positional attacks, goals scored in positional attacks, efficiency of counterattacks, number of counterattacks, goals scored in counterattacks, save efficiency, number of saves, efficiency of defensive actions in positional attacks, number of defensive successes in positional attacks, efficiency of defensive recoveries, number of successful defensive recoveries, and the total number of defensive recovery actions.

Statistical Analysis

The collected data underwent descriptive statistical analysis, involving the calculation of mean and standard deviation for all measured variables. The normality of the distribution was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Subsequently, t-tests and Mann-Whitney U tests were employed to compare statistical differences between the Portuguese League and the EHF Champions League. Additionally, Linear Regression, a supervised machine learning method, was utilized to identify predictors of Performance and Adv. All analyses were conducted in Python, with a significance level set at $p < 0.05$. Graphical presentations will be created using Tableau Desktop Professional Edition, version 2013.1.0.

Results

Table 1 presents the characteristics of the total sample and by competition. Regarding the Placard League sample, the values for General Def., Counterattack, Positional Def., and Saves were higher than those of the EHF Champions League. There were also significant differences ($P \leq 0.05$) between the Placard League and the EHF Champions League in the number of Goals per game, General Att., General Def., Positional Att., Counterattack, Positional Def., and Retrait. Table 2 presents the descriptive analysis grouped by teams of the top six ranked teams in the Portuguese league, where it can be observed that the competition winner displayed higher performance indices, goals scored, overall attack, and positional attack. Interestingly, the third-placed team, SLB, achieved better results in terms of overall defence, positional defence, counterattack, defensive recovery, and goalkeeper saves. Despite SLB's superior defensive indices, SCP conceded the fewest goals. It is also noteworthy that FCP had the lowest period in positional attack (40.85%) and defensive recovery (6.43%) while having a higher period in counterattack (9.15%) and positional defence (43.57%) in the matches played against their opponents. Regarding the game pace, ABC had a higher average ball possession per game. In the sample ranking, ABC finished in 5th place but in the overall league ranking, they finished in 4th place, ahead of AAS.

Table 1 Descriptive analysis of the sample.

	All (N = 128), Mean ± SD	Placard League (N = 30), Mean ± SD	EHF Champions League (N = 128), Mean ± SD
Pace	56.69 ± 8.19	55.32 ± 4.84	57.01 ± 8.56
Goals [a]	62.99 ± 9.99	59.23 ± 7.03	63.88 ± 10.29
Gen. Atk., % [a]	0.56 ± 0.05	0.54 ± 0.05	0.56 ± 0.05
Gen. Def., % [a]	0.44 ± 0.05	0.46 ± 0.05	0.44 ± 0.48
Pos. Atk., % [a]	0.53 ± 0.06	0.51 ± 0.06	0.53 ± 0.06
Counterattack, % [a]	0.64 ± 0.10	0.68 ± 0.12	0.63 ± 0.09
Pos. Def., % [a]	0.47 ± 0.06	0.49 ± 0.06	0.47 ± 0.06
Retrait, % [a]	0.36 ± 0.10	0.32 ± 0.12	0.37 ± 0.10
OT, %	0.73 ± 0.05	0.72 ± 0.05	0.73 ± 0.05
Saves, %	0.27 ± 5.78	0.28 ± 0.05	0.27 ± 0.05

Notes:

[a] $p \leq 0.05$, a significant difference between the Portuguese Championship and EHF Champions League.

Table 3 presents the results of the linear regression analysis assessing the associations of the analysed variables with performance and adv. Various associations were found between the analysed variables and performance. A highly significant association (P < 0.01) was observed between Adv, Rank, Goals Scored, General Attack, and Positional Attack with Performance. Additionally, a significant association (P < 0.05) was observed between General Defence and Performance. Furthermore, a highly significant association (P < 0.01) was found between Performance, Rank, Goals Scored, General Attack, and Positional Attack with Adv. A significant association (P < 0.05) was also observed between General Defence and Adv.

Discussion

This study aimed to analyse the pace of play and metrics in key phases of the game among the teams that finished in the top 6 of the Portuguese male handball league. The results show that there are no statistically significant differences in the pace of play, OT, and goalkeepers' defences between the top 6 teams in the Portuguese handball league and the EHF Champions League. Furthermore, it was also observed among the top 6 teams in the Portuguese handball league that Adv, Rank, Goals Scored, OT, G. Attack, Positional At., and Positional Df. are significantly associated with Performance. Regarding goals scored, several studies suggest that goals scored differentiate between winners and losers, and in our case, our results are consistent with several studies (Ferrari et al., 2019; Hatzimanouil et al., 2017). In terms of positional attack, teams that achieve better results and victories have higher efficiency and score more goals during attacks that originate from organized defences because they have superior offensive capabilities to solve more complex situations (Ferrari, 2014; Ferrari et al., 2019; Rogulj, 2000). Thus, our study aligns with several previous studies. According to Yannakos et al. (2019), the efficiency of goalkeepers does not determine or guarantee the performance of a team, which coincides with our study. It was also observed that among the top 6 teams in the Portuguese handball league, OT %, Performance, Rank, Goals Scored, Attack G. %, Positional At. %, Defence G. %, and Positional Df. % are significantly associated with the Adv variable. Considering that Adv evaluates offensive performance about defensive performance, we can conclude that our study is in line with several previously addressed and analysed studies. Considering that Adv evaluates offensive performance about defensive performance, we can conclude that our study is in line with several previously addressed and analysed studies. This study has some limitations, such as not analysing all matches and teams in the Portuguese league, not distinguishing between numerical superiority and inferiority situations, considering only direct counterattacks, not considering other offensive/defensive transitions, and not taking into account the goal difference at the end of each match. This study is one of the few that includes an approach to some performance indicators in Portugal in this sport. Thus, this study can help coaches and athletes extract more detailed game data that can be useful for adapting their training and gameplay processes.

Conclusions

The results show that there are no statistically significant differences in the pace of play, OT, and goalkeepers' defences between the top 6 teams in the Portuguese handball league and the EHF Champions League. Furthermore, the findings of this study provide valuable insights due to the lack of research on the evaluation of the pace of play by researchers, highlighting the importance of positional attack efficiency. Considering the significance of offensive transitions, specifically fast breaks and their efficiency due to the evolution that has occurred in handball, it becomes evident that it promotes a faster game with a higher number of ball possessions, thereby increasing the pace of play. Based on the data obtained, many variables appear to influence the performance of handball teams, emphasizing the importance of offensive efficiency to defence, general attack, and positional attack. Additionally, we also observed the importance of shooting efficiency, as well as positional defence efficiency, to a lesser extent than expected.

Table 2 Grouped Descriptive Analysis by Teams of the Top Six Ranked Teams in the Portuguese League

Team	Rank	Final Rank	MP	Perf. (Mean ± SD)	Pace (Mean ± SD)	GS (Mean ± SD)	GC (Mean ± SD)	Att. G. % (Mean ± SD)	Def. G. % (Mean ± SD)	Pos. Att. % (Mean ± SD)	Pos. Def. % (Mean ± SD)	CA % (Mean ± SD	Retrait % (Mean ± SD)	Saves % (Mean ± SD)	OT % (Mean ± SD)	Fr. Pos. Att.	Fr. Counter
FCP	1	1	10	2.7 ± 0.67	55.2 ± 6.30	33.6 ± 5.21	29.1 ± 2.33	0.61 ± 0.05	0.47 ± 0.05	0.59 ± 0.08	0.49 ± 0.64	0.72 ± 0.15	0.32 ± 0.17	0.29 ± 0.05	0.71 ± 0.05	40.85	9.15
SCP	2	2	10	2.6 ± 0.70	54.8 ± 4.49	31.3 ± 4.19	27.8 ± 2.53	0.57 ± 0.07	0.49 ± 0.06	0.54 ± 0.07	0.53 ± 0.07	0.75 ± 0.14	0.23 ± 0.14	0.28 ± 0.04	0.72 ± 0.04	41.24	8.76
SLB	3	3	10	2.1 ± 0.88	55.3 ± 4.24	30.3 ± 3.65	28.4 ± 4.22	0.55 ± 0.04	0.49 ± 0.07	0.51 ± 0.04	0.51 ± 0.07	0.75 ± 0.04	0.35 ± 0.18	0.32 ± 0.04	0.68 ± 0.08	43.13	6.87
ABC	5	5	10	1.6 ± 0.97	58.4 ± 4.40	28.3 ± 4.76	32.5 ± 6.92	0.48 ± 0.06	0.45 ± 0.09	0.47 ± 0.07	0.47 ± 0.09	0.55 ± 0.18	0.33 ± 0.20	0.27 ± 0.07	0.75 ± 0.07	42.21	7.79
AAS	4	4	10	1.7 ± 0.95	52.7 ± 4.16	27.4 ± 2.41	28.8 ± 4.34	0.52 ± 0.04	0.45 ± 0.07	0.50 ± 0.05	0.48 ± 0.09	0.63 ± 0.16	0.31 ± 0.11	0.28 ± 0.06	0.72 ± 0.06	43.55	6.45
CFB	6	6	10	1.3 ± 0.68	55.5 ± 4.30	26.8 ± 2.57	31.3 ± 4.09	0.48 ± 0.05	0.44 ± 0.07	0.45 ± 0.05	0.46 ± 0.05	0.71 ± 0.15	0.35 ± 0.14	0.24 ± 0.07	0.76 ± 0.07	42.61	7.39

In light of all this, we can justify the importance that all stakeholders should give to offensive situations, as well as offensive transitions, as they influence and are indicators of performance. In the practical and training context, the findings of this study can be applied by coaches and athletes to enhance their strategies and preparation. The emphasis on positional attack efficiency, defensive efficiency, and goalkeepers' performance can guide training efforts toward these specific areas. Moreover, the obtained data can assist in talent identification and training load management. In summary, this study contributes to the understanding of the pace of play and performance metrics in Portuguese handball. The results highlight the importance of positional attack, defensive efficiency, and goalkeepers' performance for team success. The findings can be used by coaches and athletes to improve collective and individual performance, driving the development of handball in Portugal.

Table 3 Associations of Variables with Performance and Adv.

	Performance			**Adv**		
	B	95% CI	R^2	*B*	95% CI	R^2
Adv	8.27**	5.51, 11.04	0.95	-	-	-
Performance	-	-	-	0.11**	0.08, 0.15	0.95
Rank	-0.30**	-0.38, -0.22	0.97	-0.03**	-0.04, -0.03	0.96
Pace	-0.06	-0.48, 0.36	0.04	-0.01	-0.06, 0.04	0.11
Goals Scored	0.21**	0.12, 0.30	0.92	0.00**	0.01, 0.04	0.85
Goals Conceded	-0.22	-0.53, 0.10	0.21	0.00	-0.06, 0.00	0.65
Attack G. %	10.98**	6.64, 15.32	0.93	1.31**	0.93, 1.71	0.96
Defence G. %	22.47*	0.79, 44.15	0.67	2.80*	0.60, 5.00	0.76
Positional At. %	10.95**	6.00, 15.91	0.90	1.28**	0.68, 1.88	0.90
Counterattack %	3.82	-4.49, 12.14	0.29	0.54	-0.34, 1.42	0.42
Saves %	12.57	-7.06, 32.19	0.44	1.74	-0.18, 3.66	0.61
Positional Df. %	16.68	-2.16, 35.52	0.60	2.06*	0.02, 4.10	0.66
Retrait %	-7.49	-22.39, 7.41	0.33	-0.70	-2.60, 1.23	0.21
OT %	29.82	16.36, 43.28	0.90	3.64	2.83, 4.45	0.98
Fr. Pos. Att.	-0.38	-0.91, 0.14	0.51	-0.04	-0.11, 0.04	0.31
Fr Counter	0.38	-0.14, 0.91	0.51	0.04	-0.04, 0.11	0.31
Fr. Pos. Def.	0.27	-0.20, 0.73	0.39	0.03	-0.03, 0.09	0.28
Fr Retrait	-0.27	-0.73, 0.20	0.39	-0.03	-0.09, 0.03	0.28

* $P < 0.05$, ** $P < 0.01$.

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THE GAME BALANCE ANALYSIS IN U10 HANDBALL BEGINNERS: THE COMPARISON OF 4X4 AND 5X5 GAME FORMATS

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SUMMARY

This study aimed to analyse the game balance using two game forms at the U10 level, commonly used in the sportive community (4x4 or 5x5). Fifty-five handball beginners from six teams participated in the study. Although the game 4-a-side has generated an offensive advantage environment for the participating teams, future studies need to investigate how the balance between teams might affect the competitive environment.

