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Epidemiology and Risk Factors in Young Female Athletes: Basketball, Football, and Volleyball

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A young sprinter prepares herself with a track series to work on her explosiveness. @Jérome Aufort/Adobestock

Abstract

The aims of the study were to determine the epidemiological profile of young female athletes in Catalonia (Spain) who play team sports, and to analyse the risk factors for these injuries. A total of 1,235 adolescents (15 ± 2.4 years old) belonging to 168 teams from 17 clubs (n = 8 basketball, n = 3 football, and n = 6 volleyball) participated in the study. A descriptive and retrospective design was established, analysing the percentage and incidence rate of injuries, type of injury, body area, diagnosis, severity, mechanism and the context in which the injury was sustained. A binary logistic regression model was applied (p <.05) to determine relationships between factors, sports and injuries. The results indicated a higher percentage of female players injured in basketball and football, with acute, lower limb, long-term injuries that occurred without contact and in training, being more frequent. Volleyball was the sport with the lowest risk of injury, although the risk of injury increases if a second sport is not played. These findings serve to establish strategies that adapt the sporting environment to the development and characteristics of young athletes, encouraging their participation and ensuring the health of participants.

Keywords: injuries, prevention, team sports, women, youth.

Introduction

Sports injuries are a serious public health problem (Finch & Cassell, 2006) which generates high medical costs (Sethi et al., 2008), significant psychosocial implications (Haraldsdottir & Watson, 2021), and can also be a very important determinant of citizens' future participation in sport and physical exercise. Injuries not only affect adult athletes, but there is also a growing problem relating to sports injuries in young people. In the United States of America (USA), it has been estimated that of the 7.2 million young people who participate annually in under-18 sports competitions, approximately 2 million are injured each season, resulting in 500,000 medical service visits and 30,000 hospitalisations annually (Patel et al., 2017).

The study of the physical and physiological differences between adult and young athletes is of particular interest in understanding the occurrence of sports injuries at an early age. Such differences may make young athletes more vulnerable to health problems related to the demands of sport. Young athletes have more growth plates which are less protected against mechanical stress (Adirim & Cheng, 2003) and often use protective equipment that is inappropriate for their size, which contributes to this lack of protection. Of particular interest is compressive mechanical stress, whereby, according to the Hueter-Wolkman law, a moderate compressive load will promote growth and, on the other hand, excessive loads can damage this structure and slow or stop growth (Shapiro & Forriol, 2005). Various specialists have in the past pointed out elements such as growth spurts (which are associated with a higher risk of injury due to greater muscle-tendon stiffness and lower functional physio unit resistance), biological maturation, body measurements, training quality, inadequate pre-season training, low fitness levels, low cardiorespiratory endurance, low muscular strength level (Faigenbaum & Myer, 2010), and poor balance as intrinsic and extrinsic risk factors for injury in children and adolescents (Caine et al., 2008; Costa e Silva et al., 2022; Theisen et al., 2014). In addition, young individuals have a greater body surface area to total mass ratio, potentially leading to greater heat and fluid loss, which increases risk of dehydration and muscle injury.

Among these risk factors, those relating to gender are particularly relevant to the occurrence of injury. Generally speaking, men are more likely to experience traumatic injuries, while women are more likely to suffer injuries that will require restorative surgery (Ukogu et al., 2017). It has been highlighted through longitudinal studies that young female athletes present higher rates of overuse or repetitive mechanism injury during developmental stages (Schroeder et al., 2015). Female athletes generally suffer more hip, lower leg and shoulder injuries than male athletes, although this is highly dependent on the sporting discipline (Ristolainen et al., 2009). In addition, the influence of hormones, neuromuscular control, biomechanics, anatomy and social differences in sporting participation are some gender-related variables that result in a greater occurrence of sports injuries in female athletes (Lin et al., 2018).

In addition to the above, the role of early sports specialisation and its influence on the occurrence of sports injuries is another issue that has been widely debated in the scientific literature in recent years. Thus, young people who train in a single discipline more hours per week than their age (a ten-year-old training 11 hours per week, for example), or those who spend twice as many hours on a single discipline than in free play, are significantly more likely to be injured (Jayanthi et al., 2020). In this regard, it has been shown that specialising in a single sport increases the relative risk of patellofemoral syndrome 1.5 times, and diagnoses such as Sinding-Larsen-Johansson syndrome, patellar tendinopathy and Osgood-Schlatter disease have a four times higher relative risk in athletes who play a single sport compared to those who engage in multi-sport activity (Hall et al., 2015).

Looking more closely at team sports, a higher frequency of knee injuries (73.9%), patellofemoral dysfunction (31.3%), Osgood-Schlatter disease (10.4%), patellar tendinosis and Sinding-Larsen-Johansson syndrome (9%) was observed in young USA athletes who played basketball, volleyball and football over three seasons (Barber Foss et al., 2014). Similar results (35% knee and 21% lower back injuries) can be observed in Finnish female basketball and floorball players aged 12-20 years, also measured over three seasons. Furthermore, 44% of the recorded injuries were classified as severe (more than 28 days off training), and the occurrence of injuries was significantly higher in female players (incidence rate of 1.58 compared to male athletes of the same age and sport) (Leppänen et al., 2017). In addition to frequency, the context in which the injury occurred is relevant. Thus, it has been observed that injury rate in competition is higher than in training for all injuries (incidence rate ratio 1.19). Similarly, female athletes with a previous musculoskeletal injury presented a higher rate of injury resulting in loss of activity than injury that does not result in a loss of activity, according to a study conducted in adolescent volleyball in the USA (McGuine et al., 2020).

Understanding the epidemiology and risk factors of each sport is key to establishing efficient strategies to prevent/reduce the risk of sports injuries (Bahr & Krosshaug, 2005). Although there are not yet many randomised control trials comparing the efficacy of modality-specific injury prevention protocols (Mugele et al., 2018), from a conceptual point of view it seems a desirable strategy, as these protocols may not only decrease the risk of injury, but may also improve discipline performance (De Hoyo et al., 2015). In this country there are few epidemiological studies similar to those described above. In this sense, using a sample of 297 athletes from across 25 sporting disciplines, Pujals et al. (2016) reveal an overall exposure injury rate (training and competition) of 4.1 injuries/1,000 hours, with an increase in injury rate corresponding to increase in competitive level. There is also a higher percentage of lower limb injuries compared to other anatomical areas, with only 21.5% of participants not suffering any sports injury in the period in which the data was collected. There were no gender differences in the occurrence of injuries, but there were differences in the ages at which injuries were sustained. Finally, there is a higher frequency and severity of injuries in cooperative-opposition sports than in individual sports. Another more recent study, comprising 498 athletes aged 14-21 years, reveals an injury incidence of 44.4%, with an average rate of 2.64 injuries/1,000 hours. The ankle (36.12%), knee (19.32%) and shoulder (6.47%) regions account for the highest number of injuries. 59.8% of the injuries occurred in training and 40.72% during competition. Likewise, the risk factors that account for a greater risk of sustaining an injury were: more hours of practice per week, not warming up, using inadequate sports facilities, being between 14 and 17 years old, and not doing physical training (Prieto-González et al., 2021).

For all of the above reasons, it is of scientific and social interest to study the specific epidemiology and risk factors in young female athletes participating in team sports. Therefore, the objectives of the present study were: (i) to determine the specific epidemiological profile of young female team sports athletes in Catalonia (Spain), (ii) to analyse the risk factors for these injuries, (iii) to provide information for developing more effective and specific injury prevention protocols for each sport.

Methodology

Participants

A total of 1,439 female athletes (15 ± 2.4 years; range 11-21) belonging to 168 teams from 17 basketball (n = 8), football (n = 3) and volleyball (n = 6) clubs were the subject of the study. Based on data from the sports federations to which they are affiliated, a purposive sample determined the sports teams that were selected for participation in the study, using their sporting level as the inclusion criterion (Table 1). Those who responded positively to an invitation participated. Thus, data from 1,235 players (85.8%) were included in the final analysis. The 204 players (14.2%) who were excluded from the analysis did not meet the inclusion criteria (Table 1), were not available on the day of data collection at their club, or did not want to participate in the study.

Table 1
Inclusion criteria for study.

Criteria
Federation sportswoman.
Aged between 11 and 20.
Train and compete at the same club during the 2018-2019 and 2019-2020 season.
Not part of a high performance sports programme during the 2018-2019 season.
The club where the athlete's activity is based has a first team that competes in the highest regional category or above, or the athletes compete with their team in the highest federal regional category of their age or above during the 2019-2020 season.

Statistical power

The total number of federation licences for these three sports in Catalonia (Spain) for female athletes in the 2018-2019 season was 35,352, according to data provided by the corresponding federations. The sample collected in this study represents 3.5% of the total number of participants in these sports. This sample size allows population values to be inferred with 95% confidence and 4% precision, using an expected injury ratio of .56 (56%). This ratio was determined using previous studies with participants exhibiting similar characteristics (Eapen, 2014; Owoeye et al., 2020).

Materials and Resources

The data collection process for the present research was conducted through a retrospective observational study conducted between September 2019 and March 2020, which collected data from the 2018-2019 season provided by the athletes themselves and/or their legal guardians using a collection instrument based on the Orchard Sports Injury Classification System (OSICS) Version 10 (Rae & Orchard, 2007) and the International Olympic Committee recommendations for monitoring sports injuries in multi-sport events (Junge et al., 2008). Only injuries requiring medical attention were considered in this study (Timpka et al., 2014). The questionnaire, in its updated format, is available on demand on the SONAR project website: www.sonarinjuries.com. All data were collected by two of the researchers (BG-P and EL-F) after a period of training in use of the instrument, and after first conducting a pilot study.

Statistical Analysis

Firstly, a descriptive study was carried out. Results for continuous variables were expressed as a mean, standard deviation, minimum and maximum when following a normal distribution, while qualitative or categorical variables were shown as number and percentage. Variables were compared using the $\chi 2$ test for qualitative variables, and a binary logistic regression model was used with the input method applying the criterion injury (1), non-injury (0), to look for correlations with quantitative variables. All analyses were carried out with JASP for Mac (Version 0.16.1, University of Amsterdam, The Netherlands, 2021) and statistical significance was set to $p < .05$. Some of the graphs presented here were produced using JASP software, and others with Microsoft Excel for Mac (Version 16.58, Microsoft Corporation, USA, 2021).

Ethical considerations

Before collecting the information via questionnaire, clubs, managers, legal guardians and athletes were informed of all study procedures. Written informed consent was obtained from all participants or their legal guardians in the case of athletes under 16 years of age. All information was collected anonymously, guaranteeing the protection of personal data and following the European directives in force at the time of the study. The procedures carried out respected the Declaration of Helsinki guidelines and its subsequent updates at all times. The Research Ethics Committee of the University of Vic-Central University of Catalonia approved the content of the study and all its procedures (favourable report with internal code 71/2019).

Results

Study participants had an average number of years of sport practice of 6.5 ± 2.8 years (minimum 1 year, maximum 16 years), an average number of years of federation sport practice of 5.1 ± 2.7 years (minimum 0 years, maximum 14 years) and an average number of hours of training per week (excluding time spent in competition) of 5.5 ± 2.4 hours/week (minimum 1 hour per week, maximum 20 hours per week). 19% of federation sportswomen did not participate in school physical education, and only 11% of sportswomen practised more than one sport in the same period.

Forty-one percent of the female athletes surveyed had some kind of injury that required medical attention. Analysis by sport showed that basketball was the sport with the highest percentage of injured players (48%), followed by football (38%) and volleyball (30%). In terms of total injuries, the highest incidence rate was observed in basketball (0.046 injuries/1,000 h), followed by volleyball (0.034 injuries/1,000 h) and football (0.030 injuries/1,000 h) (Table 2). Incidence rates were calculated using only the training hours reported by the athletes.

In terms of injury type, the most common was found to be those injuries that are acute/traumatic in nature (67%), followed by repetitive and gradual onset mechanism injury (17.5%), and injuries caused by several possible mechanisms (14.5%), such as anterior cruciate ligament injuries (Table 3).

The Chi-squared test demonstrated that the observed incidence of each type of injury was not significantly different between the sports analysed ($\chi 2 = 7.879$; $p = .247$) (Figures 1, 2 and 3).

Table 2
Number of participants, injured players, percentage, total injuries, incidence and incidence rate by sport.

	Participants	Injured players (%)	Total injuries	Incidence	Incidence rate*
Basketball	521	254 (48%)	345	0.66	0.046
Football	194	73 (38%)	85	0.43	0.030
Volleyball	520	174 (33%)	257	0.49	0.034

** Injuries/1,000 h weekly training/athlete*

Table 3
Instances and percentage of injury mechanisms reported by female athletes.

Type of injury	Instances	Percentage
Acute/traumatic	283	67%
Repeated mechanism and sudden onset	4	1%
Repeated mechanism and gradual emergence	74	17.5%
Several possible mechanisms	61	14.5%
Total	422	100%

Figure 1
Percentage of each type of injury in female basketball players.

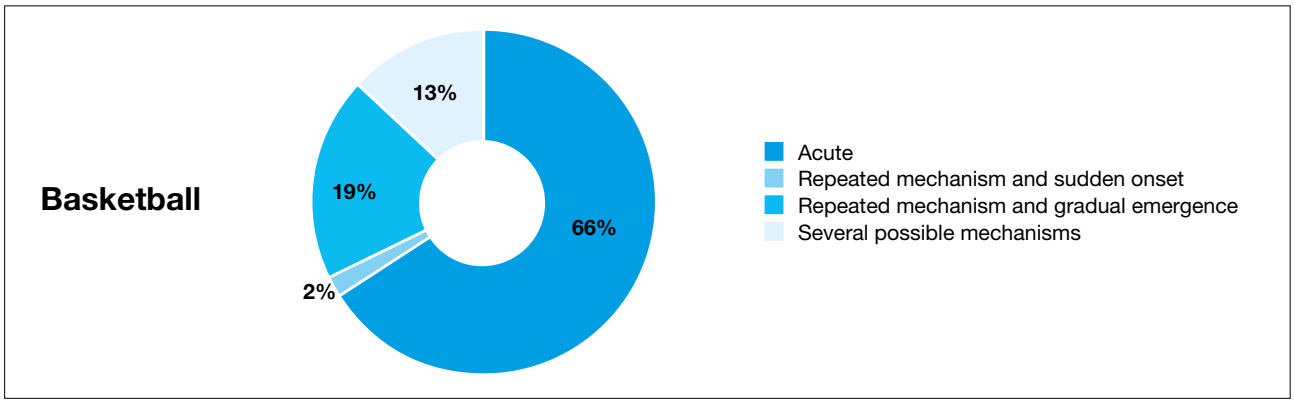


Figure 2
Percentage of each type of injury in female football players.