Keywords: handball, game balance analysis, game-based pedagogy, game formats

INTRODUCTION

In the contemporary teaching or coaching paradigm based on game-based learning approaches (Bunker & Thorpe, 1982; Mitchell, Griffin, & Oslin, 2006), players are at the centre of the educational process. In these teaching-learning methodologies, the games are modified to involve and engage the students in the learning process, in which the essentials of the game are 'understood', accessible, and playable for all (Koekoek, Dokman, & Walinga, 2023). An essential pedagogical principle when working with beginners is to design rich learning environments that are challenging, fun and pleasurable (Koekoek et al., 2023). So, the game configuration and its possible modifications should prioritize game balance, with offensive and defensive challenges for both teams, thus providing excitement, motivation, engagement and a rich learning environment for all players to achieve meaningful learning experiences (Koekoek et al., 2023).

In Portugal, a child is mainly introduced to competitive settings through reduced game forms (Gk+3x3+Gk or Gk+4x4+Gk) with individual marking, while other countries (*e.g.,* Denmark, Norway) choose to start with numerical advantage with a low-pressure defence (4x3+Gk, 5x4+Gk) (Estriga & Graça, 2022). Although it is not the purpose of this work to investigate the educational potential advantage of different perspectives, this raises the debate about how game rules modifications and competitive settings can affect fairness and kids' excitement by influencing the balance, variety, inclusion, and complexity of the game.

Game balance analysis is a didactical tool that analyses the state of gameplay to aid educators (teachers or coaches) in adopting appropriate and adjusted pedagogical decisions during the games. So, the level of challenge that attackers and defenders pose to each other during the game can be globally measured to infer about the nature of the learning environment (from a poor to a rich environment). Therefore, observation of game balance is pivotal in the game design or modification process to create rich and stimulating learning environments. The most direct way to measure the state of gameplay is the ratio of success and failure of major game principles (scoring *versus* intercepting). *"Games must be designed in such way that they offer sufficient offensive success, but at the same time leave enough space to be successful in defence" (Koekoek et al., 2023, pp.21).* To date, no studies have examined how different handball game forms generate (un)balanced gameplay situations that affect a beginner's actions and possibilities.

When teaching the handball game to beginners (U10), we must be aware of players' level of competence and which game format has a higher potential to create a rich and stimulating learning environment. Therefore, this study aimed to analyse the game balance when using two different game forms at the U10 level: 4-a-side and 5-a-side, both with individual marking. It also endeavoured to produce knowledge that could inform practitioners about the need to introduce game changes to empower positive game experiences and learning in the first stages of Handball practice.

METHODS

Design

In this study, the 4x4 and 5x5 game formats were compared with a full court marking in a reduced court (23x15m), with a semicircular goal area of 5m and a ball size 0. A total of 12 handball-friendly matches were performed (6 in each game format). Each match lasted 10 minutes. Three match sessions were organized, with four matches being scheduled per session, and where each group-team played two matches.

Six handball clubs participated with their players (U10). The matches were set up in a one-day event between the six teams, where each team played against the other twice with a different game configuration. Each team coach divided their players into two heterogeneous and balanced team-groups to play as distinctive teams. The goalkeepers were fixed in each game.

The first game format was randomly selected, and then each team played the game formats alternatively. There was a 10-minute break between the games.

Coaches were also asked to ensure balanced individual confrontation between attacker and defender (1-on-1) during matches. Teams were never outnumbered, and the throw-off was replaced by the goalkeeper throw.

The matches were videotaped with an HD video camera, positioned to cover the entire court and provide clear images.

Participants

Fifty-five male children from six Portuguese U10 teams participated in the study. All players had only a few years of practice but were already participating regularly in local competitions. Ethical canons (written informed consent with assurance of anonymity and confidentiality of personal data) were obtained from all children and their parents.

Data Collection and Analysis

A systematic observation was used to collect the data and subsequently analyse the game balance and gameplay opportunities. The Game Based Analysis tool (Koekoek et al. (2023), designed for teachers to easily monitor the competitive nature of the game that two teams are playing, was used, resulting in "rich", "poor", or "promising" learning opportunities for players. Table 1 represents the classification and criteria for Game Balance Analysis adapted from Walinga and Koekoek (2023).

Table 1. Game Balance Analysis (Walinga & Koekoek, 2023)

Ratio of Goals or shots / ball possessions	Game balance conclusion	Description	Gameplay type
Ratio of 0-19%	Imbalance (poor learning environment)	There is a unilateral power for the defense team	Defensive Power Game
Ratio of 20-39%	Small Imbalance (promising learning environment)	There are sufficient opportunities for attackers and defenders	Defensive Advantage Game
Ratio of 40-59%	Equal game balance (rich learning environment)	There are sufficient opportunities for attackers and defenders	Equal Power Game
Ratio of 60-79%	Small Imbalance (promising learning environment)	There are sufficient opportunities for attackers and defenders	Offensive Advantage Game
Ratio of 80-100%	Imbalance (poor learning environment)	There is a unilateral power for the attacking team	Offensive Power Game

The final scoring was used to investigate the game balance and game state; the final score was analysed, as the game principles (passing to score and intercepting) and the effectivity ratio of offence and defence success of the 12 matches (Koekoek et al., 2023). In addition, to analyse the offensive game play and opportunities, we used the following simple indicators, which are simple counts of game actions and performance: number of attacks, duration of ball possession, number of players involved per attack, number of passes, shots, goals, and effective ratios.

The data were recorded on a spreadsheet and exported to the SPSS Statistics (version 24.0). The level of significance was 5%.

RESULTS AND DISCUSSION

1) Competitive nature of the matches based on game balance

Obtaining a goal is the primary objective of invasion team sports. Typically, game balance analysis should consider the ratio between the number of goals scored and the number of ball possessions. Still in the early stages of handball practice (teaching-learning contexts), creating scoring opportunities may also provide relevant information regarding the game balance rather than only looking for the scoring result, as implemented by Koekoek et al. (2023). Therefore, the game balance was investigated by considering the number of goals and scoring opportunities.

The game result of the studied matches showed a high imbalance in the number of goals scored by the confronting teams. Only three games had less than 4 goal difference between the winning and the losing teams (see Table 2). However, the differences between the winning and the losing teams, in terms of the number of scoring opportunities, seem more balanced in the 4-a-side compared with differences in scoring opportunities in the 5-a-side.

Furthermore, since 75% of matches showed an imbalanced result (more than four goals difference between the winning and the losing teams), we decided to analyse the game balance and the gameplay as a function of the game format. Additionally, the game variables were compared according to teams' results (winners or losers) to investigate the potential effect of the highly imbalanced games based on scores or finishing opportunities.

Table 1. Goals (G), Number of Scoring opportunities (SO) and differences between the winning and losing teams in 4x4 and 5x5

	4x4												5x5											
	J1		J2		J5		J6		J9		J10		J3		J4		J7		J8		J11		J12	
	G	SO	G	SO	G	SO	G	SO	G	SO	G	SO	G	SO	G	SO	G	SO	G	SO	G	SO	G	SO
Winning team (Goals / scoring opportunities)	14	17	11	20	13	21	14	17	11	16	14	19	14	22	16	22	12	20	11	15	13	18	11	18
Losing team (Goals / scoring opportunities)	5	17	10	14	2	12	1	10	8	23	4	14	3	12	7	10	3	9	2	8	9	16	2	9
Difference between Goals / score opportunities	+9	0	+1	+6	+9	+9	+13	+7	+3	-7	+10	+5	+9	+10	+9	+12	+9	+11	+9	+7	+4	+2	+9	+9

2) Game balance and game format effect

The results between 4x4 and 5x5 game forms in the offensive gameplay revealed only one statistical difference (see Table 2), based on the *Wilcoxon test,* specifically in the "shots/ball possessions" ratio (p=0,028). If we interpret this result based on gameplay type, the games showed an "*offensive advantage game*" in 4x4 and a game of "*equal power*" in 5x5. So, while the 4x4 favours the creation of more finishing opportunities, the 5x5 game provides a richer learning environment for both attackers and defenders (Koekoek et al., 2023).

Table 2. Results of non-parametric Wilcoxon test in offensive gameplay categories

Offensive gameplay	4x4	5x5	p value
Number of attacks	26.3±3.09	27.25±4.85	.82
Duration of ball possession (seconds)	6.34±1.16	6.41±1.66	.61
Number of players involved per attack	1.65±0.21	1.73±0.31	.24
Number of passes	16,17±5.31	16.58±4.81	.59
Passes/Ball possessions	0.61±0.17	0.61±0.16	.81
Number of shots	16.67±3.77	14.92±5.20	.08
Shots/Ball possessions	0.65±0.18	0.57±0.22	.03*
Goals	8,92±4.81	8.59±5.04	.31
Goals/Ball possessions	0.36±0.22	0.33±0.20	.08
Miss shots	7.75±3.79	6.33±1.72	.20

The other offensive gameplay variables studied didn't reveal differences (p> 0.05) in the number of attacks, duration of ball possession, number of players involved per attack, and number of passes and shots. In both game formats, the average time per ball possession was very short. The attacks tended to be individualized, with reduced participation of the players and could be related to the court dimension (too small) or the attackers not yet understanding the interplaying concepts. In both situations, the observed number of shots was similar.

However, from a pedagogical perspective, the 4x4 was revealed to be more appropriate because, in these simplest game forms, the players were able to set up more opportunities to score, which at this stage of teaching is very rewarding and encouraging to learn handball.

2) Game format effect according to the winning and losing teams

The *non-parametric* test revealed statistical differences in the simple count of offensive gameplay variables (p≥0,05) between the winning and losing teams in 4x4 and 5x5, particularly on “missed shots”, ratio of “Goals/Ball possessions”, “number of shots” and ratio “Shots/Ball possessions” (Figure 1).

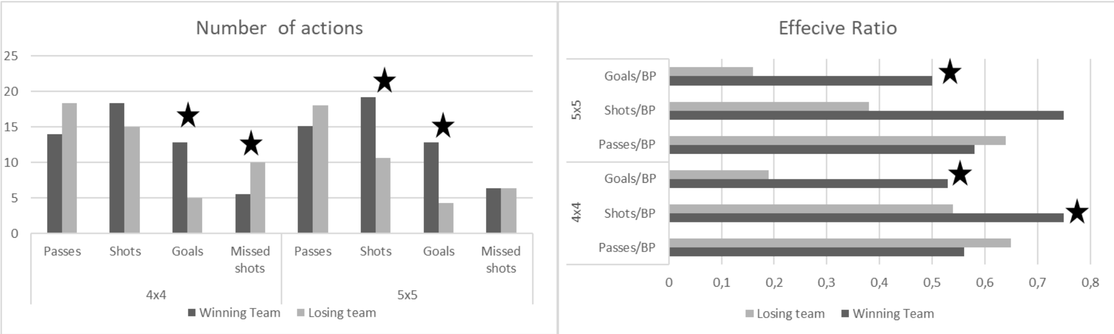

Figure 1: *Results of offensive gameplay between the winning and losing teams in 4x4 and 5x5 formats. If a p-value is less than 0.05, it is flagged with one star (*).*

In the 4x4 configuration, the losing teams showed a higher number of "missed shots" (p=0,026), a lower number of "goals" (p=0,002) and a lower ratio of "goals/ball possessions" (p=0,002) than the winning teams. In the 5x5, the winning teams showed a higher number of "shots" and "goals" and a higher ratio of "goals/ball possessions" and "shots/ball possessions" (p<0,05).

The number and ratio of passes were similar in both cases, revealing that the inter-passing actions were low affected by the game formats used and the teams' strengths difference. However, these data showed a slight tendency for the losing teams to use more relational solutions (passes), probably associated with greater difficulty in overcoming the opposition.

Independently of game format, the losing and winning teams showed the same gameplay type when considering the goals: a) the winning team an "equal power, and b) the losing team a "defensive power game", meaning a "poor learning environment" caused by the counterparts to strong defence (the winners). However, if we consider the ratio of effective shots by ball possession, the winning teams showed an "*offensive advantage game*" in both game formats. Still, the losing teams, in 4x4 format, got an "*equal power*" and in the game 5x5 format an “defensive advantage” game was observed. These results suggest that the 4x4 might be more appropriate for low-game experienced children as it tended to create a more game-balanced situation, which leads to richer learning environments, even for losing teams. In this level of learning, and Portugal's case, one of the priorities is to focus on the goal attack concept and setting up easy scoring opportunities based on transitional play by all players. Therefore, the results reinforce the pedagogical value of using reduced game forms with absolute handball beginners.

CONCLUSION

From a pedagogical perspective, when introducing handball to children, using the simplest game forms, such as 4x4, makes sense to create a less complex and demanding environment and accessible gameplay with scoring opportunities for all. However, in this study, no conclusive findings were found as to whether there is, or not, a learning advantage of using 4x4 in comparison with 5x5 in U-10 handball players. Nevertheless, it is evident that with fewer players per team, every player will have more chances to have the ball in their hands and more time and space to play.

Thus, despite the observed offensive advantage environment in the game 4x4 format, the competitive environments at these ages may be more influenced by the strengths of the different teams than by the game formats. In future research, increasing the number of games and observations is necessary to confirm some of these trends.

PRACTICAL IMPLICATIONS

The observance of extreme unbalanced game results in children's games should motivate the competition authorities, coaches, or teachers to find ways to change the game to provide more nurturing competitions experiences. The strategies such focused on keeping scores close, increasing action and scoring, and enhancing every child involvement and excitement. For example, when a defensive "power game" type occurs, the increased number of attackers (such as an advanced goalkeeper) can offer more opportunities and time to build up the attack and to create scoring opportunities.

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EXPLOITING THE EFFECT OF SMALL-SIDED GAMES WITH NUMERICAL SUPERIORITY AND EQUALITY IN CHILDREN HANDBALL

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SUMMARY

This research aimed to explore the effect of even and uneven reduced game formats on U10 children. Eight (n = 8) players (four girls) participated in two simplified games (GK+3x3+GK and 3x2+GK). A systematic observation was carried out using the Team Sports Performance Assessment Tool. The main results indicated that the 3x2+GK format presented to a greater volume of play, i.e., passes and receptions, more shooting opportunities, and higher individual participation rates.

INTRODUCTION

The contemporary teaching models of team sports there are a movement widely accepted and disseminated by the academic world that aims to boost the quality of teaching, training, and competitive models used in sports initiation, school, and associative-sports contexts. Thus, as opposed to the more traditional technical-analytical approaches centred on the adult (complete) game, the concepts of "pre-sport" and mini-sport have emerged, along with the use of reduced or modified games and forms of play as a means of training (Estriga & dos Santos Graça, 2022a). Still, it seems that there is also a great deal of disagreement in the conceptions and formats of the game implemented in different cultural and sportive contexts. In the work of Estriga et al. (2022a, 2022b), for example, a documentary collection was made about the forms of play used in handball initiation around Europe. The authors concluded that the countries adopt different modified game constraints and that they seem to reveal different player profiles and training concerns. Although most of the countries studied (Denmark, Norway, Sweden, Hungary, Germany, Spain, and Portugal) recommend the use of reduced forms of play, in some regions, such as Germany and parts of Spain, children can still experience the full formal game (7x7, on an official court), like that of adults, even before the age of 10.

On the other hand, countries seem to be organized into groups with different perspectives. In the analysis made by Estriga et al. (2022a, 2022b), the countries are broadly divided into those that advocate initiation through positional attacking play and those that advocate initiation through transition play. Among those who prefer the transition game with individual marking, some mainly use the 5x5 form of play and others the 4x4. Within the group that prioritize handball initiation through positional attacking play, some choose to play with numerical superiority (with the goalkeeper advanced, 4x3+GR), while others prefer numerical equality (4x4) (Estriga & dos Santos Graça, 2022a, 2022b).

To date, few studies have examined how different small-sided game configurations or game forms affect opportunities for beginners' participation and game actions. A game form is a modified construct of the complete handball that preserves its unique traits and seeks to facilitate players' responses to the particular problems related to the structure of the invasion games (Mesquita et al., 2012).

In this context, based on the characteristics of the game of mini handball structured around individual marking (transition play) or attacking/defending the goal (positional play), we intend to study this problematic through the manipulation of game constraints and elements that represent those two perspectives. We assume, therefore, that these differences play a role in the processes of participation and learning the game.

The aim of this study was to explore the effect of even and uneven small-sided game configurations on U10 mini-handball players.

METHOD

Participants

Eight (n= 8) children (four girls) took part in this research (mean age 8 years ± SD 0.6 year). The group was composed of by convenience as it was needed to be familiar with the applied game forms. All of them were from the same club, belonging to the U10 level of the respective club, had between three months to two years of practice and trained between two and three times a week. Each training session had 1h30 duration.

Procedures

We carried out two game forms (GF) that included changes in the ratio between attackers and defenders (3x2+GK and GK+3x3+GK), court size, defensive behaviour (single-line defence or full-court individual marking), and a fixed goalkeeper or advanced one (table 1). It is important to mention that in all cases, a soft ball (that discourages dribbling) was used to stimulate cooperative behaviour instead of individual play. Each small-sided game lasted 10 minutes, with a 10-minute interval between them. The two game forms were applied randomly. In the GF1, each team had one additional player. Besides that, the teams were kept the same during all the games.

Table 1. Configurations of the game format used in this work.

	Game Form 1 (GF1)	**Game Form 2 (GF2)**
Game format	3x2+GK	GK+3x3+GK
Court Size	20 x 15m	28 x 15m
Goal area	Semicircular of 5 m	Semicircular of 5 m
Defence	Single line defence	Full-court individual marking
Other constraints	The goalkeeper can advance to midfield; Whoever scores becomes goalkeeper.	The goalkeeper can advance to midfield; Whoever scores becomes goalkeeper.

The data was collected in a single moment at the club's own facilities, on courts marked out for the specific purpose. An HD camera (GoPro Hero 11, California, USA) was used to record the games and the action that took place. The camera was positioned perpendicularly to the court and above it, providing a full view of the game.

This research followed the tenets of the Declaration of Helsinki regarding research with human beings and was approved by the local Ethics Committee (CEFADE 24_2023).

Instruments

After recording the games, a systematic observation and coding of the occurring game actions (goals, shots, passes, receptions, steals, and dribbles, among others) was carried out based on video analysis using the Team Sports Performance Assessment Tool (TSAP) (Gréhaigne et al., 1997). The TSAP is a game-oriented authentic assessment tool aiming to support a structured observation focused on detecting each player's specific behaviours, considering the context and dynamics of a team game rather than in isolation. Table 2 below shows the adopted indices as well as their descriptions.

Table 2. Adopted game indexes (or categories)

Observation Categories by Team	
Game Balance (Goals)	Number of goals / Number of attacks
Game Balance (Shots)	Number of shots / Number of attacks
Volume of Passes	Sum of passes
Volume of Play	Sum of actions: passing, dribbling, stealing the ball, losing the ball, ball receptions and total shots

Data Analysis

An exploratory analysis of the results was carried out using simple descriptive statistics (number of goals, shots, and attacks; sum of passes; sum of actions: passing, dribbling, stealing the ball, losing the ball, receptions and total shots; finishing opportunities).

Reliability

To analyse inter- and intra-rater agreement, two observers watched and analysed 10% of the recorded videos, according to Tabachnick et al. (2013). The intra-class correlation coefficient of consistency (observer and subjects) (Weir, 2005) was then used to check the reliability of the observations. The results indicated 0.919 and 1.000 for the inter- and intra-rater analyses, respectively, which in both cases were considered excellent (Ciccheti, 1994).

RESULTS AND DISCUSSION

Considering the well-known pedagogical recommendations and real-world practices adopted for the age group under study, children under the age of 10 participated in two game forms, each following the two approaches (transitional play with individual defence and positional play with the defender located around the goal reads), with the aim of exploring their effect on handball beginners' involvement and participation.

Investigating the Game Balance

In table 3, we present the results regarding the Game Balance between attack-defence teams, considering the number of goals and the number of shots, in relation to the number of attacks. Koekoek et al. (2022) propose that the ratio between the number of attacks and goals be used as a criterion to evaluate the degree of balance of a game, being considered balanced if it varies between 40 and 59% (i.e., *equal power game*). Additionally, less than 10% is considered imbalanced (*defensive power game* - poor learning environment), between 10-20% presents a small imbalance (*defensive advantage game* - promising learning environment), between 60%-80% is considered a small imbalance (*offensive advantage game* - promising learning environment), and more than 80% is considered an imbalance (*offensive power game* – poor learning environment).

Table 3. Game Balance results

		Game Balance (Goals)	Mean balance between teams	% difference between teams	Game Balance (Shots)	Mean Balance Between Teams	% difference between teams
GF1 **3x2+GK**	**Team A**	30%	44%	27%	65%	83%	35%
	Team B	57%			100%		
GF 2 **GK+3x3+GK**	**Team A**	16%	26%	21%	47%	53%	11%
	Team B	37%			58%		

According to the criteria proposed by Koekoek et al. (2022), which classify the degree of (im)balance between attack and defence, based on goals per attack (Game Balance- Goals), GF1 (3x2+GK) was considered balanced (i.e., equal power game), while in the GB2 (GK+3x3+GK) was considered slightly imbalanced in the case of team A (i.e., defensive power game). In turn, taking into consideration the proportion of finishing situations per attack (Game Balance- Shots), we observed that, in GF1, the match presented a more imbalanced game-type situation (i.e., offensive power game), with team B achieving 100% attacking dominance (as in all the attacking situations, a scoring opportunity was created).

Although it seems that the criteria of Koekoek et al. (2022) might be an important tool for coaches for avoiding extremely imbalanced games (percentage difference between team and/or between attack and defence) we chose to also investigate the ratio between the number of attacks and the finishing opportunities. This decision was motivated considering that a player's initiative to score and to create fishing opportunities are also relevant for this discussion. Additionally, this is also a way to take the effect of goalkeeper quality out of the equation, as shooting unsuccess might be result of very skilful goalkeeper, and to really focus on on-court game play quality.

When considering the ratio between the number of shots (or finishing opportunities) and the number of attacks -Game Balance-Shots, we postulate that the GK+3x3+GK situation (GF2) is potentially more appropriate than the 3x2+GK situation (GF1), based on the supremacy of the attack and the GF2 by balance. On the other hand, proving a playing environment where each player has a chance to being in a position to attempt score has a pedagogical value that cannot be overlooked. When dealing with low experienced handball children it seems that having many scoring opportunities is essential to catalyse their enjoyment of the game through the perception of success (Estriga & Moreira, 2014). On the other hand, partial forms of the game such as 3x2 (here considered a small-sided game form), or even 2x1, 4x2 and 3x1, are not bound by the rules of parity between attack and defence. In those cases, the game problem of creating and taking goal-scoring chances is therefore exaggerated, as advocated by Bunker and Thorpe (1982). These game situations are used to benefit the attack, aiming to provide attackers with greater space-time to read the game, make decisions, and execute actions (Graça & Mesquita, 2011). Another criterion must be observed, namely, checking if everyone is participating in a fair and balanced way in the game and whether there is exclusion of players, something that can pass by the analysis (Butler, 2016).

The modifications introduced to the game forms studied allowed the teams to achieve success/failure in offensive and defensive situations, in a ratio that can be considered adequate. Therefore, we speculate that these modifications can be useful in creating favourable environments for players to learn to play in attack and defence.

Investigating the volume of play

The results regarding the volume of play (table 4) suggest that the game based on numerical advantage might have slightly improved interactions and the overall volume of actions. Furthermore, more opportunities for finishing were also observed, resulting in an increase in the number of goals. It is important to mention that only soft balls were used, which might have enforced a more interactive game as the bouncing was discouraged. Nevertheless, regarding the volume of play, 11% more overall volume of actions was observed in comparison with the GK+3x3+GK situation. In the 3x2+GK, the creation of finishing opportunities was also 55% higher, along with nearly double the scoring success between matches (19 vs 10 goals). It is widely recognized that the chances of success rise when there is more space and time to analyze, make decisions and execute actions (Estriga & dos Santos Graça, 2022b), which is the case when using numerical advantage and reduced number of players. Game formats that are based on numerical superiority, as suggested by Ranko et al. (2022), are more accessible to participants to take action in all the aspects of the game including having the chance to score, which they tend to overvalue.

Table 4. Volume of Play, passes and finishing attempts (and goals)

Game Form	**Volume of Play**		**Volume of passes**		**Finishing attempts (goals)**	
	TEAM A	**TEAM B**	**TEAM A**	**TEAM B**	**TEAM A**	**TEAM B**
GF 1	102	107	78	81	15(7)	21(12)
3x2+GK	209		159		36(19) **– 52%**	
GF 2	80	107	66	85	9(3)	11(7)
GK+3x3+GK	187		151		20(10) **-50%**	

There is no doubt that game participation is a crucial factor for learning in team sports. Likewise, when players are not actively involved, whether passing or shooting, that is, in regular contact with the ball, their opportunities for development are limited or diminished. Therefore, it is recommended that players are exposed to a wide variety of playing experiences, including different roles and positions, that lead them to successfully participate in the game and make decisions according to the different situations imposed by the game (Sánchez-Sáez et al., 2022).