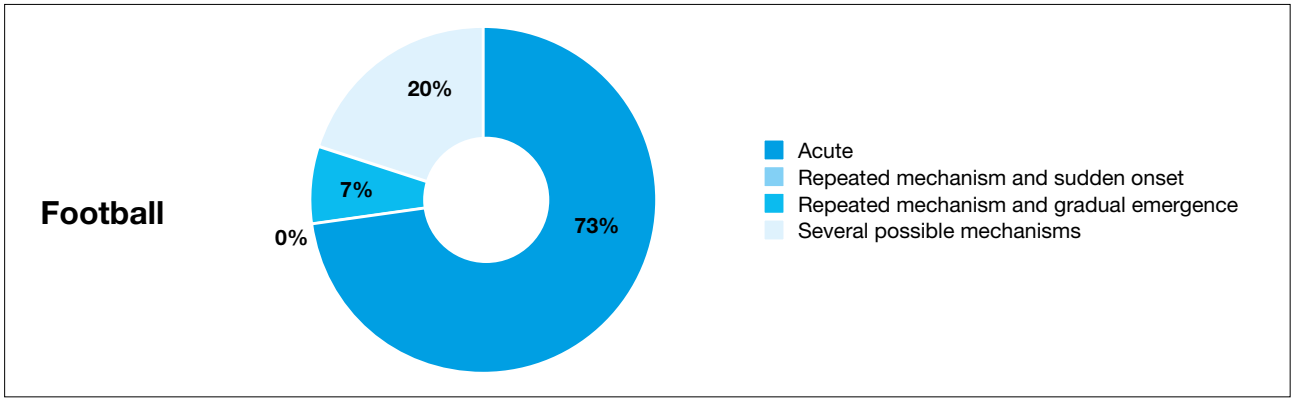


Figure 3
Percentage of each type of injury in female volleyball players.

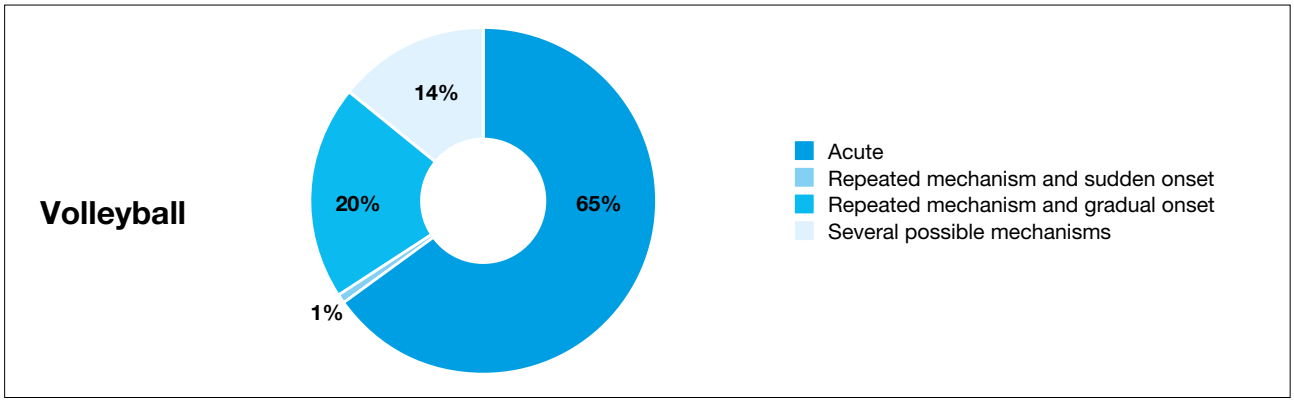
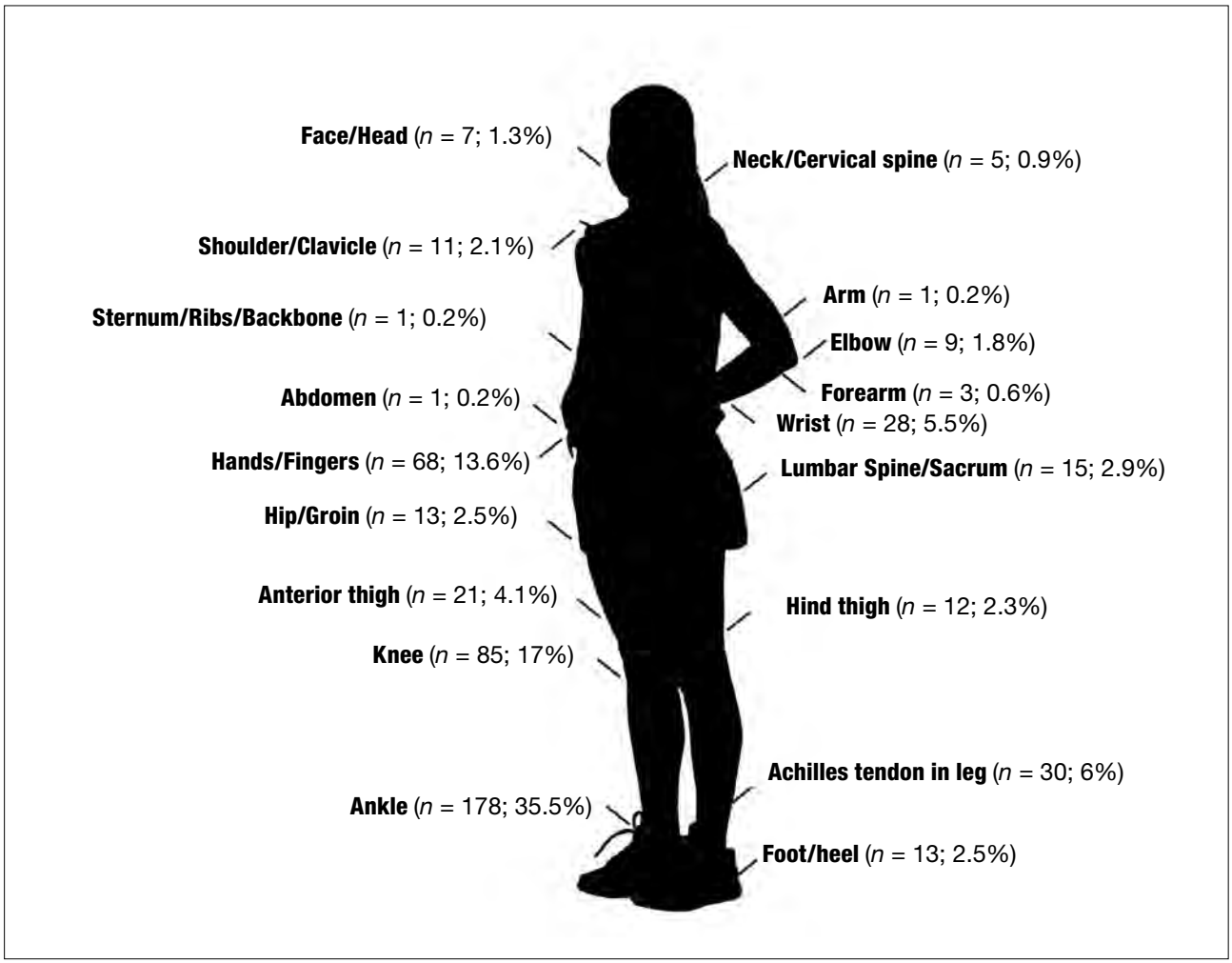


Figure 4
Total number of initial injuries sustained and percentage according to anatomical location.



In the study of the area of the body injured, no statistically significant differences were found between the type of injury and the dominant arm ($\chi 2 = 4.492$; $p = .610$) or leg ($\chi 2 = 2.478$; $p = .871$) of female athletes. The anatomical area most commonly injured in the initial injury sustained was the ankle (35%), followed by the knee (17%) and the hands or fingers (13.6%) (Figure 4), and the most common diagnosis was an ankle sprain (40%) (Figure 5).

Figure 5
Most common diagnoses of initial injuries suffered.

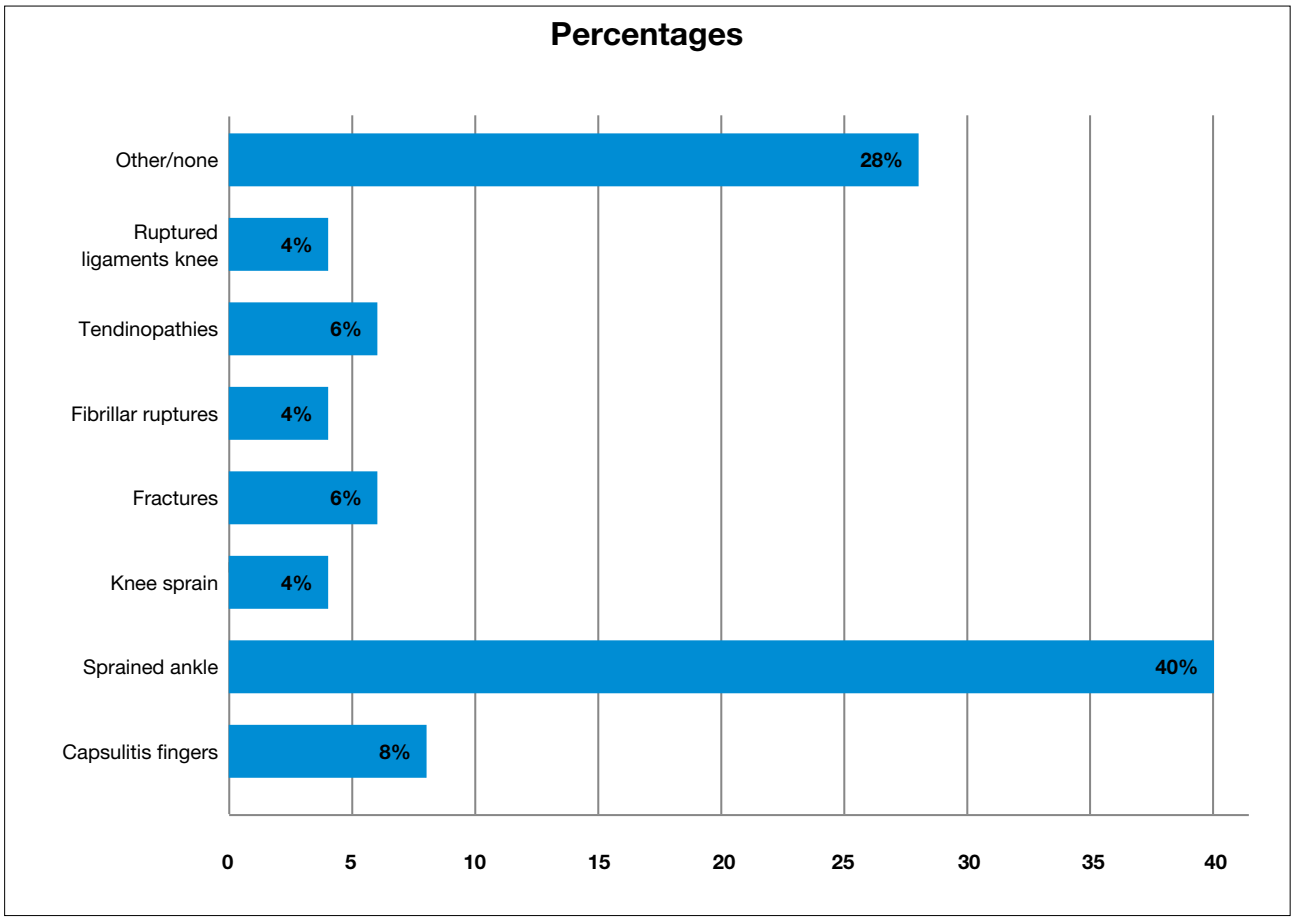


Table 4
Percentage of most frequent injury diagnoses by sport.

	Capsulitis fingers	Sprained ankle	Sprained knee	Fractures	Fibrillar ruptures	Tendinopathies	Ruptured knee ligaments	Other diagnoses
Basketball	7%	34%	2%	7%	4%	2%	3%	41%
Football	5%	34%	2%	8%	1%	1%	5%	44%
Volleyball	9%	29%	2%	5%	3%	10%	2%	41%

In terms of the second injury sustained in the same season (12% of the athletes), the most commonly injured anatomical area was again the ankle (36.5%), followed by the hands/fingers (15.5%) and the knee (14.1%). The most frequent diagnosis for second injuries was an ankle sprain (38%), fractures (12%) and capsulitis of the toes (11%). Only 2.2% of second injuries recorded ($n = 28$) were recurrent injuries that had already been sustained that season or even in previous seasons.

Regarding the diagnoses of all injuries, and comparing the different sporting disciplines (Table 4), it was observed that basketball and football had a higher percentage of ankle sprains (34% in both cases), as well as more fractures (7% and 8%, respectively). Football had a higher percentage of knee ligament tears (5%), while tendinopathies (10%) and toe capsulitis (9%) were more frequent in volleyball.

Figure 6 shows the percentage of injuries classified by severity. Of the total number of injuries, 31% were moderate (8-28 days) and, as mentioned above, only 2% of the total number of injuries were recurrent or relapsing injuries.

The majority of reported injuries occurred without contact (43%), in training (51%), and in club activity (85%), as depicted in figures 7, 8 and 9 (Figures 7, 8 and 9).

Figure 6
Severity of injuries.

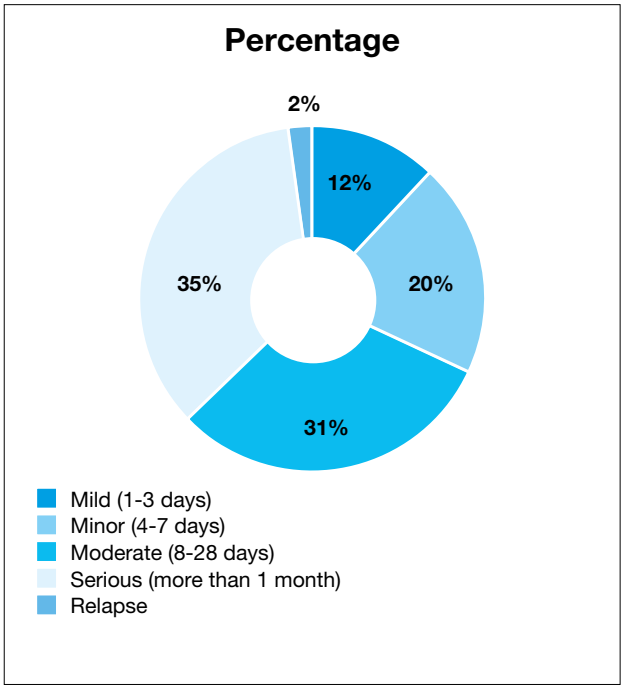


Figure 7
Percentage of mechanism of injury.