FINAL REMARKS

To enhance handball beginners' motivation, fun, and learning, it is necessary to confront them with challenging yet achievable game problems in which they feel a sense of belonging and success.

The comparison between a balanced (GK+3x3+GK) or imbalanced (3x2+GK) ratio of players between teams revealed that the numerical advantage game format (3x2+GK) contributed to a greater volume of play, i.e., passes and receptions, as well as more shooting opportunities and individual participation rates. The results suggest that educators should be aware of how different game configurations and rule modifications might affect opportunities for game participation and, consequently, motivation and enjoyment in all players.

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ABSTRACTS

ANALYSIS OF DEFENCE ACTIVITY BY POSITION AND GENDER

Based on Hungarian top league handball matches

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Abstract

When planning for training, it is necessary to have metrics and alignment points to predict match performance and the physical, technical, and tactical demands required by a position in attack and defence. Over the last decade, I have made several attempts to estimate the match demand of an attacking or defensive position. In my current research, I was looking for answers to the following questions: how many technical and tactical movements are made by players in each defensive position; what are the differences between the different defensive positions; and are there differences in the number of movements made by male and female players in these positions?

As samples I chose matches with high stakes in the men's and women's Hungarian 1st division that ended in a close result. Thus, 10-10 of the 5-5 men's and 5-5 women's matches, for a total of 20 teams, were surveyed, representing 71, 42% of the 14-14 team league.

After collating and tabulating the statistical data, it was possible to assess one defensive position to compare the half-time and overall results of six defensive positions and to analyse the gender breakdown of all teams in all matches. Horizontal analysis shows the differences between defensive positions in order on the court side by side, while vertical analysis shows the difference between the total load of the positions and the actions of male and female players.

The outcome of this survey was to establish a baseline standard that is not yet available in the literature. And in analysing the data, I hoped to draw conclusions that could help handball coaches in the future in the individual coaching of their teams and players.

Keywords: defensive positions, top teams, post-specific statistical analysis

THE INFLUENCE OF TECHNICAL EXECUTION OF SINGLE LEG JUMPS ON JUMPING PERFORMANCE

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ABSTRACT

The aim of the study was to discover the influence of technical execution of Single Leg Counter Movement (SLCMJ) and Single Leg Long jump (SLLJ) on jumps height and/or distance. Eighty top level Slovenian handball players participated in the study (age 22 ± 4; body mass 90,8 ± 10 kg; height 189,8 ± 5,6 cm). The measurement protocol consisted of six SLCMJ and six SLLJ jumps (three jumps per leg). All tests' repetitions were recorded in the lateral and frontal plane and analysed with Kinovea program. Using T-test for independent samples, statistically significant differences were found between legs in the results of jumps height and length, as well as in the kinematic variables in SLCMJ (frontal plane) at trunk tilts and in SLLJ (lateral plane) in knee, take-off, and shin angles. We can conclude that the technical execution of analysed single leg jumps effects on their height and distance. To improve the performance of the SLCMJ it is recommended to practice the technical execution of the jump with an emphasis on the elimination of the knee valgus in the take-off phase. In the case of SLLJ, emphasis in the training should be focused on lowering the take-off angle and on the explosive use of the hip joint in the horizontal direction. Additional attention is advised in eliminating the differences between the dominant and non-dominant leg in terms of ankle mobility, valgus position of the knee in the take-off phase along with decreasing asymmetries of the hip and trunk muscles.

PHYSICAL FITNESS OF HANDBALL PLAYERS IN THE ANNUAL MACROCYCLE OF THE STUDENT'S TEAM

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Abstract

Handball places high demands on the physical fitness of handball players. The sports result of the entire team will depend on the correct structure of the training process, on a rational approach to the choice of methods and means in training handball players. Systematic and constant analysis of competitive activity is an important means of managing the training process of athletes. The structure of competitive activity includes components related to the intellectual and mental activity of the athlete, the level of his technical and tactical skill and physical fitness. Improving the quality of the above components will help improve the quality of competitive activity of handball players.

During the analysis of scientific and methodological literature on the topic of research, we discovered that in handball the training process is compiled based on a single calendar plan for competitions. The task is to develop the most optimal annual macrocycle of training, in which the tasks of physical and functional readiness of handball players, technical and tactical training, and mental preparation of athletes will be effectively solved. Monitoring and testing throughout the macrocycle help assess the level of preparedness of handball players and optimize the training process to achieve maximum sports results.

The general decrease in the level of physical fitness of all players mainly occurred in December and February. The ability to quickly perform multidirectional movements was lowest in the December and February mesocycle, the maximum team-wide T-test score was 8.20 seconds and 8.22 seconds, the result for the "30-meter shuttle run" test was 6.96 seconds. and 7.01 sec. A decrease in performance for linear sprints was recorded mainly at the beginning of the season and the February mesocycle. Aerobic performance levels were reduced in December and April, which is the middle of the season. The vertical jump was most difficult for athletes at the end of the season, and the biggest decline in throwing power was recorded in December. Handball players showed the best level of physical fitness in the initial and final mesocycle (at the beginning and end of the playing season).

Indicators of physical fitness of handball players of the male student team did not have a negative impact on the effectiveness of competitive activity in the annual macrocycle. The gaming efficiency coefficient of athletes in the period from February to April increased compared to the period from October to December. It can be considered that the physical fitness of handball players is the standard for this rank of student competition

VARIOUS APPROACHES TO COORDINATION TRAINING IN HANDBALL PLAYERS 11–12 YEARS OLD

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Abstract

The professional level of team sports is accompanied by an increase in requirements for the integral preparedness of athletes and the effectiveness of the demonstrated technical and tactical actions of team players in competition conditions. Almost all experts in team sports (handball, football, basketball, hockey, volleyball, and others) unanimously note the importance of the optimal level of development of coordination abilities for the growth of sportsmanship of athletes in this group of sports. This fact means that insufficient attention to the development of coordination readiness components that are significant for handball in the early stages of long-term training of handball players can further limit the growth of their sporting achievements. In this regard, the search for effective ways to develop the most significant components of the motor-coordinating abilities of athletes for handball continues.

The aim of the study is to identify effective ways to improve the coordination abilities of female handball players aged 11-12 years at the stage of sports specialization.

Organization and methods of research: The study was carried out in the preparatory period of the annual training cycle of handball players aged 11-12 years, undergoing sports training at the stage of sports specialization. 2 experimental groups, 20 people each, used the proposed methods of training coordination abilities in the training process. Changes in the coordination readiness of female athletes were assessed using specialized tests.

The results of the study indicate that handball players aged 11-12 years need systematic use of coordination training. The targeted development of coordination abilities made it possible to obtain an improvement in performance in the "snake running" test - in the control group by 4%, in the experimental group - by 22%. The accuracy of hitting the given corners of the goal from 10 shots among handball players in the experimental group increased to 50%, in the control group - to 10%. During the pedagogical experiment, both of the applied approaches to coordination training proved to be effective: dispersed development of individual components of coordination abilities and accentuated development of leading coordination abilities. At the same time, the dispersed method of using sets of coordination-oriented exercises at the beginning of the stage of sports specialization for handball players aged 11-12 years showed a significant advantage.

CORRELATION BETWEEN THE TIME REQUIRED FOR THE 180° CHANGE OF DIRECTION AND TWO DIFERENT MOTORIC PARAMETERS

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Abstract

The purpose of this study was to determine whether there is a significant correlation between the time required for the 180° change of direction (COD), time obtained in 5-m sprint and the jumping height in the »counter movement jump« test. The survey involved 55 candidates for the youth and junior men's handball team of Slovenia in the season 2017/2018, with the average age of 17,47 ± 1,63 years. 47 subjects completed the entire measurement in the study. Test subjects performed measurements in the "8 X 40 m" test, counter movement jump and 5 m sprint with a standing start. We found a statistically significant ($p < 0,05$) correlation, both for the first and the second COD, and the times achieved in 5 m sprint. Pearson's correlation coefficient indicates a low or weak correlation (0,34) at the first COD and at the middle or moderate relationship (0,47) at the second COD. A statistically significant correlation ($p < 0,05$) also exists between the two CODs and the jumping height in the »counter movement jump« test. The Pearson's correlation coefficient at the first COD is 0,58 and for the second COD it is 0,46 (medium or moderate linear relationship).

DIFFERENCES IN SOME PHYSIOLOGICAL PARAMETERS OBTAINED IN THE 30–15 INTERMITTENT FITNESS TEST AMONG ELITE HANDBALL PLAYERS ON DIFFERENT PLAYING POSITION GROUPS

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Abstract

The purpose of the study was to assess differences in some physiological parameters obtained in 30-15 Intermittent fitness test among groups of elite handball players in different playing positions at Lactate threshold (LT), at Onset of Blood Lactate Accumulation (OBLA) and at peak velocity at the test (v30-15IFT). Twenty-four professional male handball players, members of senior national team of Slovenia, performed a shuttle run incremental field test 30–15IFT while the following parameters were measured: running velocity (v), respiratory quotient (RF), tidal volume (VT), heart rate (HR), oxygen uptake (VO2), relative oxygen uptake ($VO_2 \cdot KG^{-1}$), carbon dioxide production (VCO2), pulmonary ventilation breath by breath (VE), respiratory quotient (RQ), oxygen pulse vs. heart rate ratio ($HR \cdot VO_{2max}{}^{-1}$) and blood lactate concentrations (LA) at LT, OBLA and v30-15IFT. The players were divided in three groups based on their playing position - 8 back players (B), 8 wing players (W) and 8 pivot players (P). Results indicate that statistically significant differences (between three playing positions were found in running velocity (v30-15IFT), respiratory frequency (RF), heart rate (HR) and respiratory quotient (RQ) at LT, OBLA and peak velocity. W achieved statistically significant higher v at OBLA as B. W had statistically significant higher RF as B at peak velocity. B had statistically significant higher RQ as P at peak velocity. The statistically significant differences between all three groups of players occurred in HR at LT, OBLA and peak velocity. These results suggest that very few differences occurred in the selected physiological parameters.

COMPARATIVE TIME–MOTION ANALYSIS OF HANDBALL REFEREES AT THE EHF MEN'S AND WOMEN'S 2022 EURO'S

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Abstract

Local positioning systems have become widespread in handball to track spatio-temporal variables of handball players and referees during training and matches. The objective of this study was to compare the physical demands of elite handball referees between the EHF Women's and Men's 2022 EURO's. 60 referees, 36 from the men's (age: 40.4 ± 4.6, weight: 87.6 ±11.1 kg, height: 183.3 ± 7.2 cm, BMI: 26.0 ± 2.6) and 24 from the women's championship (age: 37.6, weight: 70.1 ± 10.5 kg, height: 174.5 ± 7.3 cm, BMI: 22.9 ± 2.1) were evaluated during 112 matches through a local positioning system that they wore on their upper body. Total distance (m), speed-categorized distance (m) and time (s), and pace (m/min) were averaged per game. A structured analytical methodology was delineated comprising three phases: 1) data acquisition pertaining to match activities and contextual information via sensor networks, the LPS system, and WebScraping techniques; 2) data processing employing big data analytics; 3) result extraction based on a descriptive-analytical approach. Comparative analyses revealed referees in the Men´s EURO run ~8% less total distance ($p < 0.001$, ES = 0.9) per match than those in the Women´s Euro (4085 ± 459 and 4441 ± 344 m, respectively). In addition, the referees in the women's matches ran for longer periods at high intensity (> 4.0 m/s) ($p < 0.001$, ES = 3.8), representing a 13% of total match time, compared to 7% for referees in men's matches. Pace also resulted higher ($p = 0.008$; ES = 0.7) for referees in the women´s tournament compared to their peers (69.4 ± 7.6 and 74.4 ± 5.5 m/min, respectively). International referees and physical trainers should be aware of the specific time-motion needs of each tournament to optimize their physical condition, and referee committees should consider the differences presented hereabout in their selection of referees for men's and women's championships.

STRATEGIC PREPARATION OF THE MATCH IN HANDBALL: A STUDY WITH ELITE SPANISH AND PORTUGUESE COACHES

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Abstract

This study explores a game model conceptualization and a strategic plan preparation of a successful elite handball coach from the Iberian Peninsula. The coach's philosophy, practices and strategic preparation for competition in elite national teams (adult level) were captured through a semi-structured interview. Five elite coaches (four from Spain and one from Portugal) participated in the study. Data were analysed using a thematic content procedure (Patton, 2002). The results showed: (a) in the team's game model building, the characteristics of the players is the main element to be considered; (b) in the defensive phase, most coaches (four out of five) value defensive principles related to proactive defence and ball recovery; (c) from the offensive phase, all coaches pointed out that having set plays or schemes with variants to employ against different defensive responses is an important aspect; (d) when structuring a match plan, the analysis of the opponent is a key-strategy; (e) four out of five coaches emphasized that beforehand of possible opponents analysis helps to gain time within a European or World Championship; (f) after gathering the information, the coaches convey to their players how opponents can pose problems and, in return, how can they create problems to the others; (g) during competition, match plan transmission is done by all coaches mainly through video sessions, in meetings before and on the match day; (h) just before the match (in the locker room), the main game plan aspects are reviewed; (i) four out of five mentioned having a pre-match self-routine preparation, which included the mentalization of different match scenarios that may occur. The team's game model and the collection and analysis of information about the opponent seem to be the main elements elite handball coaches consider when carrying out match's strategic preparation.