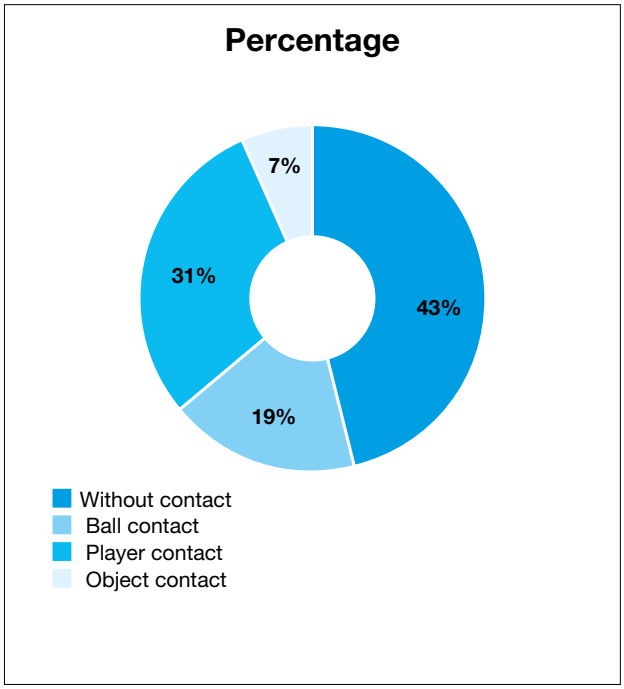


Figure 8
Number and percentage of injuries in the context in which the injury occurs in the 2018-2019 season.

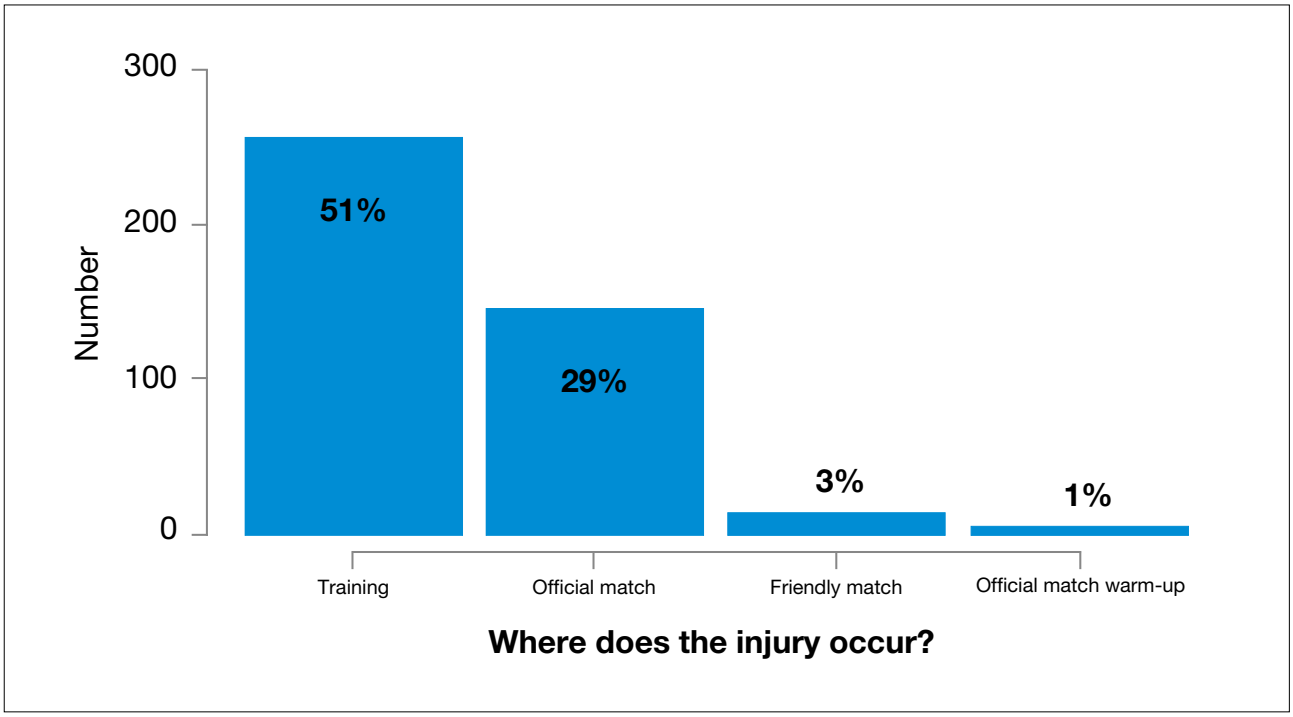


Figure 9
Number and percentage of injuries by activity involving injuries occurring in the 2018-2019 season.

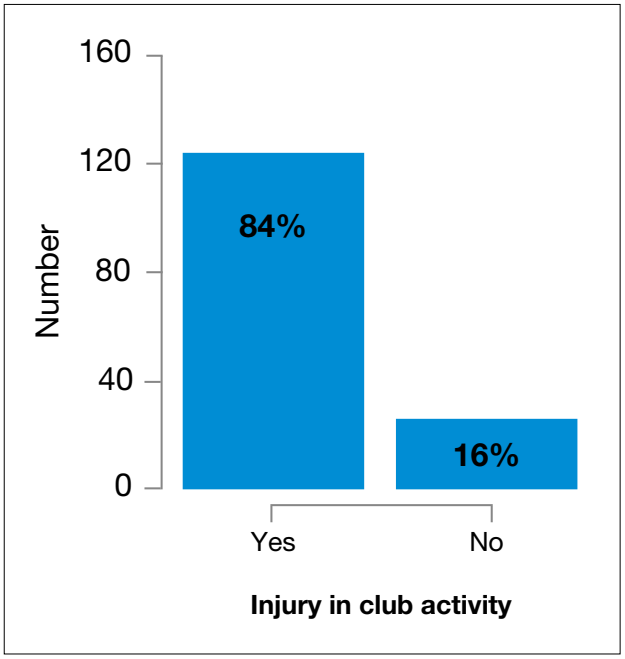
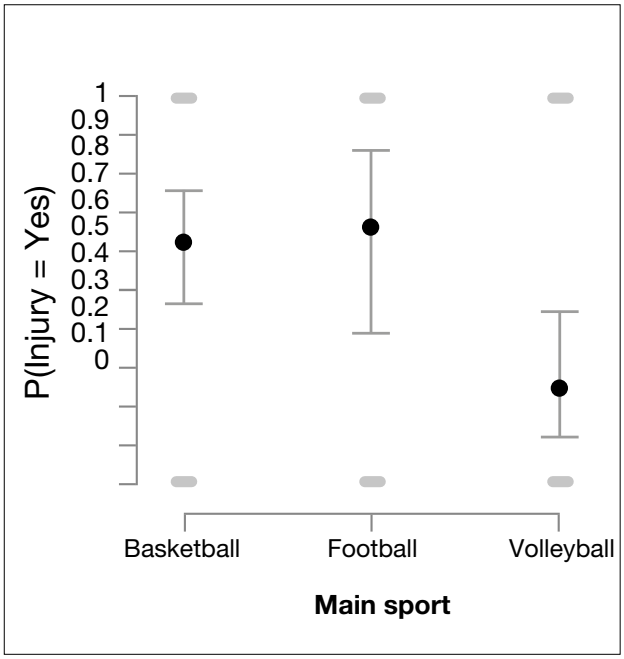


Figure 10
Probability of injury depending on the sport practised.



A binary logistic regression test was conducted to determine the effects of age, preferred sport, years of playing that sport, years of playing that sport as a federation sport, hours of practice per week, playing a second sport, hours spent playing a second sport, whether or not the sport was part of school physical education and hours of physical education, on the likelihood of participants sustaining a sports injury. The logistic regression model was statistically significant ($\chi 2$ (1,217) = 49.902; p <.001), revealing a sensitivity of 21% and a specificity of 89.5%.

Of all the factors analysed, only volleyball was associated with a decreased risk of injury compared to the other sports (volleyball = 20%; basketball = 62%; football = 65%) (Figure 10). When playing volleyball, a connection was also found between not playing a second sport and the probability of sustaining an injury, which in this case increased 2.5 times (Table 5).

Table 5
Binary logistic regression model variables showing statistically significant association with injury occurrence.

Variables	Estimate	Standard error	Odds Ratio (OR)	*z* statistic	Wald statistic	Degrees of freedom (df)	*p*-value
Constant	-0.664	0.592	0.515	-1.120	1.255	1	.263
Main sport (Volleyball)	-1.613	0.470	0.199	-3.434	11.793	1	**< .001**
Main sport (Volleyball) + Playing a second sport (No)	0.951	0.481	2.588	1.978	3.912	1	**.048**

Discussion

The main aim of this study was to determine the specific epidemiological profile of young female team sport players in Catalonia, analysing the risk factors for these injuries. The results show that the percentage of injured players is higher in basketball and football, with a higher injury incidence rate in basketball. These findings are consistent with those of García González et al. (2015), who found that the sports with the highest injury rates were football (27.6%), running (8.6%), indoor football (7.9%) and basketball (7.7%) in an epidemiological study on Spanish leisure sports.

Acute injury is the most frequent type of injury, with no significant differences between sports. Injuries to the lower limbs (ankles and knees), that are long term (more than 28 days without training), sustained without contact and in training were also the most common among young athletes. Finally, volleyball appears to be the sport with the lowest risk of injury, although the probability of injury increases if a second sport is not played.

Although in sports such as basketball and football the simultaneous occupation of space allows for some contact between players, most injuries occur without contact and acutely in all sports. The lower risk of injury associated with volleyball has traditionally been accounted for by the lack of contact between athletes, but, in view of these results, other factors could be conditioning these incidence rates (training time and competition effort, player substitutions, means of recovery, etc.). These data create a need to address the movement patterns that have caused the injury, analysing how biomechanical factors focused on the kinematics or kinetics of movement, neurophysiological aspects such as fatigue and decreased coordination capacity, or psycho-physiological variables related to the sporting context are contributing to injury.

In relation to body area, this study shows an increase in ankle injuries, compared to the predominance of knee injuries found in other studies (Leppänen et al., 2017). The explosive jumping action, which is very common in basketball and volleyball, as well as changes of direction or support on uneven surfaces in football, could explain this fact. In this sense, the high number of hand injuries reported for volleyball would be related to the hits and interceptions typical of actions of maximum intensity such as spiking and blocking, especially the latter.

Analysing the context of injury, it is surprising that the training setting is the most common in terms of number of injuries, as competitive demand, both physically and psychologically, often indicates higher injury rates in matches (McGuine et al., 2020). It is possible that the characteristics of the sample influenced these results. It could be hypothesised that the lack of homogeneity in aspects such as average number of years of sport practice, average number of years of federation sport practice, or average number of hours of training per week among the participants may have conditioned these results.

The importance of playing a second sport to reduce the risk of injury in young volleyball players could be related to the importance of different movements in order to avoid repetitive patterns that can lead to overuse injuries, or acute injuries at a predetermined sporting instant. This is consistent with multi-sport development approaches, which appreciate that a wide range of experiences based on the practice of numerous sporting activities improves participation in a sport, while increasing the likelihood of success and decreasing the risk of injury (Carder et al., 2020). And, although analysis of the reasons for the reduction of injury risk is beyond the scope of this review, it is worth highlighting that the practice of various sporting disciplines will allow young athletes to increase their motor literacy and, with it, the control of various movement challenges for motor control (DiStefano et al., 2018). This recommendation is applicable in all contexts, although in this study we only found an association between the likelihood of a lower risk of injury when playing another sport in volleyball players.

It should be noted that none of the 7 injuries recorded as being located on the face/head were diagnosed as concussion. This suggests that in Catalonia this condition may still be under-reported in medical settings, as in other scientific evidence Ia studies (Pfister et al., 2016) the incidence stands at 0.23 injuries per 1,000 h of exposure in football, 0.13 in basketball and 0.03 in volleyball. This fact requires special focus since, although it has been reported in other sports, such as judo, head injuries can be a clear risk factor for triggering acute subdural haemorrhage (Nagahiro & Mizobuchi, 2014). Also, the risk of repeated head trauma can trigger long-term fatal effects, such as encephalopathies (Cantu & Bernick, 2020). Therefore, the importance of paying attention to face/head injuries in order to prevent negative effects is justified.

In Spain there is currently no national programme for monitoring sporting injuries. In fact, care for this sport-related health problem is fragmented between the private sector (hospitals and sports mutual insurance companies) and the public health system. This situation,

as well as the current European regulations on personal data protection, makes it very difficult for initiatives to publicise in detail the extent of the problem of sporting injuries in children and adolescents. Therefore, scientific studies revealing epidemiological data and assessing risk factors are needed in order to implement age-, gender- and sport-specific prevention strategies, as well as policies or changes in sporting regulations aimed at improving the health of young athletes.

Conclusions

The results obtained in relation to the epidemiological profile of young sportsmen and women in Catalonia indicate that a higher percentage of injuries occur in basketball and football, with volleyball being the sport with the least injuries. Acute injuries are the most common injuries in all sports, as well as lower limb injuries occurring without contact and in training situations. Most of the injuries resulted in long-term absences. The practice of a second sport at this age is also recommended to reduce the risk of injury, especially in volleyball. These findings could be useful for helping coaches, physical trainers and sport managers, as well as the athletes themselves, establishing injury prevention programmes adapted to the sport practiced, preparing athletes in a way that is consistent with their development, and generating regulations and competition environments adapted to the characteristics of young female athletes. Furthermore, it opens up an interesting line of research into examining the mechanisms of injury, preventing an increase in incidence rate and encouraging participation in sports programmes in this age group and gender.

Limitations

The present study is observational and retrospective (evidence IIb), and does not allow cause-effect relationships to be established. The information was collected from the players themselves, which results in the loss of some diagnoses, as well as giving rise to inaccuracies in some answers due to memory bias, despite the fact that the collection procedure was conducted rigorously. The participating clubs were selected through purposive sampling, so there is a selection bias in this study despite its large sample size. The injury incidence rate for each of the disciplines was calculated using training hours only. As we are talking about very different disciplines, with very different match times in competition, and as we did not have any reliable instrument for recording the playing time of each player, it was impossible to incorporate this information in the final calculation. In some cases, two mechanisms of injury are possible and the analysis of injury mechanisms has considered four possibilities instead of the usual three. In addition, there was a great deal of heterogeneity in the professionals who diagnosed them. Finally, the sample was uneven for each sport, preventing balanced comparisons in all cases.

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Analysis of Corporal Expression in the Degree in Primary Education

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A young sprinter prepares herself with a track series to work on her explosiveness. @Jérome Aufort/Adobestock

Abstract

Corporal expression is a well established component of physical education in Spain. However, there is a historical deficiency in the training that prospective teachers receive in this regard. The standardisation of degrees introduced after the establishment of the European Higher Education Area has led to a credit reduction in the degree in Primary Education, specialising in Physical Education, compared to the previous degree in Teaching, specialising in Physical Education, which may have aggravated the situation described above.

The aim of this study was to analyse the current situation in which corporal expression has been included as a training component in undergraduate degree courses at Spanish universities.

For this purpose, the syllabuses of the 113 university centres that offered a degree in Primary Education in the 2021/22 academic year were analysed, specifically selecting those subjects that included corporal expression among their contents.

The results revealed a lack of training; in some cases training was non-existent, and in others it combined several topics within the same subject, with less than half of the centres offering at least one subject exclusively dedicated to this discipline. Consequently, there was no guarantee of quality training to meet the employment needs of graduates in their future as teachers, at least as far as corporal expression as a physical education content in primary education is concerned.

Keywords: curricula, higher education, Physical Education, primary school teacher, training.

Introduction

Corporal expression (CE) is a discipline that has been included in the subject of Physical Education (PE) as its own content area since the implementation of the Law on the General Organisation of the Education System (LOGSE, 1990), both in primary and secondary education. Under the previous General Education Law (LGE, 1970), it was included as part of dynamic expression, together with musical content (Coterón, 2007). However, there are numerous authors who have recorded a lack of training among teachers and professors in this discipline over the years (Archilla & Pérez Brunicardi, 2012; Cuéllar & Pestano, 2013; Hernández Álvarez, 1992; Monfort Pañego & Iglesias García, 2015; Montávez, 2011; Sánchez-Sánchez & López-Pérez, 2019; Villada, 2006; Villard, 2014). This situation, as pointed out by Cuéllar and Pestano (2013), was aggravated by the reform carried out following the implementation of the European Higher Education Area (EHEA), which replaced the diploma in Teaching, specialising in PE, with a specialisation in PE as part of the degree in Primary Education, which does not provide sufficient training in this area, thereby jeopardising the quality of teaching in the subject of PE at this stage of education.

To mitigate this impact on quality, Cuéllar and Pestano (2013) proposed actions aimed at making better use of the credits taught in degree programmes, redirecting the teaching guides towards more diversified content. They proposed broadening educational interventions in line with current trends by means of a more innovative subject design, greater coordination between subjects to promote the acquisition of transversal competences and avoid overlapping between subjects, adjusting training to the needs of future employment, offering training scenarios that complement what is learnt in the degrees, increasing resources and increasing coordination between specialists and PE teachers.

In this regard, Canales-Lacruz and Sanagustin (2019) considered that school PE has followed a path towards "sportsmanship" at the primary education stage in Spain, ignoring other content areas such as CE, which has repercussions on the time allocated by teachers to this area. This devaluation of CE in teaching practices was based on the prioritisation of other content and the lack of confidence to implement it. Montávez (2011) detected something similar when defining the profile of PE teachers in primary education and suggested, based on the comments of the teachers themselves, that CE is a new subject with little tradition in PE, in addition to having a low credit load in initial training plans. An inversely proportional relationship was observed between time on the job and time dedicated to CE, with teachers stating that, in some cases, this content was non-existent in their classes. They claimed that they lacked experience in CE, not only in their university studies, but also in their previous training (primary and secondary), which resulted in its negligible presence in their teaching practice.

Initial training

The lack of teacher training can be observed in the findings of Sánchez-Sánchez and López-Pérez (2019) in their analysis of the training provided in CE in Spanish public universities offering a degree in Primary Education. They conducted a descriptive analysis of 24 teaching guides, revealing a predisposition towards optional CE in the training of future primary school teachers. They highlighted the scarce presence of specific CE techniques, although they were combined with other disciplines such as dance or theatre, and even with "expressive techniques" which are not included in the teaching guides. A previous study carried out by these authors pointed out the importance of including disciplines that encourage the development of creativity and free expression through movement in the educational environment, thus alluding to CE (Sánchez-Sánchez & López-Pérez, 2017).

Lafuente and Hortigüela (2021) observed a change of perspective on CE in students taking the Primary Education degree specialising in PE, before and after taking the subject. The qualitative study carried out presented the students' perception of CE prior to their taking the subject, and found that they considered the content to be difficult or far removed from the usual concept of PE and highlighted the lack of training of PE teachers in this discipline. During the course, they began to appreciate aspects of CE, such as the need for progression in terms of disinhibition and the ease of teaching CE without overly specific material.

After having studied the subject and the experience it offers to students, they perceived the content as easy to teach and showed willingness to carry it out in their future teaching. They expressed a need to increase the credit load of CE in the training of future PE teachers. In addition, they highlighted the benefits in terms of social relationships, emotional work, self-awareness and the development of creativity (Lafuente & Hortigüela, 2021).

Regulations and legislation

The syllabus, corresponding to Royal Decree 1440/1991 of 30 August, which established the official university degree of Teaching in its various areas of specialisation and the general guidelines for the syllabuses required to obtain it, was the key reference for the establishment of the different specialities within the professional profile of teacher. It established the speciality of Early Childhood Education, Primary Education, Foreign Language, PE, Music Education, Special Education and Hearing and Language, all of them with the classification of a university degree. In the specific case of specialisation in PE, in the field of CE didactics, motor learning and development and perceptual-motor skills were proposed as core related subjects, in the same way that psychomotor skills were proposed as a related subject for the specialisation in Infant and Primary Education. There is no explicit mention in the regulations of CE as PE content. Cuéllar and Pestano (2013) considered that its absence was not in keeping with training needs or the curriculum for this stage of education. Sánchez-Sánchez (2012) argued that the main reason for the absence of CE in primary classrooms was the lack of training of PE teachers, who at that time were still trained according to speciality. However, in the analysis carried out by Villada (2006) on Spanish universities teaching the subject of PE, it can be observed that in 36 of the 43 syllabuses analysed, at least one subject related to this discipline was offered, although in five of them it was optional.

As part of the process of homogenisation of university degrees in Europe, in accordance with the EHEA, the National Agency for Quality Assessment and Accreditation (ANECA) produced a series of white papers with guidelines on what the curricula of the new bachelor's degrees should consist of. In the case of teaching qualifications (ANECA, 2005), the competences related to the CE content in the Primary Education teaching qualification were indicated. Specific teaching competences were identified for disciplinary knowledge (to know), such as "Knowing and mastering the basics of corporal expression and non-verbal communication" (p. 110). As well as for professional competences (know-how), "Using the fundamentals of corporal expression, sports training, development of physical abilities and different types of motor games at school" (p. 112). CE was also among the competences to be developed in the specialisation in Foreign Language, as a professional competence (know-how) and as a teaching competence specific to the Foreign Language profile. However, the current Order ECI/385/2007, which establishes the requirements for the qualification, sets out generic competences for the PE module, in which reference is made to the need to develop the contents of the school curriculum for the subject.

The aim is therefore to analyse the way in which CE has maintained its presence in the curricula, leading to the current specialisation in PE in the degree of Primary Education in Spanish universities.

Methodology

Sample

All degrees in Primary Education (or Teaching in Primary Education) taught in Spain have been analysed, including those taught at public and private centres, taking each centre teaching this degree as a sample unit. Those centres that belonged to the same university but had a specific curriculum (their own or adapted) and/or differentiated teaching guides, whether they were different faculties, sites (geographical adaptation) or affiliated centres, including if they had a differentiated distance learning modality, were established as different centres. Expired programmes or those that had not yet started were discarded. The sample used covered the entire sample population of Spain.

Procedure

The Registry of Universities, Centres and Degrees (RUCT) was used in order to identify all the universities that, in the 2021/22 academic year, offered degree courses in Primary Education, by collating the data on the website of the Ministry of Science, Innovation and Universities (Source: Ministry of Science, Innovation and Universities, date accessed 21/02/2022), selecting those universities that had a current curriculum at the date of access.

Within each university, the centres offering the degree, different faculties, branches of the same faculty or affiliated centres were identified. In the case of two curricula coexisting in the same centre, it was decided that the one with the greatest number of current curricula should be selected.

The data were obtained from the official websites of each faculty, school or study centre, compiling the curricula, from which the learning guides of the subjects that could include CE content and whether or not they offered the specialisation in PE, were obtained.

For each of the sample units (centres), aspects related to the Autonomous Community taught in, the ownership of the centre, the offer of a specialisation in PE, and the subject most closely linked to the contents of CE were taken into consideration. Within each subject selected, the name, compulsory or optional nature, the year of teaching and the responsible teaching staff were identified.

In order to select the subjects, those belonging to the subject area of PE were initially analysed; in the event of not finding any subject whose content included CE content, all subjects in the syllabus that referred to "PE", "movement", "corporal", "expression" or similar terms were analysed.

The nomenclature in the selected subjects was very heterogeneous, which, on occasions, could be due to a preference for synonymous terms (equivalent nomenclature), with terms analogous to CE, names analogous to the content blocks that the educational regulations set out in primary education, such as "The body: expression and communication" (LOGSE) or "Artistic-expressive physical activities" (Organic Law of Education). In other cases, however, the title bought together the different content and subjects covered by the subject in question.

Four different groupings were established according to whether the title referred exclusively to CE, physical-expressive activities (PEA) or equivalent (and could include terms such as "movement" or "communication"); whether it was a specific CE subject that simultaneously dealt with content linked to motor development (basic physical education or psychomotor skills); whether it was a specific subject dealing with another of the manifestations of motor skills, such as playing or the performing arts (PA), not as a working technique within CE, but as an autonomous subject; and finally, subjects of a more generic nature, which combine three or more subjects and in which CE is approached as a specific topic or content in a more superficial way. In case of doubt about the nomenclature of a subject, the teaching guide was analysed in depth in order to infer the approach and purpose of the subject.

The categories established to group the subjects were as follows:

A. Exclusively CE (PEA or equivalent).
B. CE-specific, linked to motor development.
C. CE-specifc, linked to manifestations of motor skills.
D. Generic subjects in the field of PE (not exclusive or specific to CE).

Statistical Analysis

In order to categorise the subjects according to their nomenclature, a qualitative analysis was carried out, both of the degree itself and of the contents of each learning guide, using QSR Nvivo software (v.10).

All data were collected and imported into SPSS software (V. 26) for subsequent quantitative and descriptive analysis of the values obtained, focusing mainly on presence and frequency values.

Analysis was carried out by groups of subjects related by geographical distribution, ownership of the centre, the presence of a specialisation in PE, the nature of the subject and the year in which it is taught.

Results

Presence and geographical distribution

During the 2021/22 academic year, the Bachelor's Degree in Primary Education was taught in 67 Spanish universities, offered as a degree in 113 centres and present in all the Autonomous Communities (AC) and autonomous cities, according to the distribution presented in Table 1.

Madrid is the region with the highest number of centres offering the degree, as well as the one with the highest number of private centres. Andalusia was second in terms of number of centres, while Castile and León was third in total, but first in terms of public centres. 54% of the centres offering the degree are publicly owned, compared to 46% that are privately owned.

Specialisation in Physical Education

The majority of centres offered specialisation in PE (Table 1), with a similar percentage among publicly and privately owned centres. The offer of this specialisation was present in all the ACs, either in public (except Cantabria) or private centres (except Castilla-La Mancha, Galicia and the autonomous cities of Ceuta and Melilla). The Autonomous Communities of Andalusia and Madrid have the highest number of centres offering a degree specialising in PE, Madrid was once again the region with the largest number of private degree programmes, while Andalusia had the largest number of public programmes.

Table 1
Degree in Primary Education, distribution by Autonomous Community and ownership.

Autonomous Community	No. of Universities	Public centres	Private centres	Total centres	Public centres specialised in PE	Private centres specialised in PE	Total PE specialisation
Andalusia	9	8	8	16	8	7	15
Aragon	2	3	1	4	3	1	4
Asturias	1	1	1	2	1	1	2
Balearic Islands	2[1]	3	1	4	3	1	4
Canary Islands	3	3	1	4	2	1	3
Cantabria	2	1	1	2	0	1	1
Castilla-La Mancha	1	4	0	4	4	0	4
Castile and León	7	9	5	14	6	5	11
Catalonia	10	6	5	11	6	4	10
Ceuta	11	1	0	1	1	0	1
Valencian Community	6	3	6	9	3	4	7
Extremadura	1	2	1	3	2	1	3
Galicia	3	5	1	6	2	0	2
La Rioja	2	1	1	2	1	1	2
Madrid	12[1]	4	14	18	4	11	15
Melilla	1[1]	1	0	1	1	0	1
Murcia	2	2	2	4	2	2	4
Navarra	2	1	1	2	1	1	2
Basque Country	3	3	3	6	1	2	3
Total	70[1]	61	52	113	51[2] (83.6%)	43[2] (82.7%)	94[2] (83.2%)

[1] *The University of Granada offers the degree in the autonomous cities of Ceuta and Melilla. The University Pontificia de Comillas offers degrees in Madrid and the Balearic Islands.*
[2] *The percentage of centres offering a specialisation in Physical Education in relation to the total number of centres (public, private and total) is shown.*
PE: Physical Education.

Presence of CE content in the degree and nomenclature

After analysing the different curricula and reviewing the subjects offered, in 105 of the centres analysed it was possible to find at least one subject in which the teaching guide identified CE as content to be developed. While in eight of the centres no subject including this topic could be found (four public and four private), in three of these centres specialisation in PE was offered (one public and three private).

In Table 2, it can be seen that 76 centres (72.4%) had a subject dedicated to CE ("Corporal Expression"), while it was exclusive for 40 subjects (52.6%). In the remaining 36 subjects (47.4%), their content was linked to another discipline ("Image, perception, expression and body communication"). In the remaining centres (29), CE was approached as a content block of a more generic subject covering three or more disciplines related to PE ("Physical Education and its didactics").