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INDICATORS THAT DISCRIMINATE BETWEEN WINNING AND DEFEATED TEAMS, DEPENDING ON THE SHOOTING ZONE IN THE SYSTEM ATTACK. IN THE PORTUGUESE SENIOR MEN'S HANDBALL CHAMPIONSHIP 2018/19.

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Abstract

The main objective of this study was to identify the indicators that best discriminate the winning and losing teams, considering the shooting zones in the "attack in system", according to the obtained effectiveness, percentage of shots and percentage of goals. Observational Methodology was used, and the descriptive analysis was done using frequency and percentage measures. To differentiate the teams, the t-test for independent measures ($p \leq 0.05$) and the Discriminant Function Analysis ($CE \geq 0.30$) were used, with the purpose of identifying indicators that can discriminate between the victorious and defeated teams. The sample results from the analysis of the 29 games which ended with victory/defeat of the "A Group" of the Portuguese National Championship, called "Andebol 1" 2018/19 of senior men. From the results obtained, it was possible to highlight that regarding the shots made in the "attack in system" phase, the indicators that better discriminate the winning teams from the defeated ones in the 1st division in Portugal are: (i) higher percentage of shots from the wings (17.8% vs 10.3%) and lower percentage in first-line shots (43.3% vs 52.4%); (ii) higher effectiveness of first-line shots (49.7% vs 33.7%); (iii) more goals scored in the wing zone (17.9% vs 12.3%). First-line shots are the ones that are most frequently performed in the handball game, so the effectiveness obtained in this type of shot, as well as the repercussions for defence and attack, assume particular importance in differentiating between teams.

Keywords: Handball, Attack, Game Analysis, Shot, Effectiveness

IMPROVEMENT IN DECISION-MAKING INDEX IN THE U-11 TEAM AFTER AN INTERVENTION GUIDED BY TGFU

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Abstract

The evaluation of aspects related to learning is a fundamental aspect of team sports, as they provide information on the performance of players and the team. The Game Performance Assessment Instrument (GPAI) aims to offer teachers/coaches a means of observing and coding performance behaviours (such as decision-making, appropriate movement, and skill execution) linked to tactical problems of invasion sports, like handball. This study aimed to evaluate decision-making rates after an intervention of 14 handball training sessions guided by TGfU approach in a team aged between 8 and 11 years. The GPAI was applied before (pre) and after (post) the intervention, in 5' games with GK+3 vs. 3+GK, which were recorded for analysis of tactical behaviours. There was an improvement in participants' decision-making after the intervention in the male (pre=1.69 and post=1.78) and female (pre=1.64 and post=1.71) teams. These results reinforce what is proposed by the teaching approach used and indicate possible processes that can be implemented in younger teams to improve the quality of decision-making. We conclude that at this stage of development, decision-making processes should be advocated based on the experiences provided by the game itself.

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HOW TO PLAY THE INFINITE GAME OF HANDBALL – LESSONS LEARNED FROM HAPPY LEAGUE

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Abstract

Across countries and various target groups, sport participation is characterized by competitiveness with a dominating focus on promoting performance and results. Unsurprisingly, children and youth most often have other motives (e.g. having fun, being part of a team, learning skills), although they are embedded in competitive sport cultures. As competitiveness is linked to reduced sport participation, there is a growing interest in initiatives that attempt to transform sport cultures. In this paper we use a successful case, Happy League, to describe which actions can be made to transform a competitive sport culture to an inclusive sport culture. Happy League is a handball community with more than 400 volunteer coaches and 1200 children with various special needs and or disabilities across 82 clubs in Denmark, Faroe Islands and Greenland. Inspired by James Carse's 'game theory', that divide games into either finite (competitive) or infinite (lifelong), we describe the concrete actions within the game, they promote an infinite game of handball. Based on a 'theoretical' thematic analysis, we identify concrete actions within training (e.g., bending the rules for each player) and organization of competitions (e.g. making players signing up for tournaments instead of teams), that facilitate an infinite game approach. The findings have the potential to inspire practitioners and researchers in ways to promote the infinite game of handball.

DIFFERENCES IN ANTERIOR AND POSTERIOR THIGH MUSCLE STRENGHT AND THEIR IMPACT ON INJURY PREVENTION IN SPORTS

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Abstract

The purpose of this study was to highlight the risks of serious injuries in handball. Injury prevention in sports is a topical issue that ensures not only the athletes' participation in competitive sports for a longer period of time, but also the quality of life in sports and after a sports career. There is a scientifically proven relationship between muscle strength and joint stability, between muscle strength imbalance and the risk of injuries in a particular joint. The stability of the knee joint is ensured by several factors, including the anatomical features of the athlete, the shape of the legs, the Q-angle, but the ligamentous muscle apparatus is also of great importance. There is evidence in the scientific literature that an imbalance of the knee flexors (hamstrings) and extensors (quadriceps) is a potential risk factor for non-contact injuries. A percentage ratio of hamstrings to quadriceps in the range of 60-80% is considered the norm, however, for athletes, a ratio of 80% is desirable (i.e., to ensure the stability of the knee joint, the hamstrings should not be weaker than 20%). On the other hand, if the percentage ratio of H:Q is less than 60%, it shows the increased stability of the knee joint and the increased risk of injuries during rapid movements. Study included 17-28 y.o. male subject (n=38) from handball, football and basketball who participated in muscle (hamstrings/quadriceps) imbalance testing with CON-TREX human kinetics device. Study show, that there is significant difference between athletes who train in close cooperation with a physical fitness coach and physiotherapist and those who mostly work only with coaches of the respective sport.

Key words: muscle strength, muscle imbalance, injury prevention

MONITORING TRAINING LOADS WITH ACCELEROMETER-DERIVED METRICS: A STUDY WITH AN ELITE MEN'S HANDBALL TEAM

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Abstract

The current study attempted to document and analyse the demands of contemporary high-performance handball training. Players (n=16) from a professional Portuguese men's handball team were monitored over the course of two months during on-court training sessions, to characterize the weeks during this information-gathering period. During the data collection period, 34 training sessions were monitored, spread over the weeks in which there were matches from the EHF European League, National Championship and Portuguese Cup competitions. The data were collected using inertial measurement units (at 100 Hz), WIMU, and the acceleration-based metric called Dynamic Stress Load (DSL, Beato et al., 2019) was used to quantify the external load of the athletes in training. The data were computed in Python programming language, resulting in 481 experimental points (one per player and session). Two types of weeks were observed, Non-Congested Weeks (NCW, one or two matches at the weekend) and Congested Weeks (CW, a weekday match, and a weekend match, e.g.: Tuesday and Saturday). Results obtained for the NCW showed that between 5 days and 4 days before the match, the external load increased, three days before the match the load didn't change, but then decreased until the day before the match. For the CW, the load 2 days before the game was marginally lower than the match day eve, and when a training session occurred on Match Day, its training load was the week's lowest. These results confirm our previous hypotheses about the distribution of workload according to the type of week and the number of days until match day. The used tool can provide immediate and easy access to some quantitative exertion information; therefore, it is an extra and promising tool to help better prescribe handball training and maximize its effectiveness according to competition demands.

EFFECTS OF A PLYOMETRIC TRAINING PROGRAM WITH DIFFERENT FREQUENCIES IN FEMALE HANDBALL PLAYERS AGED 16 TO 23 COMPARED TO HANDBALL TRAINING – A PRELIMINARY STUDY

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Abstract

Handball is characterized by body contact between players, which occurs during defensive controls and 1v1 duels, in rapid changes of direction, accelerations, thrusts, ground receptions, starts and braking. It is therefore necessary to dedicate time to this type of work.

The main aim of this study is to evaluate the effectiveness of a plyometric training plan for female handball players, both in the upper and lower kinetic chain and to understand which training frequency brings the most advantages to the athlete's performance (2 or 3 times a week).

In this study, 30 female handball players were organized into 3 different groups: performing plyometric training 3 times a week (N=10), 2 times a week (N=10) and a control group (N=10). The athletes were assessed before and after the training program, using these 3 exercises: 30-meter sprint, CMJ and medicine ball throws. After the first assessment, a training program consisting of 5 exercises was applied for 6 weeks, 2 for the upper kinetic chain and 3 for the lower kinetic chain.

We can conclude that plyometric training influences the athlete's performance in sprinting and CMJ. On the other hand, we were able to ascertain that plyometric training in the upper kinetic chain was not effective in this group of athletes. In addition, it was shown that a moderate volume of training, twice a week, is more effective than a higher volume of training, three times a week. Therefore, we can say that the plyometric training program applied to these athletes for 6 weeks proved to be effective and is an important parameter that must be considered in handball training.

WHAT ARE THE MOST PHYSICALLY DEMANDING AREAS OF THE HANDBALL COURT? A STUDY CONDUCTED ON SUCCESSFUL YOUNG MALE PLAYERS.

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Abstract

Elite handball is intense, fast, and extremely physical for the players, leading to increased concerns about fatigue, recovery, and injury risk management. It is therefore why, in highly intense tournaments (e.g., European and World Championships), squad rotations during a match and throughout the competition are wise to protect key players from overload situations that may put them at injury risk. In addition, there is evidence that injuries (such as ACL ruptures) affect players' positions differently (Bere et al., 2015), but it is still unclear how load relates to playing zones and tactical functions performed in positional attack. This study intended to characterize the spatial distribution of the external match load of all playing positions and try to identify possible load spatial distribution patterns. A total of 27 matches from the EURO M20 Male Handball Championship were analysed, involving 180 players (711 dataset samples) and 11 national teams. The data were collected with WIMU, an integrated tracking device system comprised of a local positioning system (20 Hz) and inertial measurement units (100 Hz), and all the data was treated with Python programming language. To quantify the players' match load throughout the tournament, we used an acceleration-based metric called Dynamic Stress Load (DSL)(Beato et al., 2019). A simple visual inspection of the preliminary results reveals clear critical areas in the field where the players produce the most DSL. We also found qualitative different load distribution patterns between players in similar positions (e.g., left vs. right backs) and some surprising high load areas in the goalkeeper position that goes in line with the continually rapid nature of handball. These preliminary findings should be further analysed as it can help to better understand exertion in handball and prepare the training sessions and matches.

CONTRIBUTION OF THE RESEARCH IN HANDBALL MATCH ANALYSIS TO THE COACH'S WORK

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Abstract

The aim of this communication is to present outcomes that result from handball match analysis, and that have a direct impact on the teams' game model and consequently on the coaches' work.

We often perceive the idea that scientific research work, particularly in the area of game analysis, is work of a theoretical nature and has no applicability in the coach's daily practice. Through analysis of the literature undertaken in scientific and academic research, it is easily perceptible that there is a lot of pertinent information that contributes to the definition of a more effective game model, enabling a more rigorous and objective analysis of a team's performance. This way, it is possible to clearly distinguish opinions from facts.

Match analysis scientific research uses large databases which does not permit to explain all situations that occur in the competition but allows with rigor the definition of guidelines that conduct the teams' actions. With this in mind, this communication will present concrete examples of scientific results that, after being properly analysed, were transformed into concrete aspects that can be applied in guiding teams in training and competition.

Thus, we seek to establish a link between rigorous and duly validated scientific research, but hermetic and therefore often overlooked by coaches and other elements in practice, transforming it into a language that is easily perceptible and applicable in the team´s everyday life.

NAÏVE AUTOMATED TACTICAL ANALYSIS – AN EXPLORATORY STUDY BASED ON POSITIONAL DATA.