Looking at the characteristics of each subject, it was found that most of the subjects were optional (80%), although generally compulsory to qualify for specialisation, with a predominance of subjects exclusive to CE (46.4%), while among the compulsory subjects (20%), generic subjects clearly predominated (85.7%), with the exception of the universities of Lleida and Vic (specific subjects) and the University of Navarra (exclusive).

With regard to the ownership of the centres, the predominance of exclusive subjects (42.1%) in public centres stands out, with a more homogeneous distribution in private centres.

Although the majority of centres offered specialisation in PE, less than half of them offered a subject exclusively focusing on CE (42.9%), with almost a quarter of them opting to include it as part of a generic subject (23.1%). In two specific centres, CE content was presented in a specific subject, but linked to another subject (Foreign Language at the University of the Mid-Atlantic and Music at the University of Alicante).

In the centres that did not offer a specialisation in PE, the majority (57.1%) included CE content within a generic subject, in particular, the School of Education and Tourism of Avila (USAL) was the only centre that does not offer specialisation in PE that offers a subject exclusively in CE, while the International University of Valencia offered a specific subject together with music content within the degree in Music.

In terms of year, the majority of subjects were taught in the 4th year (55.2%). In the first two years, the majority of subjects offered were of a generic nature (78.6%), while in the 3rd year there was a clear predominance of exclusive subjects (48.5%). In the 4th year, exclusive subjects continued to predominate, although in a less noticeable way (37.9%).

Table 2
Characteristics of subjects by nomenclature.

Nomenclature		A CE Exclusive	B Linked to motor development	C Linked to other manifestations	D Generic about Physical Education	Summation
Nature	Compulsory	1	0	2	18	21
	Optional	39	19	15	11	84
Ownership	Public	24	10	10	13	57
	Private	16	9	7	16	48
Specialisation in PE	Yes	39	19	12	21	91
	No	1	0	5	8	14
Year in which it is taught	1st	0	0	0	3	3
	2nd	2	0	1	8	11
	3rd	16	8	4	5	33
	4th	22	11	12	13	58
TOTAL subjects (Percentage)		40 (38.1%)	19 (18.1%)	17 (16.2%)	29 (27.6%)	105 (100%)

Discussion

The data on the number of centres offering the degree (113), as well as specialisation in PE (94) are in line with the upward trend reflected in Villada's contribution (2006), which identified 56 centres offering a teaching degree, 43 of them offering specific PE teaching (already present in all the Autonomous Regions except Navarre). Cuéllar and Pestano (2013) reported the specific presence of 47 different curricula for the teaching degree, specialising in PE (four more than Villada, 2006), and Sánchez-Sánchez and López-Pérez (2019), who analysed public universities where the degree in Primary Education is taught, found 79 records. A clear increase in the number of centres offering the degree can therefore be seen.

The lack of subjects developing CE content in three of the centres that did teach the subject in PE may appear to indicate a decrease in comparison with the data of Villada (2006), who recorded seven centres where Corporal Expression (the subject's name) was not taught, or those of Cuéllar & Pestano (2013), with another seven records of centres where no subject related to body language, CE, traditional dances, dance, drama, theatre, mime, drama or rhythm (a broader nomenclature) was taught. Both investigations were on teaching degrees, specialising in PE. However, in the specialisation in PE within the degree in Primary Education, there are generic subjects, which aim to provide a basic introduction to any of the disciplines that may be covered by the degree, as Villada (2006) has already recorded in relation to the didactics of PE, which is present in all teaching specialisations. In these cases, it has been observed that the content (and, by extension, the amount of time devoted to it) on CE in this type of subject, when there is any, is very superficial (one topic or section), which is incompatible with a basic minimum of specific training. The presence of this content has also been noted in two subjects linked to other specialisations (Foreign Language or Music), different from the subject of PE, in line with the development of motor competence postulated by Cañabate et al. (2018). Bearing these considerations in mind, it must be affirmed that, with respect to the previous specialisation in PE, in the current specialisation in PE there is a notable increase in the number of centres (26) that do not offer exclusive or specific subjects in CE linked to this specialisation, perhaps opting to prioritise sportsmanship in the training offered (Canales-Lacruz & Sanagustin, 2019), such that the specific training in this discipline of students graduating from these centres would be deficient.

With regard to the presence in a single subject of CE contents together with those of some other discipline (specific subjects), Villada (2006) has already pointed out a possible justification for being able to combine subjects, stating that "it seems to be understood that expressive contents are integrated within motor perceptual skills, thus justifying that body perception as well as spatial and temporal perception are key elements in expressive development" (p. 386), in clear reference to subjects such as Psychomotricity or Motor Development. Perhaps for the same reason, Royal Decree 1440/1991, which regulates the teaching degree and its specialisations, included subjects such as psychomotor development (specialisation in Early Childhood Education) and motor learning and development (specialisation in PE) among the subjects to be developed in the area of knowledge Didactics of corporal expression. For their part, it has already been observed that Cuéllar and Pestano (2013) included among the subjects related to CE those artistic manifestations linked to dance, drama or rhythm, an argument supported by Castillo-Viera et al. (2021).

For its part, the white book for the degree in Physical Activity and Sport Sciences (ANECA, 2006) considered CE to be one of the manifestations of motor skills, among which it also included games. Therefore, the agglutination of two subjects that could be considered related in the same subject is justified, in accordance with Cuéllar and Pestano's own recommendations, despite the fact that this results in a lower capacity to develop the contents of CE.

The majority of subjects considered exclusive or specific to CE are optional (but not the generic ones), an aspect already described by Cuéllar and Pestano, stating that "in many curricula, there are no compulsory subjects on Corporal Expression" (2013, p. 125), ratified by Sánchez-Sánchez and López-Pérez (2019), although Villada (2006) reduced this requirement to five of the subjects offered. However, these subjects must be taken in order to specialise in PE, such that, even though they are not formally required, they could be considered compulsory for this specialisation.

In closing this discussion, it is worth returning to Cuéllar and Pestano's assertion in their prediction that:

> The offer of the subject Corporal Expression for teachers specialising in Physical Education was not sufficient for its role in the educational curriculum and the training needs of the graduates. However, the implementation of the current reform and the removal of specialisations poses an even more uncertain future, raising the question of whether these changes will lead to a further deterioration of the profession and, consequently, of the quality of Physical Education in schools. (2013, p. 126)

Conclusions

The main conclusions of this work are considered to be the following:

- There is a clear regression in the training of Primary Education teachers with a specialisation in PE in relation to CE content.
- The presence of CE in the curricula of the subject area of PE is in many cases associated with some other subject or even as a topic within generic subjects that are dealt with in an introductory way together with other PE content.
- Adequate CE training is not guaranteed, in accordance with the demand established in the educational legislation in relation to the contents of PE, due to the absence or superficial treatment of this discipline.

In addition, the following secondary conclusions have been drawn:

- There has been an increase in the number of mainly privately owned institutions training teachers in PE at primary level.
- The nomenclature of the subjects that deal with CE content has been replaced by synonyms or terms associated with their use in conjunction with other subjects, which makes it difficult to assess the real time spent on the teaching of this content.

As a foresight, it is considered necessary to ensure adequate and specific training in CE for future PE teachers. This discipline could be considered a core subject in the Primary Education degree, as its influence is not only limited to the subject of PE, but also has a place in other subjects such as Foreign Language or Music. Likewise, and in terms of employment, CE is valuable in the fulfilment of other professional opportunities associated with the degree.

At the same time, it is considered appropriate to propose a specific qualification in PE in primary education which, taking the former specialisation of Teacher Training as a reference, would guarantee students specific, quality training for the specific professional practice of the subject of PE in general and of CE in particular.

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Figure 1
Institutional logos of the funding entities (UPM, Mº Universities and UE-Next Generation)

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Situational and Game Variables in Rink Hockey: A Systematic Review

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A young sprinter prepares herself with a track series to work on her explosiveness. @Jérome Aufort/Adobestock

Abstract

The main objective of this paper was to review the available literature on situational and game variables in the sport of rink hockey. The most common research topics were identified, their methodologies described and the evolving trends in this area of research systematised. A systematic review was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic reviews and Meta-analyses) guidelines. The following keywords were used: rink hockey and ice hockey, each combined with the terms "situational variables", "match variables" and "game variables". The databases used for the review were Pubmed, Web of Science and Google Scholar. The inclusion criteria were: (1) relevant data on match variables in the sport of rink hockey; (2) data referring to professional competitions and/or senior/superior categories and (3) written in English or Spanish. After the review process, 20 studies met the inclusion criteria. Situational variables such as the location of the match, the scoreboard status, spectators' presence or the level of the teams, as well as the influence of set pieces and the role of the goalkeeper, have been included as research objects, as they seem to be effective variables of performance in rink hockey.

In view of the limitations of the studies reviewed, future research should provide predictive models and integrate situational and interactive contexts into the analysis of rink hockey performance. It should also provide more scientific knowledge on the sport, using new technologies and new approaches to study tactical elements in a sequential way.

Keywords: game analysis, game variables, performance analysis, rink hockey.

Introduction

The increasing professionalisation of high-level sport has led to an increase in the number of studies on the parameters that influence the final match outcome in a team sport context in recent years (Lago-Peñas et al., 2016b). Consequently, there is now a growing trend towards studying all possible game variables.

Performance analysis, defined as the description and understanding of the properties of the different variables that condition performance in competitive sports, is of great interest. Game analysis is widely recognised by coaches, sport analysts and athletes themselves as a relevant procedure for analysing and improving performance (Liu et al., 2016). Accordingly, a performance indicator is defined as a selection or combination of different sport variables that aims to define some or all of the aspects related to their effectiveness or influence (Hughes & Bartlett, 2002). In this sense, the need to identify these indicators for each sport, as well as to understand and establish their impact on the result, seems evident.

A number of studies have examined the importance of performance indicators in team sports. In recent years, they have been studied in sports such as basketball, handball and football (García Rubio et al., 2015; Lago-Peñas et al., 2016a). Many of these contributions have identified influential variables such as ball possession (Gómez et al., 2015), sending off players (Lago-Peñas et al., 2016b), match location (Pollard et al., 2017), substitutions (Gómez et al., 2016), and time of scoring (Baert & Amez, 2018).

Rink hockey is a very popular team sport in Spain. The men's national team is the current European champion and is also the most successful national team in the world, with a total of 17 world championships. Paradoxically, however, research aimed at analysing characteristic aspects of the sport is scarce. Of the few recently published studies on game variables, those referring to context stand out, such as the analysis of home advantage (HA) (Arboix-Alió et al., 2020; Arboix-Alió & Aguilera-Castells, 2019; Gómez et al., 2011), which estimates a 60% influence in men's rink hockey, similar to that of other team sports. Other studies have analysed factors such as scoring the first goal of the match (Arboix-Alió & Aguilera-Castells, 2018), the goalkeeper's performance (Sousa et al., 2020), the influence of set piece actions (Trabal et al., 2019b; Trabal et al., 2020a) and competitive balance between teams in the same leagues (Arboix-Alió et al., 2019a; Arboix-Alió et al., 2021b).

However, as far as the authors are aware, there is no systematic review on the influence of situational and game variables on the final result in rink hockey. The findings of this review could provide an insight into the most relevant information related to sport and performance variables in rink hockey, providing a useful tool for a better understanding of the game as well as highlighting potentially significant data for coaches and staff. For these reasons, the purpose of the present study is to systematically review and organise the existing literature on situational and game variables in rink hockey in an attempt to identify the most common research topics, classify their methodologies and systematise the evolutionary trends in the sport.

Methodology

Documentary sources and selection criteria

A systematic review of the available literature on game variables in rink hockey was carried out following the guidelines of the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-analyses) guide according to Moher et al. (2009). In addition, the quality of all eligible studies was assessed using a table following the criteria of Law et al. (1998). This table is composed of 16 indices measuring the methodological quality of the studies (Table 1). The scoring for each index follows a binary scale (0/1) where 0 corresponds to a negative response and 1 to an affirmative response. Out of the total 16 indices, two (6 and 13) were not applicable to all studies, so the option NA (not applicable) was included. The sum of the total number of positive indices was used to indicate the quality of the study. According to their score, articles were classified as: a) low methodological quality (< 50%), b) good methodological quality (51-75%) and c) excellent methodological quality (> 75%) (Sarmento et al., 2018).

A search of the current literature was conducted using the electronic databases PubMed (1969-28 December 2021), Web of Science (1969-28 December 2021) and Google Scholar (1969-28 December 2021). The search strategy for each database is listed in Table 2.

Table 1
Analysis of study quality (Law et al., 1998).

Reference	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
(Arboix-Alió & Aguilera-Castells, 2018)	+	+	+	+	-	NA	+	+	+	+	+	+	NA	+	+	+
(Arboix-Alió et al., 2020)	+	+	+	+	-	NA	+	+	+	+	+	+	NA	+	+	+
(Arboix-Alió & Aguilera-Castells, 2019)	+	+	+	+	-	NA	+	+	+	+	+	+	NA	+	+	+
(Arboix-Alió et al., 2022)	+	+	+	+	-	+	+	+	+	+	+	+	NA	+	+	+
(Arboix-Alió et al., 2021c)	+	+	+	+	+	+	+	+	+	+	+	+	NA	+	+	+
(Arboix-Alió et al., 2021f)	+	+	+	+	+	+	+	+	+	+	+	+	NA	+	+	+
(Arboix-Alió et al., 2021e)	+	+	+	+	+	+	+	+	+	+	+	+	NA	+	+	+
(Arboix-Alió et al., 2021a)	+	+	+	+	+	+	+	+	+	+	+	+	NA	+	+	+
(Arboix-Alió et al., 2021d)	+	+	+	+	+	+	+	+	+	+	+	+	NA	+	+	+
(Camões et al., 2022)	+	+	+	+	-	NA	+	+	+	+	+	+	NA	+	+	+
(Gómez et al., 2011)	+	+	+	+	-	NA	+	+	+	+	+	+	NA	+	+	+
(Kingman & Dyson, 1997)	+	+	+	+	-	NA	+	+	+	-	+	+	NA	+	-	-
(Kingman & Dyson, 2001)	+	-	+	+	-	NA	+	+	+	+	+	+	NA	+	+	-
(Sousa et al., 2020)	+	+	+	+	-	NA	+	+	+	+	+	+	NA	+	+	-
(Sousa et al., 2021)	+	+	+	+	+	-	+	+	+	+	+	+	NA	+	+	+
(Trabal et al., 2020a)	+	+	+	+	-	NA	+	+	+	+	+	+	NA	+	+	+
(Trabal et al., 2020b)	+	+	+	+	-	NA	+	+	+	+	+	+	NA	+	-	-
(Trabal et al., 2019a)	+	+	+	+	-	NA	+	+	+	+	+	+	NA	+	+	+
(Trabal et al., 2019b)	+	+	+	+	-	NA	+	+	+	+	+	+	NA	+	-	-
(Trabal et al., in press)	+	+	+	+	-	NA	+	+	+	+	+	+	NA	+	+	+

Tabla 2
Search strategy, filters and databases used.

Database	Records identified	Search strategy
MEDLINE (Pubmed)	*n* = 25	1 "rink hockey" OR "roller hockey" 2 "game variables" OR "match variables" 3 1 AND 2
Web of Science	*n* = 26	1 "rink hockey" OR "roller hockey" 2 "game variables" OR "match variables" 3 1 AND 2
Google Scholar	*n* = 29	1 "rink hockey" OR "roller hockey" 2 "game variables" OR "match variables" 3 1 AND 2
Total	*n* = 80	

Inclusion and exclusion criteria

Inclusion criteria for these articles were: (1) relevant data on match variables in the sport of rink hockey; (2) data referring to professional competitions and/or senior/superior categories and (3) written in English or Spanish. Studies were excluded if: (1) they included basic or training (non-senior) categories; (2) they did not include any relevant data; and (3) they were conference abstracts. In addition, articles with insufficient discussion, poor data presentation and unclear or vague descriptions of the applied protocols were excluded (see flow chart of the search and study selection in Figure 1).

The lead author (J. A.-A.) carried out the data analysis and search process in the main databases. All electronically identified records were evaluated by title and abstract. Duplicate articles, which appeared in more than one database, were eliminated and considered only once. The full texts of all articles deemed potentially eligible were obtained. The first and last authors (J.A.-A., G.T.) then independently examined the pre-selected records and chose the final studies for inclusion in the review. In case of disparity, the opinion of the second author (B.B.) was considered.

Results

Search results

Two independent reviewers identified a total of 81 articles in the initial search. 36 articles were duplicates, leaving 45 unique items. Based on the title/abstract, after reviewing the full text, 25 articles were excluded because they did not meet the inclusion criteria. On the basis of this selection, a total of 20 articles were chosen for the final review (Figure 1).

Of the twenty studies reviewed, the match variables studied were: match location (Arboix-Alió et al., 2020; Arboix-Alió et al., 2021d; Arboix-Alió & Aguilera- Castells, 2019; Gómez et al., 2011), scoring first (Arboix- Alió & Aguilera-Castells, 2018), influence of set pieces (Arboix-Alió et al., 2021c; Arboix-Alió et al., 2021e; Arboix-Alió, et al., 2021f; Camões et al., 2022), the result of direct free kicks (Trabal et al., 2019b), situational variables (Arboix-Alió et al., 2022; Arboix-Alió et al., 2021a) and goalkeeper intervention (Kingman & Dyson, 2001; Sousa et al., 2020; Trabal et al., 2019a; Trabal et al., 2020a; Trabal et al., 2020b).

The results are presented below according to the main objective of the study. Table 3 shows the main features of all the studies reviewed, highlighting the type of study, the sample used, the variables analysed and the results obtained.

Discussion

The main objective of the present research was to identify the situational and game variables studied by the scientific literature in the sport of rink hockey. Most research to date has focused on analysing the influence of context, the relevance of set piece plays and the influence of the goalkeeper on the final result. Each type of analysis is discussed below.

Figure 1
PRISMA flowchart of the search and selection of studies.

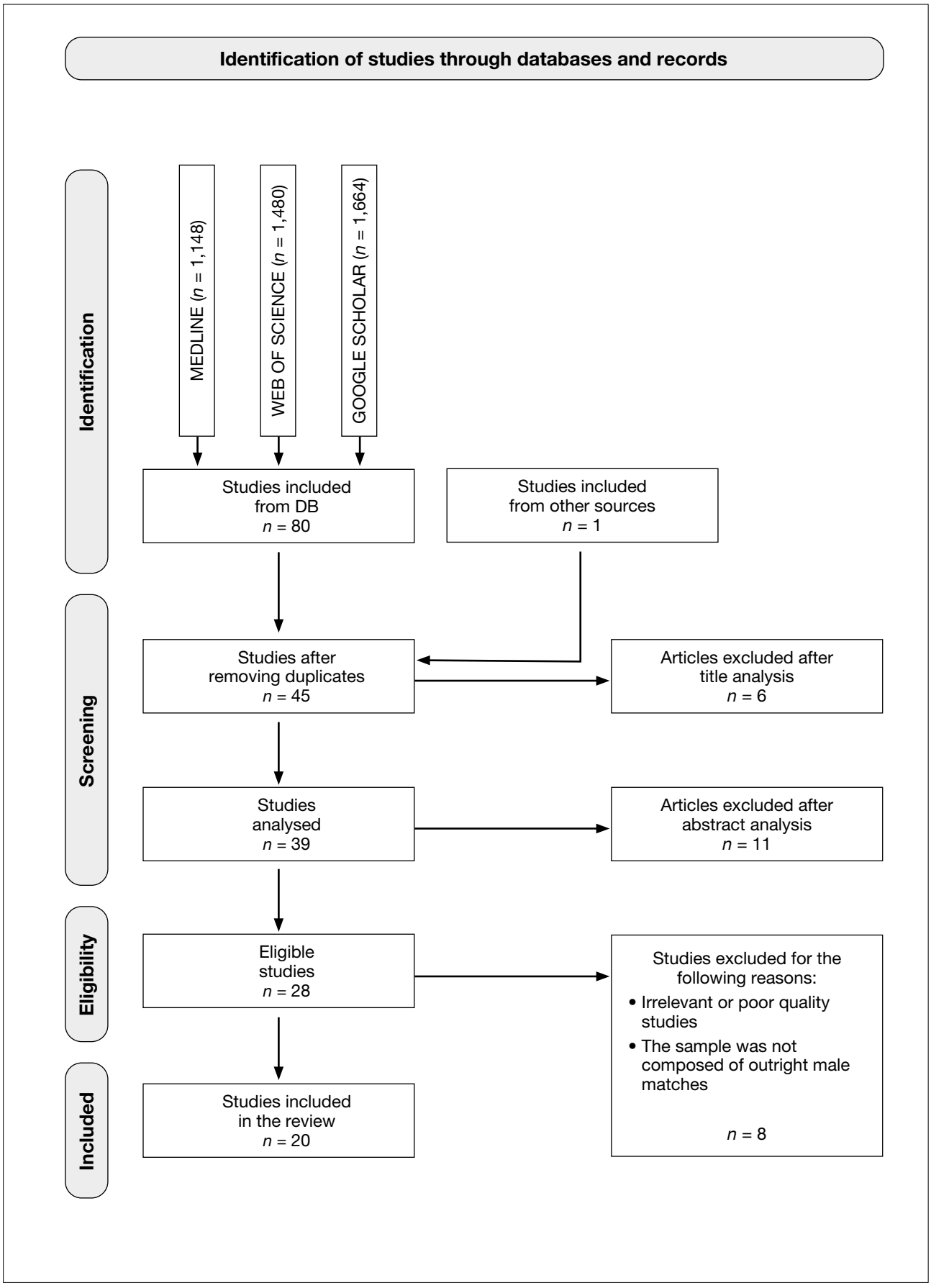

Table 3
Results of the review: Match variables in rink hockey.

References	Objective	Type of study	Sample	Variables	Results
(Arboix-Alió & Aguilera-Castells, 2018)	To study the advantage of scoring the first goal of the game in rink hockey and to identify its impact on the final result.	Original article	240 matches in the Ok Liga and 182 in the First National Division. 2016-17 season.	Match result. First goal scored. Match location.	There is an advantage to scoring first in both leagues (64.14% and 62.91%, respectively). A significantly higher advantage in terms of scoring the first goal is obtained when teams are playing at home in the National First Division and a high correlation exists between the final performance of the teams (points obtained in the ranking) and the advantage of scoring the first goal.
(Arboix-Alió et al., 2020)	To quantify and compare the home advantage in the men's and women's rink hockey leagues in the Portuguese professional first division.	Original article	2,080 matches (*n* = 1,632 men's league and *n* = 448 women's league). 2009-2010 and 2016-17 seasons.	Match location. Goals scored by location.	Home advantage values were above 50% in both leagues, with significantly higher values in the men's league (60.88% compared to 54.33%). Significantly more goals are scored when playing at home in both the men's and women's competitions with no differences between the two leagues.
(Arboix-Alió & Aguilera-Castells, 2019)	To analyse the home advantage when playing in the Spanish men's professional rink hockey league (Ok Liga).	Original article	3,964 matches. Ok Liga season 1999-2000/ 2015-16.	Match location. Goals scored by location. Old regulation/new regulation.	Existence of home advantage in the Ok Liga at a value of 59.8%. Higher number of goals when playing at home. Decreased home advantage under the new regulations and increased number of goals per game.
(Arboix-Alió et al., 2022)	To analyse and predict the influence of the different game variables in the end result of the rink hockey matches.	Original article	440 matches. Ok Liga seasons 2017-18 and 2018-19.	Win at half-time (WH). Win by more than one goal at half-time (WHG). Match location (GL). First goal (SF).	The following variables were found to be predictive of victory: WHG (OR 4.47), WH (OR 3.35), SF (OR 2.05) and GL (OR 1.83).
(Arboix-Alió et al., 2021c)	Set piece plays (FDH and PEN) and the final ranking of the teams.	Original article	1,680 matches. 6,920 set piece actions (4,332 FDH and 2,588 PEN). Ok Liga seasons 2012-13 to 2019-20.	Points scored. Goals scored and conceded by FDH. %Efficiency of Goals scored and conceded by FDH. Goals scored and conceded by PEN. %Efficiency of Goals scored and conceded by PEN. % of total goals scored and conceded from set pieces.	Teams with a superior final ranking had a higher percentage of effectiveness in set piece play. The goalkeepers of these teams also had a higher success rate. Significant correlations were obtained between the final score and the variables.

Table 3 (Continued)
Results of the review: Match variables in rink hockey.

References	Objective	Type of study	Sample	Variables	Results
(Arboix-Alió et al., 2021f)	To analyse the home advantage when playing in the Spanish men's professional rink hockey league (Ok Liga).	Original article	196 matches. 621 FDH and 292 PEN. Top competitions. Ok Liga seasons 2009–10 to 2018–19.	Match location. Time of the match. Scoreboard status. Importance of play	Only the variable "scoreboard status" was significant. The players were more successful in FDH when they led by two goals (OR = 2.4) and in PEN by three or more goals (OR = 3.83). Players were less effective in FDH when down by two goals (OR = 0.38). Situational variables have little influence on set piece actions.
(Arboix-Alió et al., 2021e)	To analyse the influence of set piece plays (FDH and PEN) on the outcome of the matches.	Original article	161 matches (82 semi-finals and 79 finals). Top competitions. Ok Liga seasons 2009–10 to 2018–19.	Match result. Goals from set piece plays	Scoring more from set pieces than the opponent was associated with winning (OR = 6.1; 95% CI: 3.7, 10.0). More relevant in imbalanced matches (OR = 19.5; 95% CI: 8.6, 44.3) than in balanced matches (OR = 2.3; 95% CI: 1.2, 4.5).
(Arboix-Alió et al., 2021a)	To analyse the predictive value of different situational variables interacting with each other on the outcome of matches.	Original article	238 matches. Ok Liga season 2017-18.	Team level. Opponent level. Match location. Score the first goal. Result at half-time.	The variable with the highest predictive power was the score at half-time, followed by the level of the opponent, the level of the team itself and the location of the match.
(Arboix-Alió et al., 2021d)	To analyse the influence of spectators on the performance of rink hockey teams.	Original article	1,665 matches (654 Ok Liga, 497 1a Divisao, and 514 Serie A1).	Spectator presence. Match location. Goals scored. Set piece plays. Fouls committed. Cards received.	The HA phenomenon was not eradicated despite playing without spectators, but decreased from 63.99% to 57.41% (p = .002). Playing without spectators damaged the performance of local teams, especially in the Portuguese and Italian leagues.
(Camões et al., 2022)	To analyse the correlations between the team's set pieces plays and the overall performance of the team.	Original article	182 matches. 1st Division (Portuguese season 2018-19).	Goals scored. Goals conceded. Free kicks. Penalties. Points at end of season.	Teams with a superior final ranking had a higher percentage of effectiveness in set piece play. The lower the final ranking, the higher the percentage of goals scored from set pieces compared to the total number of goals scored (1st to 4th: 15.3%; 5th to 9th: 25.6%; 10th to 14th: 23.9%; p < .05).

Table 3 (Continued)
Results of the review: Match variables in rink hockey.

References	Objective	Type of study	Sample	Variables	Results
(Gómez et al., 2011)	To analyse home advantage in nine professional team sports in Spain (including rink hockey).	Original article	1,200 matches. Ok Liga season 2005-2006/2009-2010.	Match location.	Existence of home advantage in the Ok Liga at a value of 58.3%.
(Kingman & Dyson, 1997)	To study the influence of the scoreboard, time of match and pitch position on the type of actions.	Original article	2 matches. Premier League Roller Hockey.	Actions (intensity, direction and type of action). Match result. Time of the match.	No significant differences were found in actions according to player position. The scoreboard had a small effect on the shooting actions. The match timing conditioned the number of high-intensity actions, with this being higher in the first half.
(Kingman & Dyson, 2001)	To analyse the shooting position and movement of goalkeepers during rink hockey matches.	Original article	6 matches. 1st English Division.	Shooting location. Goalkeeper efficiency.	The highest percentage of shots were aimed at the bottom corners of the goal. Goalkeepers receive an average of one shot every 67 seconds.
(Sousa et al., 2020)	To analyse the performance of goalkeepers and determine whether this is influenced by offensive patterns, actions and competence of opponents.	Original article	1,713 shots. Portuguese 1st Division 2016-2017 season.	Context (1st half, 2nd half, scoreboard status, final result). Goalkeeper performance zone. Shooting zone. Goalkeeper technique.	Goalkeepers performed better in the first half when the score is a draw. Goalkeepers tend to be less effective when shots are aimed at the upper areas. The most common goalkeeper technique is "knee on the ground".
(Sousa et al., 2021)	To analyse the perception of rink hockey coaches on the use of match analysis as a tool for match preparation.	Original article	7 coaches of Portuguese 1st Division.	Observation categories: goalkeeping action, overall game dynamics, attributes of opposing players, timing of the game, statistical data, behaviour of the opposing coach.	Video analysis proves to be the most widely used tool by rink hockey coaches. The main aspects to be observed are: analysis of the opposing goalkeepers and 5 specific match moments (defensive organisation, offensive organisation, defensive transition, offensive transition and set piece).