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Abstract

Real-time location data is frequently used to extract exertion metrics but can also be fed to into a computational system for it to *see the game* and *reason on it*. No doubt AI systems will soon start to provide insight on the tactical aspects of the games as they already do in many other areas, from chess to war. They generally start by being able to quantitatively classify the strength of each spatial position and then are added with the ability to search over many evolution options and make choices based on that classification mechanism. We have applied some of these ideas to the handball game more than a decade ago on 10 minutes of offline data painstakingly obtained from manual digitization of overhead video records at a national handball tournament (FPA 2010). We have concluded that much more data was needed for the evolution of these techniques until any meaningful results could be extracted. A decade has gone and, in this communication, we report our current progress in this path by presenting a naïve classification system for the handball game based on real-time positional data from the M20 EHF EURO 2022. The main idea is to produce a simple space decomposition based on each player's *geometrically dominated space* - a Delaunay triangulation - and value the possible paths to a shot to goal based on this *dominated space* concept. This *threat* function to the opposing goal also has some account for the laterality.

This is very much a work in progress but soon Artificial Intelligence will play a role in the education of future coaches and, eventually, will ease the task of analysing opposing teams, etc. We should not fear this tool but be able to use it to our advantage when it is ready.

EFFECTS OF SMALL-SIDED GAMES FORMATS ON PERFORMANCE OF U11 HANDBALL PLAYERS

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Abstract

The aim of this study was to examine how the individual performance of young players varies based on the type of defence (man-to-man or zone) in two small-sided games formats: four-a-side (GK+3 vs 3+GK) and six-a-side handball games (GK+5 vs. 5+GK). Twenty-eight handball players (twenty-seven boys and one girl), aged between nine and eleven years old (U11), participated in the study.

An observational system with 25 variables was designed to characterize players' offensive and defensive performance. The Mann-Whitney test unveiled significant differences in the number of interceptions and shots taken by players, contingent on the type of defence and game format. In the four-a-side game, players performed significantly more interceptions with a man-to-man defence compared to a zone defence. When comparing the four-a-side and six-a-side games, both utilizing a zone defence, a significantly higher number of shots were recorded in the six-a-side game format. These results emphasized the importance of designing practical tasks that stimulate greater player involvement in the match and enhance overall player performance.

LINKS BETWEEN JUMPING PERFORMANCE AND PERCEIVED RATINGS OF WELLNESS IN U19 FEMALE PORTUGUESE HANDBALL NATIONAL TEAM BEFORE WOMEN´S EHF EURO 23

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Abstract

Monitoring perceived wellness indices has become crucial for coaches to better control training loads in team sports. Since handball is broadly characterized by jumping and landing actions, quick stops, sudden cuts or decelerations with changes of direction, it is of utmost importance to assess central and peripheral fatigue of players in order to monitor the training process.

This study had two aims: (i) to investigate intra-individual variation in vertical jumping performance and inter-individual agreement in perceived wellness ratings over time; (ii) to examine the associations between jumping performance and ratings of perceived wellness.

Sixteen U19 female Portuguese handball players (age=18.31±0.48 years; training experience=9.56±2.10 years; height=1.72±8.21 m; weight=71.09±10.02) were assessed every 48 hours over 9 training sessions. Players performed the "free arms" countermovement jump using a device to measure the vertical jump, which is commonly used as an indicator to monitor peripheral fatigue during the preparation of the EHF U19 Euro 23. In addition, they answered a readiness questionnaire to assess the perception of fatigue levels and muscle injuries. Each question individually scored on a scale from 1 ("very high") to 5 ("very low"). Data was analysed using both parametric and non-parametric techniques.

Results showed high consistency of intra-individual performance across time in countermovement jump (R=0.984, $p<0.001$), but moderate and fair agreement among players in self-reported pain perception ($W=0.44$, $p<0.001$) and fatigue perception ($W=0.34$, $p<0.001$), respectively. Furthermore, players who performed better in countermovement jump reported significantly higher levels of perceived fatigue (R=−0.574, $p<0.05$), whereas the jumping performance and levels of perceived pain were not significantly related (R=−0.37, $p>0.05$).

Our findings highlight that jumping performance was not affected by the training loads to which players were exposed during the preparation for the European Championship. Also, the perception of fatigue appears to have no impact on physical performance.

ANALYSIS OF OFFENSIVE EFFECTIVENESS IN ATTACKS CARRIED OUT WITH AN EMPTY GOAL – STUDY CARRIED OUT WITH THE 2022 EUROPEAN WOMEN'S HANDBALL CHAMPIONSHIP

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Abstract

Handball is a dynamic and exciting team sport that requires individual technical skills and efficient collective tactical aspects, which are essential for success in this modality. Over the years, due to the evolution of handball, there has been a significant increase in the use of the 7x6 offensive organization, therefore the objective of this work is to evaluate the offensive effectiveness and frequency of use of this system.

A quantitative analysis of 24 games from the Women's European Championship 2022 was executed, with the aim of characterizing the various match systems, as well as analysing the effectiveness of using the 7x7, 7x6, 5x6, and 6x6 systems and the shots from the various specific positions. Thus, we aim to conclude about the advantages or disadvantages of the goalkeeper's substitution in the attack, whether in situations of numerical equality or in situations of numerical inferiority. The results demonstrate that: i) attack situations involving equal numbers of players (7X7) in which teams replace the goalkeeper with a field player, using the 7X6 attack, happen less frequently than the use of the 6X6 organization; ii) when teams are in numerical inference (6X7) in most situations they substitute the goalkeeper to attack 6X6, compared to attacks in which they play 5X6; and iii) in both cases, there is an improvement in effectiveness when the goalkeeper is replaced. Match analysis on the collective tactical aspects of handball is essential for the evolution of scientific knowledge and for better team performances.

RUNNING CARDIORESPIRATORY AND METABOLIC CHARACTERISTICS OF HIGH-LEVEL PORTUGUESE FEMALE HANDBALL PLAYERS

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Abstract

Modern elite female handball is physically demanding, marked by intermittent play and high relative workloads that require a well-developed aerobic capacity for a sustained peak performance. In addition, activities change during the game and their intensity indicate significant anaerobic energy utilization during specific match periods (that are probably delayed when disposing of a high cardiorespiratory proficiency). The aim of this study was to evaluate cardiorespiratory and metabolic functions in the Portugal female handball team. Twenty high-level female handball players, with 25.6 ± 6.2 years, 70.3 ± 8.2 kg of body mass, 174.8 ± 4.9 cm of height and 24.2 ± 2.6 kg/m^2 of body mass index, volunteered to participate. Players performed a square wave transition running test at the velocity corresponding to the maximal oxygen uptake, established using the individual velocity of the last stage of the yo-yo intermittent test level 2, on a treadmill with 0% grade (AMTI, Watertown, MA, USA). This test until voluntary exhaustion allowed to determine their time limit at that specific intensity. Most common cardiorespiratory variables were continuously assessed breath-by-breath (K5, Cosmed, Rome, Italy) and capillary blood lactate (Lactate Pro 2, Arkay, Inc, Kyoto, Japan) was evaluated during the third min of recovery. The time limit reached 292 ± 127 s, leading to elevated values in oxygen uptake (47.8 ± 6.2 mL·kg^{-1}·min^{-1}), minute ventilation (107 ± 9 L·min^{-1}), respiratory frequency (51 ± 7 b·min^{-1}), tidal volume (2.1 ± 0.3 L), heart rate (184 ± 6 b·min^{-1}) and blood lactate (9.6 ± 2.2 mmol/L). Data show that female handball players of the national Portuguese team have favourable cardiorespiratory fitness to overcome the game demands. However, considering the substantial stress placed on cardiorespiratory function during both training sessions and matches, it remains crucial for players to engage in consistent training regimens aimed at sustaining and enhancing their cardiorespiratory fitness levels.

Keywords: oxygen uptake, heart rate and blood lactate

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THE PLAYERSCORE: A SYSTEMATIC GAME OBSERVATION TOOL TO DETERMINE THE INDIVIDUAL PLAYERS PERFORMANCE IN TEAM HANDBALL COMPETITION

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Abstract

Introduction: In team handball, the individual match performance of each player is essential for winning games; however, a validated match analysis system is still lacking. Consequently, the aim of the study was to justify (1) the different relevant variables and their scoring within the individual match analysis (PlayerScore), (2) to determine the intra-rater reliability and validity of the PlayerScore, and (3) to determine the influence of the rater in relation to their degree of expertise level.

Methods: Six games (three games each of Spain and Brazil, one game twice) of the 2021 World Championship were analysed by six different raters. The PlayerScore was calculated for each field player of Spain and Brazil in all seven analyzed games.

Results and Discussion: We found a high intra-rater reliability (ICC = 0.97) for the two rated games (Spain against Germany), a highly significant difference ($P < 0.001$) between the summarized team PlayerScore of Spain and Brazil, as well as significant differences ($P < 0.001$) for the factor "game" and "rater" ($P < 0.05$) but no significant interaction for "game × rater" ($P = 0.90$) in the two-way repeated measures ANOVA. We conclude that the PlayerScore is a reliable and valid rating tool to determine the individual players' performance in team handball; however, the raters should have sufficient experience in the different techniques and tactics in team handball.

THE RELATIONSHIP BETWEEN SPECIFIC GAME-BASED AND GENERAL PERFORMANCE IN YOUNG ADULT ELITE MALE TEAM HANDBALL PLAYERS

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Abstract

Introduction: Physical performance is an essential factor for becoming a top elite team handball player; however, the relationship between specific and general physical performance is not well known. Consequently, the aim of the study was (1) to analyse the relationship between specific game-based and general physical performance in young elite male team handball players, and (2) to reduce the number of tests for a more practical implementation of physical performance diagnostics in team handball.

Methods: Twenty young adult elite male team handball field players (18.6 ± 2.1 years) performed the team handball game-based performance test (GBPT), including specific movements in offense and defence such as catching, passing and throwing a ball, sprinting, stops, changes in direction, jumping, checking and screening, as well as general tests, including a 20 m sprinting test, a repeated sprint ability test (RSA), a modified t-test, countermovement (CMJ), squat (SJ) and drop jump test (DJ), a standing long jump test, a single-leg lateral three jumps test, a standing throw test, and the determination of the one repetition maximum (1RM) in the bench press, bench pull, front squat, and deadlift.

Results and Discussion: Significant correlations were mostly found between different sprinting and jumping tests as well as between different strength tests. The principal component factor analysis revealed four components (power and speed, strength, jump shot performance, and endurance) including 21 variables of high loads (>0.60 or <−0.60). Due to the correlations between the different tests, we suggest a more practicable testing procedure including the 20 m sprinting test, CMJ test, 1RM in the bench press and front squat, as well as the GBPT for elite teams, or the t-test and the YoYo intermittent recovery test for youth and non-elite teams. Despite some correlations between specific and general tests, we suggest using the GBPT to measure specific performance in team handball.

BARRIERS FOR THE DEVELOPMENT OF FEMALE HANDBALL PLAYERS IN A BRAZILIAN CLUB

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Abstract

Clubs play an important role in the development of athletes in various sports, which also applies to handball in the Brazilian context. However, there are few studies on the challenges faced by club coaches who coach female handball teams. This study aimed to identify and analyse the barriers related to the long-term development of female handball players across different categories within the context of a club. Three coaches of female teams (from the U-12 to U-18 teams) for one of the main clubs in Brazil were interviewed, and their speeches were analysed through reflexive thematic analysis. Our findings revealed that the main challenges faced by coaches are: 1) the heterogeneity of the teams, caused by the players from different experiences in public or private schools; 2) the increased demands of the sport, which requires dedication from the players, and results in a greater demand for improved performance and significant competitive results; and 3) the overload of personal and team activities. These aspects are especially challenging as players have to balance their activities (school demands, and college admission exams, in U-18 teams) and commitments with those related to the team (performance in matches, and the athlete selection process in junior and adult teams).

TACTICAL-TECHNICAL ASPECTS OF LONG-TERM TRAINING OF YOUTH TEAMS IN A HIGH-PERFORMANCE HANDBALL CLUB

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Abstract

As athletes must comprehend the game context and adapt their actions to reach success in these situations, it demonstrates the importance of planning and executing efforts being appropriate to the goal stipulated for each team. However, it is noted a gap in investigations addressing the youth teams in handball, for better work based on athletes' development. In this sense, this study aimed to investigate the development of concepts related to the game in the youth categories of a high-performance club in Brazilian handball. Interviews were carried out with the coaches of each category (U12, U14, U16 and U18), using the reflexive thematic analysis to analyse the obtained data and one of the identified subthemes was 'Technical-Tactical Knowledge'. It revealed the development of individual skills and relations for the initial stages (U12 and U14), the inclusion of team (collective) situations as players gained experience in handball (U16) and the specialization in specific positions as they conclude the formation stages (U18). This study concluded that the progression in teaching the concepts must stimulate the athletes' reflection and must be adequate for the age group.