Table 3 (Continued)
Results of the review: Match variables in rink hockey.

References	Objective	Type of study	Sample	Variables	Results
(Trabal et al., 2020a)	To analyse the effect of situational variables of the match on the intervention of the rink hockey goalkeeper during free kicks.	Original article	637 free kicks. Ok Liga season 2015-16.	Free kick result (goal/non-goal). Match minute, scoreboard status, point in the season, importance of the free kick and location of the match.	The match minute presented a significant relationship with goalkeeper effectiveness ($\chi^2 = 17.665$; Sig. = .04; $p < .05$; w = .167), an increase in the frequency of free kicks in the closing moments (43.96% are committed in the last 10 minutes of the match) and an improvement in the efficiency of the goalkeeper in critical moments (77.1%).
(Trabal et al., 2020b)	To identify the most frequently occurring goalkeeper and player behaviours in the FD and determine their influence on FD effectiveness.	Original article	637 free kicks. Ok Liga season 2015-16.	% free kick efficiency. Player behaviour. Goalkeeper behaviour.	No significant relationships between player and goalkeeper behaviours on FD effectiveness. Players, highest % result in zone 3.
(Trabal et al., 2019a)	To identify the technical skills of the rink hockey goalkeeper in free kicks.	Original article	637 free kicks. Ok Liga season 2015-16.	% free kick efficiency. Goalkeeper technical ability.	The technical skills most utilised by the goalkeeper are PASV (hurdling) (35.6%) and PNTLL (screening) (24.6%).
(Trabal et al., 2019b)	To determine if there is a relationship between free kicks and the final ranking of teams in rink hockey.	Original article	240 matches. Ok Liga season 2015-16.	% free kick efficiency. Team ranking.	No significant correlation between FD variables (number of goals, number of FDs and percentage of effectiveness) and the final ranking of the teams.
(Trabal et al., in press)	To compare performance variables between the national championships of Spain (OK Liga), Portugal (1st Division) and Italy (Series A1).	Original article	1,665 matches (654 Ok Liga, 497 1a Divisao, y 514 Serie A1).	League. Goals scored. Set piece plays. Fouls committed. Cards received.	In Spain, teams score fewer goals per game (3.18 vs. 3.66 and 3.76 in Portugal and Italy). In Portugal, there are more penalty and free kick shots and goals, more fouls and cards and a higher percentage of goals from set pieces in relation to total goals.

Situational influence

The situational influence on performance is a latent issue that has historically been of interest in the world of sport. As early as the 1970s, the effect of the competition's location on the final result has been studied (Pollard, 1986), a phenomenon that was termed "home advantage" (HA), since in most sports there is a tendency to perform better when competing at home compared to competing away from home.

The HA phenomenon has probably been the most studied situational variable in the sporting world and the influence of this factor has been analysed in most sports. The scientific literature provides various studies, on the one hand, in individual sports such as tennis (Koning, 2011), judo (Ferreira Julio et al., 2012) or golf (Nevill et al., 1997). On the other hand, it has also been studied in team sports, which are the most analysed, particularly in football (Pollard & Gómez, 2012). In most of these team sports the HA factor exists and is estimated to be around 60% (Jamieson, 2010). However, the values may vary for the same sport depending on the type of competition, nationality or level of competition. Specifically in Spain, rugby is the sport with the highest rate of HA at 67%, while volleyball has a rate of 55.73% and water polo has a rate of 56.2% (Gómez et al., 2011).

As for rink hockey, Gómez et al. (2011) and Arboix-Alió and Aguilera-Castells (2019) have studied the HA factor in the men's Ok Liga (Spain) finding a value of 58.3% and 59.8%, respectively. In the Portuguese championship, values of 60.88% in the men's competition and 54.33% in the women's competition have been reported (Arboix-Alió et al., 2020). In another predictive study, Arboix-Alió et al. (2022) estimated that Ok Liga teams were twice as likely to win when playing at home (OR = 2.085). Although there is a lack of studies in the present sport in relation to tactical and game aspects comparing winning and losing teams, these findings indicate that strategies in hockey may be influenced, in part, by the location of the match and that teams may alter their style of play accordingly. Pollard and Pollard (2005) highlight seven factors that explain HA, divided into psychological factors, tactical factors, territoriality, familiarity with the venue, referee bias, spectator support and physical fatigue caused by pre-match travel. Among these seven factors, it is worth highlighting the recent study published by Arboix-Alió et al. (2021d), who, taking advantage of the pandemic situation caused by COVID-19, which led to many matches being played behind closed doors, analysed the influence of spectators on HA in the Spanish, Portuguese and Italian leagues. Although the HA phenomenon did not vanish, its value experienced a significant decrease (63.99% with spectators vs. 57.41% without spectators), as well as revealing changes in different game variables. These include a decrease in goals scored at home and an increase in fouls committed or cards received for home teams when playing without a home crowd.

In relation to scoring the first goal of the match, as in other team sports, this is an advantageous factor for the final result of the match. Arboix-Alió and Aguilera-Castells (2018) found that the advantage of scoring the first goal of the match amounted to 64.14% for the Ok Liga and 62.91% for the Ok Plata (Spain's second highest national competition). Additionally, this factor has been estimated to have a predictive power of an OR of 2.289 (Arboix-Alió et al., 2022). Another of the situational variables studied in this sport has been leading at the end of half-time. This situation seems to have the highest predictive value (OR = 7.862) (Arboix-Alió et al., 2021a), and is even more evident when the result is positive with a difference equal to or greater than two goals (Arboix-Alió et al., 2022).

The above situational variables could be explained by several reasons. Authors such as Jones (2009) would attribute the importance of scoring first or winning at half-time to the mere fact that this factor is already reflected in the final result of the match. Other authors attribute this to the psychological momentum theory, an explanation for the added advantage gained when an initial successful event occurs in a sporting context, which produces a psychological momentum in the athlete that will lead to subsequent success (Gayton et al., 1993).

In rink hockey alone, Arboix-Alió et al. (2021a) have analysed the interaction between the different situational variables, and it seems that, as in other team sports, the sum of these variables tends to increase their influence on the final outcome of matches (Lago-Peñas & Dellal, 2010; Lago et al., 2010).

Influence of set piece plays

As far as set piece plays are concerned, there are two situations that occur frequently in rink hockey matches: direct free kicks (FDH) and penalty kicks (PEN). In FDH the kicker has five seconds to kick off (from 7.4 metres), with a choice between a direct kick or dribbling towards the goalkeeper, whereas, in PEN, the kicker has five seconds and must kick directly from the penalty spot (at 5.4 metres). In both situations there is a direct interaction

between player and goalkeeper, the former being the more frequent due to the new rules of the European Committee of Rink Hockey (CERH), which in 2009 introduced the rule of penalising blue cards or the accumulation of 10 defensive fouls with a free kick for the offending team.

In this sense, Arboix-Alió et al. (2021c) reported that 21.08% of the Ok Liga goals are scored by FDH and PEN (11.58% and 9.49%, respectively), values similar to those of Camões et al. (2022) regarding the Portuguese league. Also, when comparing the effectiveness of set piece plays with end of the season ranking, the best teams launched a greater number of plays and obtained a higher effectiveness. The teams ranked in the top positions of the table have a significantly higher average number of goals from set pieces than the rest of the teams. Moreover, their effectiveness was higher, indicating better performance in this type of play (Arboix-Alió et al., 2021c).

In terms of set-pieces conceded, there were also significant differences in the performance of goalkeepers according to the final ranking of the teams. The results showed that goalkeepers of teams ranked in the top positions of the table (1st to 4th) had a lower percentage of goals conceded (27.19%) compared to teams that achieve promotion or relegation (34.78% and 38.23%, respectively) (Arboix-Alió et al., 2021c). This trend has already been observed by Trabal et al. (2019b) in the Ok Liga teams, who demonstrated that the best teams tended to have the best goalkeepers in set pieces.

On the other hand, the study by Arboix-Alió et al. (2021e) reported that scoring more set pieces than the opponent was associated with the chances of winning (OR = 6.1; 95% CI: 3.7, 10.0) in a match sample composed only of national and international championship semi-finals and finals. In this sense, the authors confirmed the popular belief among coaches, players and supporters of rink hockey that the effectiveness of set pieces is a determining factor in the outcome of matches in contemporary hockey.

Finally, as regards the influence of situational variables on set-piece plays, neither the study by Trabal et al. (2020a) with a sample from the Ok Liga, nor the study by Arboix-Alió et al. (2021f) with a sample of matches corresponding to finals and semi-finals of national and international competitions, seem to indicate that context has a great relevance in the performance of these actions. Only scoreboard status had a significant influence on both FDH and PEN effectiveness. The players were significantly more successful in FDH when they led by two goals (OR = 2.4) and in PEN by three or more goals (OR = 3.83). In contrast, aspects such as location and time of match were not significant. In this sense, the present results reveal little influence of situational variables on the performance of these types of actions.

Goalkeeper influence

Another area that has brought together an important element of research on game variables in this sport has been related to the actions and influence of the figure of the goalkeeper. The behaviour of the goalkeeper, widely recognised as the most decisive figure in rink hockey (Sousa et al., 2021; Trabal, 2016), has been analysed both in the overall match (Sousa et al., 2020) and in an analytical way in set-piece, FD and PEN actions (Trabal et al., 2019a; Trabal et al., 2020b). Likewise, these studies have also analysed the influence of the situational variables: match time, type of defended actions and the scoreboard status, on the effectiveness of the goalkeeper.

In a recent study in the Portuguese 1st Division, Sousa et al. (2020) found that goalkeeper effectiveness was significantly better in the first half (OR 1.388) compared to the second half. This difference in effectiveness between halves could be explained by the inherent physical exhaustion of the goalkeepers involved in the match itself, a situation already observed in various technical actions with other team sports (Sarmento et al., 2014) and because in the second halves the goalkeeper has to face a greater number of set pieces (FDH and PEN) in which the percentage of effectiveness is lower than any other type of shot made during the course of a match (Sousa et al., 2020). The effectiveness observed in FDH is between 66.1% and 70.2% and in PEN, between 50.8% and 56.5% (Arboix-Alió et al., 2021f; Sousa et al., 2020; Trabal et al., 2020a), both percentages lower than the other types of finishes. Specifically, in the Ok Liga, 82.74% of FDH are executed in the second half (Trabal et al., 2020a), and in international competitions, 74.9% of FDH and 54.1% of PEN are executed in the second half (Arboix-Alió et al., 2021f).

Another situational variable influencing goalkeeper effectiveness is the scoreboard status. With two goals or more conceded, the effectiveness over the course of the match decreases by 45% compared to a draw (Sousa et al., 2020). The same trend is observed in FD and PEN, where the percentage decreases to 57.7% and 32.2%, respectively (Trabal et al., 2020a). In these actions, the goalkeeper can be affected by a loss of concentration and motivation due to a decrease in the chances of winning the match (Trabal, 2017).

The technical characterisation of the goalkeeper in FD makes it possible to identify two basic starting positions, which are the knee on the ground (49.1%) and the half-screen (28.2%), with a direct relationship with the two most used technical skills, "hurdling" (35.6%) and "screening" (24.6%) (Trabal et al., 2019b). The goalkeeper-player opposition in FDH creates a reciprocal influence on each other in which they condition one another. The most commonly used action against free kicks is "screening", a technical action that has proven to be the most effective against these types of shots. On the other hand, in the face of dribbling, it is "hurdling"; a technical alternative based on the goalkeeper's comfort and not so much on effectiveness (Trabal et al., 2019a; Trabal et al., 2020b).

Limitations and recommendations for future research

In this systematic review, most of the references are from 2018 or later, which indicates that the study of match variables in rink hockey has historically had little relevance, although it has recently attracted interest and has been gaining popularity among the sports science community. On the other hand, although this restricts historical comparisons, it ensures the validity of the analyses carried out, since they take into account the changes in regulations and playing trends currently used by teams and players. Only articles in English and Spanish have been included, so the lack of potentially relevant articles in other languages (i.e. Portuguese or Italian) may be a possible additional limitation. On the other hand, being a minority sport worldwide, but of great importance in certain territories of some countries, means that the vast majority of the research comes only from these geographical areas (e.g. Spain and Portugal). It would be interesting for future research to carry out studies with samples from other international leagues, as well as from different sports divisions in the same country in order to obtain a more global spectrum of sports data.

At the methodological level, it has been observed that most of the studies analysed have been descriptive in nature. This leads to lower levels of scientific evidence than systematic reviews that consider scientific studies of a different nature (i.e. randomised clinical trials). However, given the scarcity of research in the sport of rink hockey, presenting all the evidence to date in a single article that synthesises it all is of great interest as it allows for learning about hitherto little-known data and can provide new information on the match variables in this team sport. However, for future studies and following the recommendations of authors such as Gréhaigne et al. (2001), it is suggested that it is necessary to prioritise prospective studies with more complex designs and methodologies of analysis that allow for analysing the factors that explain sporting success in rink hockey to a greater extent and independently.

Conclusions

After conducting this systematic review, the authors confirm the influence of the situational variables and the degree of interaction of each one on both the outcome of the match and the competition in general. In the same way, the high relevance of set-piece actions in rink hockey and the role played by the goalkeeper in these actions is corroborated.

The results of the present review are of general interest in the field of sports science, as they provide new data on match analysis in this collective sport, something that has never been seen before.

On the other hand, and more particularly, these findings can provide valuable information to coaches and practitioners of this sport in aspects such as line-ups, according to the needs of the team itself, the characteristics of the opponent, the time of the match or the location. In this sense, they could also help coaching staff members to design specific training sessions based on specific match situations or also to simulate different match scenarios where the scoring advantage or disadvantage is present. These hypothetical situations could be useful to analyse and assess individual athletes' responses to such situations and thus improve their performance under pressure. For this reason, it would also be advisable to consider the application of psychological alternatives to optimise sporting performance in moments of psychological pressure or sporting uncertainty inherent to competitive sports.

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Do Water Polo's Rule Changes Affect Team Performance at Different Levels and Genders?