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ANAEROBIC TRAINING – AN IMPORTANT FACTOR IN THE TRAINING OF ELITE TEAM HANDBALL PLAYERS

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Abstract

Working demand analyses of elite team handball have shown that various types of anaerobic performance are highly crucial for playing performance and match outcome in elite team handball. Thus, an intensified focus on anaerobic training aspects including resistance training seems highly relevant especially in male elite team handball players. Anaerobic exercises should be in focus in the physical training of elite team handball players for improving their ability to repeatedly perform anaerobic exercise and to rapidly recover after periods of high-intensity exercise. Consequently, players will be more capable of performing the above playing actions at high levels sustained throughout the entire match. Moreover, elite team handball players should not train solely to be able to tolerate the average physical load during an entire match, but also to be able to perform maximally during the most intense, but brief time periods throughout the game.

Anaerobic training can be divided into two main training areas: speed training and speed endurance training. Speed endurance training can be further divided into production training and maintenance (tolerance) training. The principles for these training modalities are descripted in detail in the present article. Even though strength training due to its high intensity and short exercise duration is anaerobic of nature, a review of the principles of this form of training is not included in this article.

Anaerobic training leads to significant adaptations in the muscles that are activated during the training as well as in the nervous system. High-level physical performance in an intermittent sport like team handball is among other things conditioned by a large capacity to develop strength quickly (i.e., a high rate of force development) that can be sustained over longer periods of match-play. This is created by a combination of optimized coordination, strong ability for rapid force development, a high anaerobic energy release rate (anaerobic power) and a large total anaerobic energy release (anaerobic capacity).

The physiological elements that are essential for optimizing the anaerobic exercise ability can be built up fairly quickly (weeks). This means that it is not necessary for elite team handball players to perform systematic anaerobic training all year round. Consequently, the anaerobic training should only be intensified when elite players are approaching the start of the competitive season or a performance peak.

DEVELOPMENT OF GAME AND RULES IN CHILDREN HANDBALL

Autors:

Lars Møller, Head of development

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Institution:

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Abstract

With a project designed by the board of the national federation in 2018 it was decided to analyse and redesign the rules and the game of Children's handball. Project was regarding the age category of U13 and younger. The main issue was an attempt trying to facilitate more appropriate levels of challenge considering the respective age category of the children. Issues to consider was in particular to analyse the game of different age category and to redesign the size of the court that is used. The main target was trying to get more speed and action in the game of the children's than we know from the game played on 40x20 meter court. The methods included observation and analysis of matches and by further actions it ended up in a project from 2019 until 2023. Handball in Denmark has been played on three different sizes of courts with sizes of 20x13 meters, 25,5x20 meters and 40x20 meters. As another important issue of the project, it has been discussed, analysed, and played with different number of players on each team. The last question taken into consideration in the project is the size of the ball to be used in the game of children. It has been a discussion about the size of the ball and especially regarding the material talking about using a ball of leather or a ball of different soft materials. In the late of 2023, we will end the project and conclude about the future rules and game of the children handball in Denmark.

DEVELOPMENT AND VALIDATION OF AN OBSERVATIONAL GAME ANALYSIS TOOL WITH ARTIFICIAL INTELLIGENCE FOR HANDBALL: HANDBALL.AI.

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Abstract

Performance analysis based on artificial intelligence together with game-related statistical models aims to provide relevant information before, during and after a competition. Due to the evaluation of handball performance focusing mainly on the result and not on the analysis of the dynamics of the game pace through artificial intelligence, the aim of this study was to design and validate a specific handball instrument based on real-time observational methodology capable of identifying, quantifying, classifying, and relating individual and collective tactical behaviours during the game. First, an instrument validation by an expert panel was performed. Ten experts answered a questionnaire regarding the relevance and appropriateness of each variable presented. Subsequently, data were validated by two observers (1.5 and 2 years of handball observational analysis experience) recruited to analyse a Champions League match. Instrument validity showed a high accordance degree among experts (Cohen's kappa index (k) = 0.889). For both automatic and manual variables, a very good intra-((automatic: Cronbach's alpha (α) = 0.984; intra-class correlation coefficient (ICC) = 0.970; k = 0.917) (manual: α = 0.959; ICC = 0.923; k = 0.858)) and inter-observer ((automatic: α = 0.976; ICC = 0.961; k = 0.874) (manual: α = 0.959; ICC = 0.923; k = 0.831) consistency and reliability was found. These results show a high degree of instrument validity, reliability and accuracy providing handball coaches, analysts, and researchers a novel tool to improve handball performance.

Keywords: handball; performance indicators; artificial intelligence

SUSTAINABILITY IN EUROPEAN PROFESSIONAL FOOTBALL CLUBS AND LEAGUES – FACING DIGITAL AND MANAGERIAL CHALLENGES IN CONSIDERATION OF EUROPEAN UNION'S CORPORATE SUSTAINABILITY REPORTING DIRECTIVE – LEARNINGS FOR EUROPEAN HANDBALL

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Abstract

The current debate on sustainability regulations plays a crucial role in science, politics, society, and economy. This is especially the case for professional football, as it can reach out to millions of supporters and a wide range of sponsoring partners to develop and execute sustainability strategies. In 2015, the United Nations (UN) published its non-binding recommendations, known as the Sustainable Development Goals (SDGs). As a regulatory game changer, the European Union (EU) recently approved its Corporate Sustainability Reporting Directive (CSRD) to be introduced in several stages starting on 1st January 2024 affecting the football business industry, especially clubs and leagues, and global sponsoring partnerships, to binding regulations. The preliminary conclusion is that there is high pressure to implement CSR activities both at the league and club levels. Due to mandatory CSR reports, CSR is at the forefront of management initiatives. In this sense, it is currently undergoing a normalisation process in all realms of the international football business sector, facing clubs and leagues to institutionalise CSR as an organisational structure. Fundamental club and league-based CSR-linked management decisions and transformation processes regarding EU's CSRD guidelines could not be identified yet but are expected for further analysis. As all clubs must follow CSR rules and regulations, the organisational change to transform CSR into a formalised process depending on higher expectations such as EU's CSRD is yet to come. What can European Handball learn from this?

THE EFFECT OF BLOCKED PRACTICE AND RANDOM PRACTICE TO IMPROVE TEAM HANDBALL FUNDAMENTAL SKILL FOR BEGINNER UNIVERSITY STUDENTS

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Abstract

The effect of practice is a matter that has a long research tradition in the field of skill acquisition. In recent decades, interest has focused on analysing if random practice has a more favourable learning effects than a blocked practice (i.e., more repetitive practice). This was the aim of this study in which forty-four university male students with no experience in team handball. Participants were randomly assigned into three experimental groups (i.e., blocked practice, random practice, and control group). The performance of fundamental team handball skills such as dribbling, passing, catching, and shooting were tested in three different times: pre-intervention, post-intervention, and ten days after post-intervention, with no practice at all. The results showed that for all fundamental skills, the performance of participants has improved significantly for both blocked and random practice groups ($P < 0.05$), but not for control group. In addition, there was no significant different in performance between blocked and random practice. Moreover, there was a statistically significant interaction effect between time (i.e., pre, post, retention tests) and intervention (i.e., three experimental groups). The results did not support the contextual effect, and random practice for handball novices showed no better effects over blocked practice. The author suggests that the level of experience and the short time between post and retention test might play an important role in the similarity of the results of the two groups (blocked and random).

THROWING LOAD IN HANDBALL

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Abstract

In handball there are many shoulder injuries, probably due to too many throws during training and matches. Yet, it is difficult to measure number of throws during training. Therefore, the aim of this study was to investigate if it was possible to measure throwing volume: absolute number of shots and passes, as well as the frequency of passes and shots and the intensity of shots with an inertial measurement unit (IMU) and if there are differences between sexes, playing positions and different training exercises in order to monitor training load and prevent potential injuries. During the season 2022-2023, training load was monitored in twelve male and nine female youth elite players from all playing positions (except goalkeepers) of the Dutch Handball Academy (mean age=17.3 yrs.). The IMU was attached to the wrist to collect 3D accelerations and angular velocities during throwing. Eight different training exercises were determined: warm-up, passing exercise, goalkeeper warm-up, individual development plan (IDP), and small sided games (SSG) half field and whole field both smaller than 4x4 and equal or higher than 4x4. Mixed model ANOVAs were used for each dependent variable to test the effect of sex, playing position and exercise type. Significant differences in frequency of passes and shots among training exercises were found ($p<0.001$). Passing frequency was significantly higher for females compared to males ($p=0.012$). In SSG whole field ≥ 4x4 the passing frequency of back players is higher compared to wing players ($p=0.035$). Throwing volume differed between different training exercises, passing exercises, goalkeeper warm-up and IDP showed the highest values. It was concluded that during training in general females have a higher passing frequency during all training exercises. Back players pass more in match resembling training exercises compared to wings. Goalkeeper warm-up and IDP are the most demanding exercises as they show the highest throwing volumes.

A PILOT STUDY: THE EFFECT OF WEARABLE RESISTANCE ON FOREARM UPON THE THROWING VELOCITY.

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Abstract

Throwing velocity is in many sports an essential performance variable for handball athletes. During competition season it is often difficult to train resistance training for overarm throwing, while it tends to decrease during season, while with wearable resistance it is possible to train specific strength training for throwing, during normal handball practice. Therefore, the purpose of this study was to investigate the training effect of wearable resistance on forearm for throwing velocity. 10 female handball (7 in experimental group, 3 in control group) players performed a 6–10-week training intervention with extra weights attached by a sleeve and velcro on their forearm (Lila™, Kuala Lumpur, Malaysia) during handball training. The weights gradually increased from week to week and a minimum of 3 trainings per week. Before and after the training period players tested maximum throwing velocity by performing 5 standing throws on a target (0.6x0.6m) 5-m away, measured with a radar gun (Stalker ATS II, Richardson, TX, USA). A two-way (training group and test occasion) ANOVA with repeated measures showed that a significant effect over time ($F=6.3$, $p=0.036$, $\eta p2=0.44$) was found, without any significant interaction or group effect ($F\leq2.76$, $p\geq0.14$, $\eta p2\leq0.25$). Post hoc comparison showed that the control group decreased ball velocity significantly with 4.6%, while the experimental group did not significantly change throwing velocity (-0.9%). It is concluded that it seems that wearable resistance attached to the forearm can keep throwing velocity up during competition season, compared to throwing training with regular balls. However, a study with more handball players must be performed and during another part of the season as the current study had a very low number of subjects, before we can confirm the statement about the use wearable resistance attached during handball training practice as specific resistance training.

THE CLOSED KINETIC CHAIN UPPER EXTREMITY STABILITY TEST (CKCUEST) PERFORMANCE IN ELITE TEAM HANDBALL PLAYERS PLAYING WITH SHOULDER PAIN, PREVIOUS PAIN OR WITHOUT SHOULDER PAIN.

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Abstract

Physical therapists attempt to develop training for overhead throwing athletes to prevent injury, enhance performance and safely progress rehabilitation in the process to return to sport. The Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) has been presented to determine muscular capacity and dynamic shoulder stability in overhead athletes. However, it is not known if the test also can be used to distinguish between handball players playing with or without shoulder pain and between male and female players. Therefore, the aim of this study was to investigate if the performance of the CKCUEST variates between male and female elite handball players playing with shoulder pain, previous pain and no pain. A total of 106 elite team handball players, 49 female (1.74 ± 3 cm, 70.4 ± 6.7 kg and 22±4.9 years) and 57 male (1.90±7.5 cm, 91.6±11.4 kg and 22 ± 5.4 years) participated in this cross sectional study. Significant differences were found between the female and the male handball players when comparing all the three CKCUEST scores ($p<0.01$). However, no significant differences between the different groups (no, previous, shoulder pain) were found. It was concluded that due to the differences in scores between men and female athletes that a comparison across sex is not suitable, due to the possible positive influence of height in the test set-up. Furthermore, the CKCUEST was not able to differentiate between elite handball players who are still playing with shoulder pain, previous shoulder pain and no pain.

HANDBALL LEARNING ASSESSMENT: TRAINING TO DEVELOP AND HUMANIZE

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Abstract

This study presents an innovative analysis system for handball coaches, designed to identify the development/ training needs for children and young athletes. We designed the Sports Development Screening Toolkit: Psycho, Technical-tactical (BADD.PT), which comprises assessment of technical and tactical knowledge/ skills of young athletes, as well as psychological and behavioural component (coach, athletes, and team, assessed individually and between).

We present the preliminary composition of technical-tactical component, which consists of 131 items, that compose four dimensions: Individual Technique, Individual Tactics, Group Tactics, and Identification of Handball Phases and Rules (each one subdivided into attack and defence components). The pilot study was carried out with 59 athletes, aged between 5 and 17 years old.

The results show that BADD.PT has good internal consistency, and it's valid for identify specific training needs, facilitating the structuring of multi-level training, in line with individual's technical and interpersonal skills and the team's profile.

Keywords: Handball training, Handball management, Children and young athletes, Skills

COMPLETING THE "CIRCLE OF A HANDBALL LIFE" – THE HANDBALL 4 HEALTH PROJECT

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Abstract

For several years, the European Handball Federation has advocated the sustainability of team handball, namely by endorsing recreational team handball, an adapted version of the official game. This to inspire former players and the general population to embrace an active and healthy lifelong lifestyle through sport. Aim that is aligned with the World Health Organization's (WHO) central policy recommendation of promoting sports for all, within the WHO Global Action Plan on Physical Activity. Recreational team handball has proven to be an effective, feasible, and enjoyable strategy for enhancing health and physical fitness across several populations, with and without experience with the sport. It encompasses a holistic blend of endurance, strength, balance, and aerobic high-intensity interval training, offering a comprehensive health and fitness stimulus.

This presentation will showcase research findings from diverse populations, spanning from adults to the elderly and including individuals with specific health conditions. Furthermore, the practical implementation challenges demanded by the modifications required to the official sport version, with a particular focus on the use of same and mixed-gender game formats will be examined. This is especially pertinent in community settings where classes are often comprised of participants of both genders. The purpose of this presentation is to equip practitioners with evidence-based insights to inform their decisions when implementing recreational team handball.

This work is supported by national funding through the Portuguese Foundation for Science and Technology, I.P., under project UIDB04045/2020.

ANTHROPOMETRIC AND PHYSICAL PERFORMANCE OF YOUNG TEAM HANDBALL PLAYERS CLASSIFIED BY PLAYING POSITION AND AGE CATEGORIES IN QATAR– A CROSS SECTIONAL STUDY.

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Abstract

The study aimed to investigate the anthropometric and physical performance of male young team handball players classified by playing position and age categories. The handball players were recruited from the Qatar handball first league. Twenty players under 15 years (U15) (age: 14.5 ± 0.51 years) and 20 players under 18 years (U18) (age: 16.9 ± 0.91 years) were categorized as backs (6/6), pivots (3/4), wings (6/6) and goalkeepers (5/4). Measurements included anthropometric data (height, mass, body mass index (BMI) and body fat) and different physical performance tests: agility T-half; squat jump (SJ), and countermovement jump (CMJ) test, sprint 15 and 30 m; medicine ball throw (MBT). The aerobic capacity was evaluated using the Yo-Yo Intermittent Recovery Test level 1 (Yo-Yo IR1). Anthropometric data revealed significantly differences between U15 and U18 regarding body height ($p = 0.005$, $\eta_p^2 = 0.193$; U15: 1.63 ± 0.11 m vs. U18: 1.74 ± 0.11 m) and body weight ($p = 0.012$, $\eta_p^2 = 0.155$; U15: 66.5 ± 16.4 kg vs. U18: 81.4 ± 19.0 kg). Regarding physical performance we detected significant ($p < 0.05$ and $\eta_p^2 > 0.15$) age related differences in sprint 15 m ($p < 0.001$, $\eta_p^2 = 0.276$), SJ ($p = 0.001$, $\eta_p^2 = 0.254$) and CMJ ($p = 0.012$, $\eta_p^2 = 0.154$). Back players showed the highest performance level in both age groups in Yo-Yo IR1, SJ and CMJ. The differences of anthropometrics and physical performance between players of different age groups and playing position underline the importance of a careful scouting and position-specific training and assist in talent identification for male team handball players.

Keywords: performance; playing position; anthropometrics; young players; team handball

SHORT-TERM INACTIVITY AFTER WARM-UP AFFECTS THE PHYSICAL PERFORMANCE IN FEMALE ELITE TEAM HANDBALL PLAYERS

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Abstract

In team handball, unlimited substitutions are allowed during the game, which means that despite previous inactivity on the bench, players can be immediately sent on the pitch to perform at maximum intensity. The aim of this study was to investigate the effects of inactivity after a match warm-up on the physical performance and physiological responses of female elite team handball players and to examine a possible connection between the examined parameters. Twelve female adult elite field players were examined. All tests were assessed in two different situations: (a) immediately after a standard warm-up (T1-AW) and (b) after a 15 minutes inactivity period (T2-IP). The physical tests performed were: Countermovement jump with arms fixed (CMJ AF), squat jump (SJ), medicinal ball rotational throw test right (MBTT-R), medicinal ball rotational throw test left (MBTT-L), and 10 m acceleration test (TA 10m). The physical parameters analysed for both CMJ AF and SJ were jumping height (JH), reactive force index (RSI1), peak jump power (PP) and peak jump speed (PV). For MBTT, peak throw power (PP) and peak throw velocity (PV) were measured. Heart rate (HR) was measured during warm-up and at T2-IP, while body temperature (BT), lactic acid (LA), serum glucose (G), and blood oxygen saturation (SpO_2) were measured at T1-AW and T2-IP.

Significant differences were found at T2-IP for RSI1 ($t= 2.88$, $p < 0.01$), and PP ($t= 2.24$, $p < 0.05$), specific to CMJ AF and RSI1 ($t= 3.88$, $p < 0.01$), and for PP specific to SJ ($t= 2.28$, $p < 0.05$). All physical indices correlated positively with the physiological ones. In addition, two significant correlations were identified, one between the decrease ($r=0.59$, $p<0.05$) in the reactive strength index (RSI 1) and peak power (PP) for the countermovement jump (CMJ AF) and another between the decrease ($r=0.60$, $p<0.05$) in the PP and body temperature (T_c) for the squat jump (SJ).

The present results show that the effects of short-term inactivity counteract to some extent the physical and physiological benefits that players derive from warming up. The 15 minutes inactivity led to a significant decrease in some parameters specific to both jump tests. In addition, a positive correlation between the decrease in body temperature and the decrease in peak power specific to squat jump performance was identified. This indicates that lower body temperatures that result caused by a short period of inactivity can lead to a reduction in jumping performance just before players would enter the game.

EXPLORING THE EFFECT OF NUMERICAL SUPERIORITY AND EQUALITY IN SMALL-SIDED GAMES IN CHILDREN HANDBALL

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Abstract

To enhance handball beginners' motivation, fun, and learning, it is necessary to confront them with challenging yet achievable game problems in which they feel a sense of belonging and success. To date, few studies have examined how different small-sided game configurations affect opportunities for beginner's participation and game actions. The aim of this study was to explore the effect of even and uneven small-sided game configurations on U10 mini-handball players. Eight (n= 8) children (four girls) took part in this research, who were used to playing in the applied game forms. The games were performed with a fixed goalkeeper and an advanced goalkeeper, as well as played on a reduced court (23x15m), with a semicircular goal area of 5m, and with a soft ball size "0" to discourage dribbling. Each match lasted 10 minutes and was recorded digitally. We used the Performance Evaluation Instrument for Team Sports system to analyse variables such as participation, game balance, and volume of play. In general, the results indicated that the 3v2 format contributed to a greater volume of play, i.e., passes and receptions, as well as more shooting opportunities and individual participation rates. The results suggest that educators should be aware of how different game configurations and rule modifications might affect opportunities for game participation and, consequently, motivation and enjoyment in all players.

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USING BIOMECHANICAL METHODS TO DESIGN INTERVENTION PROGRAMS TARGETING INJURY PREVENTION AND PERFORMANCE ENHANCEMENT IN HANDBALL – HOW CAN IT HELP?

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Abstract

Introduction

One of the challenges as a coach or strength & conditioning trainer in team sports is to design training programs aimed to enhance the performance of individual players. Subjective analyses of player performance and physical testing are the standard means of assessing deficits that may need to be addressed to improve performance. Many testing protocols available for handball coaches are low-tech solutions which works fine for several purposes, but very often also need the specificity to improve individual training advice. As an example, measuring time of a 30-meter sprint provides estimation of maximal sprint velocity, a quality important for performance, but does not really provide much insight into what the individual player should focus on. Would an eventual poor sprint performance be due to deficits in eg. hip extensor power, plantarflexor power or maybe sub-optimal running technique? Biomechanical analyses can provide a full analysis of how inter-segmental coordination or specific joint power production may influence performance, and as such assist in designing individually tailored training programs.

The aim of this presentation is to display examples of how biomechanical testing may assist in disclosing risk factors for injuries and providing insight in which exercises and specific execution techniques may be optimal in addressing these risk factors, as well as how biomechanical analyses can discover key parameters of technical details important for performance in handball.

The presentation will discuss three different aspects of handball: 1) Jumping performance with jump shot as example, 2) Throwing performance, with special emphasis on injury prevention, and 3) Prevention of anterior cruciate ligament injuries (ACL), including risk factor identification and consequences for exercise selection for prevention.

The presentation will be based on both published results and new previously unpublished results in order to elucidate the problems and provide an up-to-date status on what is known, what to implement and what is to be further investigated.

Finally, concluding the presentation will be a discussion on how to implement the results obtained through biomechanical methods into daily practice, both from the perspective of the youth handball coach and the elite coach.

CHANGES IN MATCH DEMANDS FOR THE TOP-4 TEAMS DURING THE MEN'S EHF EURO 2022

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Abstract

The aim of this study was to investigate changes in team handball match demands during an official tournament, by comparing matches in the preliminary round (P), main round (M) and finals (F) for the top-4 teams (Sweden, Spain, Denmark, and France) using Kinexon data from the MEN'S EHF EURO 2022.

From each match, we included in the analysis data from the 6 outfield players with the most time played in each team. Comparisons were made considering relative values (per min). One-way ANOVA or Kruskal-Wallis test were performed after assessing for normality (Shapiro-Wilk test).

Distance covered was higher during F and M than P (80±7 and 80±8 vs. 77±7, m/min; P<0.05), which was related to higher distance covered with low-speed running in F and M than P, and more high-speed running in P than M. Top speed was also not different between P, M, and F (25.9±2.4, 26.0±2.4 and 25.6±2.4 km/h, respectively). No differences were found between P, M, and F for the number of accelerations (1.0±0.3, 1.1±0.3, and 1.1±0.3, respectively) or decelerations (0.7±0.2, 0.7±0.3, and 0.7±0.2, respectively). No differences were observed in the number of jumps (0.29±0.17, 0.31±0.18, and 0.34±0.20, respectively) or number of changes of direction (0.18±0.13, 0.18±0.11, 0.18±0.12, respectively). The number of impacts were higher during F than P (0.38±0.26 vs 0.26±0.26; P<0.05) and tended to be higher than M (0.28±0.26; P=0.074). Accumulated acceleration load tended to be higher in F than P (10.2±1.3 vs. 9.6±1.3 AU; P=0.051), but not than M (9.8±1.2 AU). In conclusion, minor changes were observed in the match demands throughout the tournament for the top-4 teams, with these changes being related to a higher number of impacts and accumulated acceleration load in the finals.

GETTING EVERY KID IN ACTIVE PLAY IN PHYSICAL EDUCATION: A PLAYBBOOK FOR SAFE, FAIR, POWERFUL AND FUN HANDBALL LEARNING

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Abstract

There is huge evidence of problems of access, participation, and achievement in PE classes. Gender, different skill levels, and special needs fused with race and social status put considerable percentages of students at risk of marginalization, alienation, and underachievement. Part of this is because PE teachers remain unprepared to solve problems of exclusion and underachievement, namely in team games, which are an important part of most PE teaching curricula. So, to provide a Quality of Physical Education (QPE), it is necessary to create opportunities for all student-players to be physically active in fun, safe, inclusive, energizing, and rich learning environments.

This presentation aims to present an **interactive e-book** designed to assist PE teachers in accommodating student diversity and to deal with heterogeneous student groups, helping them in the complex process of involving all student-players in action by playing handball. Therefore, changing the focus of game learning from an excluder egocentric performance toward a play-full teamwork creation. The pedagogical toolkit was designed based on game-based approaches for inclusion (rather than elitism) to involve all in action by playing handball. Therefore, it is a roadmap with key strategies to change the game, make it better played, and accommodate diversity, by removing barriers towards active play and inclusion. It includes: (i) shaped game play forms designed to empower teamwork, active play, game understanding, game skills and social skills development (fair play and respect), (ii) game simplifications to represent the tactical logic of the game at the developmental readiness of the learners, and changes to manipulate game initiative (when and how), (iii) how to modify the game and player possibilities for action (affordances) and communication according to student-players learning needs, by using exaggeration, elimination, or reduction of aspects of the playing environment, (iv) thematic learning tasks based on principles of play (e.g., retaining ball possession, making forward progression, and attacking the goal), and (v) examples of guided inquiry through student-player problem solving and teacher use of observation, well-well-thought-out and assertive questioning.

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