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A young sprinter prepares herself with a track series to work on her explosiveness. @Jérome Aufort/Adobestock

Abstract

The aim of this study was to verify the effect of rule changes in the 2019 water polo (WP) rules on the performance of sub-elite and elite level teams of both genders, comparing pre- and post- moments. The data were collected through official game reports from Brazilian and European WP tournaments, totaling 533 matches, referring to goals (G), goals per quarter (GQ1 to GQ4), exclusion fouls (EF) and penalty fouls (PF). Mean, standard deviation and 95 % confidence intervals were calculated for all variables. Generalised estimating equations were used to compare the variables pre- and post-WP rule changes. Effect sizes (Cohen's *d*) were calculated. SPSS 20.0 was used in all analysis. The alpha significance level was established at.05. At the level of the sub-elite teams, women decreased GQ1 and increased GQ2, GQ3, GQ4 and EF, while men increased only EF and PF. At the level of the elite teams, women did not change the variables, whereas men increased G, GQ1, GQ2, EF and PF. The 2019 WP rule changes provoked different responses according to gender and the competitive level of the teams.

Keywords: notational analysis, rule modification, team sports, water sports.

Introduction

Water polo (WP) is an invasion team sport with opposition-cooperation played in water (Argudo et al., 2020a, 2020b). The high shot rate and its effectiveness, positional attack with successful individual defense-breaking actions, the high conversion rate of power-play situations and goals per quarter are determining factors for victory (Canossa et al., 2009; Ruano et al., 2016; Tucher et al., 2015). The development of WP throughout its history has been conditioned by technical-tactical innovations and rule changes, a common way to change game conditions (Hraste et al., 2013). In general, the rule changes provide the specific requirements of game action and impose technical-tactical demands, which modify the player's perception and actions in the game (Rodrigues et al., 2013). Usually, rule changes are applied to improve performance, attract spectators, address commercial interests, adapt the sport to new practitioners and to avoid injuries (Madera et al., 2017).

The continuous rule changes throughout its history has hampered the dynamics and speed of the WP (Hraste et al., 2013). The changes in WP rules provided, over the years, the reduction of ball possession time, and the increase of game duration, which consequently led to a rapid ball circulation, rapid counter-attacks and great physical, technical-tactical and cognitive demands (Canossa et al., 2009; Hraste et al., 2013). Basically, time element changes have been present in WP development (Canossa et al., 2020).

In 2018, the International Amateur Swimming Federation (FINA) presented a new set of WP rules, implemented in 2019 (Lozovina & Lozovina, 2019). The intention of rule changes is to make WP more attractive to the media and the public through a faster game, with more goals and less violence (FINA, 2019). The main rules changed were: (i) reduction of the ball time possession at the second attack from 30 to 20 s (after a rebound or a corner); (ii) a free throw shall be taken at the location of the ball; (iii) shooting after a foul, even if it is not directly to the goal (after the ball is out of hand, the player can swim, pass the ball or shoot); (iv) permission for flying substitutions from the lateral area, outer side of the field; (v) the increase in area in front of the post from 5 to 6 m; and (vi) expanding the penalty foul's repertoire of actions (FINA, 2019).

Despite research about the effects of the WP rule changes (Argudo et al., 2020a, 2020b; Lozovina & Lozovina, 2019), no studies aiming to verify the effects on different levels and genders in the same research, with notational analysis, were found. According to Lupo et al. (2012b), notational analysis has been shown to be an effective tool for increasing the knowledge of team sports and for better coaching, especially regarding complex sports, like WP. Therefore, the aim of this study was to verify the effects of 2019 WP rule changes on the goals (G), goals scored per quarter (GQ), exclusion fouls (EF) and penalty fouls (PF) performance in different technical levels and both genders. The hypothesis is that the rule changes will induce an increase in the frequency of goals, especially in the initial quarters. This must occur by increasing in offensive actions frequency caused by the reduction of the ball time possession at the second attack. In addition, there should be an increase in exclusion fouls and penalty fouls. The rule changes intended to induce dynamism and fair play into the game, making it more attractive and penalizing players who carry out brutal actions. In addition, it is supposed that the 2019 WP rule changes will affect differently women and men in different competitive level of the teams.

Methodology

Experimental Approach

The analyses were performed by comparing the effects of pre- and post-rule-changes on the sub-elite and elite-level teams for both genders through the G, GQ, EF and PF. The GQ were described as GQ1, GQ2, GQ3 and GQ4.

Procedures for obtaining the data

The data were collected through official game reports from Brazilian and European leagues for female and male WP tournaments. The data referring to G, GQ1 to GQ4, EF and PF were recorded in electronic spreadsheets for later statistical analysis. Considering that the analysed official game reports were obtained from public sites with free access, analysis by the research ethics committee was not necessary. On the other hand, the researchers pledged not to disclose any data individually.

Sample

The WP teams participated in two tournaments (pre- and post-rule changes) at the sub-elite and elite level for females and males. In this way, an overall of 533 WP matches from the preliminary phases of the tournaments were analysed.

The sub-elite level

The teams participating in the Brazilian WP League in 2018 and 2019 were analysed. Three women's teams that participated in the two editions of the Brazilian Women's WP League were selected. In the pre-rule changes (2018), data were collected regarding 30 matches played by these teams. In the analysis of the post-rule changes, data were collected from the Brazilian Women's WP League games played in 2019, with a total of 23 matches. Eight male teams that participated in the two editions of the Brazilian Men's WP League were selected. In 2018, referring to the pre-rule changes, data were collected over 95 matches played by these teams. In the post-rule changes, data were collected from the Brazilian WP League matches played in 2019, totaling 98 matches.

The elite level

The teams participating in the Ligue Européenne de Natation (European WP leagues, LEN) in the 2017/2018 and 2019/2020 seasons were analysed. All twelve female teams that participated in the two editions of the LEN Euro League Woman were selected. In the 2017/2018 season, referring to the pre-rule changes, data were collected regarding 36 matches played by these teams. In the post-rule changes, data were collected from the LEN Euro League Woman played in 2019/2020, with a total of 36 matches. Nine male teams that participated in the two editions of the LEN Champions League were selected. In the 2017/2018 season, with respect to the pre-rule changes, data were collected regarding 126 matches played by these teams. In the post-rule changes, data were collected from the LEN Champions League matches played in 2019/2020, with a total of 89 matches.

Statistical analyses

A longitudinal study analysis with pre- and post-measures was performed. As descriptive statistics, mean, standard deviation, and 95 % confidence intervals were calculated for all variables. To compare all variables, variables pre- and post-WP rule changes, generalised estimating equations (GEE) were applied. The GEE were designed to analyze paired and longitudinal data, and can be applied regardless of the data distribution. The rule changes effect sizes were identified with Cohen's *d* and interpreted with the following criteria: 0-0.19 trivial, 0.2-0.59 small, 0.6-1.19 moderate, 1.2-1.99 large, 2.0-3.99 very large and > 4.0 nearly perfect (Hopkins, 2002). SPSS 20.0 was used in all analyses. The alpha significance level was established at .05.

Results

Table 1 presents the G, GQ1 to GQ4, EF and PF for females and males at the sub-elite-level championships. Comparisons were performed between the pre- and post-WP rule changes of 2019. For females, only G and PF did not statistically change from pre to post. For these variables, effect sizes were small and trivial, respectively. The EF presented a statistical increase with a large effect size in the post-WP rule changes. The GQ1 decreased statistically, and the effect size was very large. However, GQ2, GQ3 and GQ4 increased statistically with moderate to very large effect size. Although for males, just the EF and PF increased statistically, with a moderate to large effect size. The other variables did not statistically change from pre to post. For these variables, effects sizes varied from trivial to small.Table 2 presents G, GQ1 to GQ4, EF and PF for females and males at elite-level championships. Comparisons were performed between the pre- and post-WP rule changes of 2019. For females, no statistical differences were found, and the effects sizes were just from small to moderate (only for the PF). Although for males, with the post-WP rule changes, there were statistical increases in G, GQ1, GQ2, EF and PF, and effect sizes were from moderate to large (only for the EF and PF). The GQ3 (moderate effect size) and GQ4 (small effect size) did not statistically change from pre to post.

Discussion

The aim of this study was to verify the effect of the 2019 WP rule changes on the performance of teams of different levels and genders. Specifically, we compared (i) goals, (ii) goals per quarter, (iii) exclusion fouls and (iv) penalty

Table 1
Mean ± standard deviation, 95% confidence intervals, p-value and effect size (ES-d) for the goals (G), goals per quarter (GQ1 to GQ4), exclusion fouls (EF), and penalty fouls (PF) at sub-elite-level championships for females and males, pre- and post-WP rule changes (n = number of games).

	Females			Males		
	pre *n* = 30	post *n* = 23	*p*-value; d	pre *n* = 95	post *n* = 98	*p*-value; d
G	9.3 ± 2.1 [7.0 to 11.7]	10.3 ± 1.0 [9.2 to 11.3]	0.17; 0.6 small ES	9.5 ± 2.8 [7.6 to 11.4]	9.7 ± 1.6 [8.5 to 10.8]	.94; 0.1 small ES
GQ1	3.6 ± 0.2 [3.3 to 3.8]	2.5 ± 0.8 [1.6 to 3.5]	< 0.001; 2.0 very large ES	2.4 ± 0.9 [1.8 to 3.1]	2.4 ± 0.4 [2.1 to 2.7]	.61; 0.1 small ES
GQ2	1.8 ± 0.8 [0.9 to 2.6]	3.0 ± 0.3 [2.6 to 3.4]	< 0.001; 2.2 very large ES	2.3 ± 0.7 [1.8 to 2.7]	2.4 ± 0.6 [1.9 to 2.8]	.53; 0.1 small ES
GQ3	1.8 ± 0.6 [1.2 to 2.4]	2.3 ± 0.3 [1.9 to 2.7]	0.05; 1.0 moderate ES	2.4 ± 0.6 [2.0 to 2.8]	2.3 ± 0.4 [2.0 to 2.6]	.59; 0.3 small ES
GQ4	1.8 ± 0.2 [1.6 to 2.0]	2.5 ± 0.2 [2.2 to 2.7]	< 0.001; 2.9 very large ES	2.5 ± 0.6 [2.0 to 2.9]	2.6 ± 0.5 [2.3 to 3.0]	.82; 0.3 small ES
EF	6.5 ± 0.8 [5.6 to 7.4]	7.9 ± 1.5 [6.1 to 9.6]	< 0.001; 1.2 large ES	6.1 ± 1.4 [5.1 to 7.0]	7.4 ± 1.2 [6.6 to 8.3]	.03; 1.0 moderate ES
PF	1.1 ± 0.7 [0.3 to 1.8]	1.1 ± 0.2 [0.9 to 1.3]	0.94; < 0.01 trivial ES	0.8 ± 0.1 [0.7 to 0.9]	1.2 ± 0.3 [0.9 to 1.4]	< .001; 1.6 large ES

G = Goals; GQ = Goals per Quarter; EF = Exclusion Fouls; PF = Penalty Fouls

Table 2
Mean ± standard deviation, 95% confidence intervals, p-value and effect size (ES-d) for the goals (G), goals per quarter (GQ1 to GQ4), exclusion fouls (EF), and penalty fouls (PF) at elite-level championships for females and males, pre- and post-WP rule changes (n = number of games).

	Females			Males		
	pre *n* = 36	post *n* = 36	*p*-value; d	pre *n* =126	post *n* = 89	*p*-value; d
G	10.9 ± 2.6 [9.5 to 12.4]	11.7 ± 2.8 [10.1 to 13.3]	0.37; 0.3 small ES	10.3 ± 1.7 [9.2 to 11.4]	11.9 ± 1.9 [10.7 ± 13.1]	.03; 0.9 moderate ES
GQ1	3.1 ± 1.1 [2.4 to 3.7]	2.8 ± 0.8 2.3 a 3.2	0.43; 0.4 small ES	2.6 ± 0.6 [2.2 to 3.0]	3.0 ± 0.3 [2.9 to 3.2]	.02; 0.9 moderate ES
GQ2	2.8 ± 1.2 [2.1 to 3.5]	3.0 ± 1.0 [2.4 to 3.6]	0.44; 0.2 small ES	2.4 ± 0.6 [2.1 to 2.8]	3.0 ± 0.6 [2.6 to 3.4]	< .001; 0.9 moderate ES
GQ3	2.7 ± 1.0 [2.1 to 3.3]	3.0 ± 0.7 [2.6 to 3.4]	0.34; 0.4 small ES	2.5 ± 0.5 [2.2 to 2.9]	3.0 ± 0.7 [2.5 to 3.4]	.09; 0.7 moderate ES
GQ4	2.7 ± 0.7 [2.3 to 3.1]	2.9 ± 1.1 [2.3 to 3.5]	0.29; 0.2 small ES	2.7 ± 0.3 [2.5 to 2.8]	2.9 ± 0.6 [2.5 to 3.3]	.41; 0.4 small ES
EF	8.2 ± 1.4 [7.4 to 9.0]	8.9 ± 1.7 [7.9 to 9.8]	1.00; 0.4 small ES	9.1 ± 1.2 [8.3 to 9.9]	11.2 ± 1.3 [10.4 to 12.1]	< .001; 1.7 large ES
PF	0.6 ± 0.6 [0.3 to 1.0]	1.1 ± 0.5 [0.8 to 1.3]	0.06; 0.7 moderate ES	0.4 ± 0.2 [0.3 to 0.6]	0.9 ± 0.3 [0.7 to 1.1]	< .00; 1.9 large ES

G = Goals; GQ = Goals per Quarter; EF = Exclusion Fouls; PF = Penalty Fouls

fouls. The 2019 WP rule changes intention was make the game more attractive, instigating more dynamism and creativity by the speed promotion and violence reduction. Therefore, it was expected an increase in goal frequency, penalty fouls and exclusion fouls. However, the different genders and level teams could provoke different results.

At the sub-elite level, for females, goals in second, third and fourth quarters and exclusion fouls increased, while goals in first quarter decreased. For males, just exclusion fouls and penalty fouls increased. At the elite level, no statistical difference was observed for females; however, for males, goals, goals in first and second quarter, exclusion fouls and penalty fouls increased. These results must be interpreted considering the changes in rules and the short time given to players to adapt to these changes. Thus, the hypotheses were partially confirmed: the increase in goals, especially in the initial quarters, exclusion fouls and penalty fouls occurred only in male elite level teams.

Sub-elite-level analysis

Goals did not change from pre to post for females, and the effect size was only small. Although goals in second, third and fourth quarters increased statistically, and the effect sizes were from moderate to very large, goals in first quarter decreased, and the effect size was very large. Thus, the combined effect of increasing the average number of goals in second, third and fourth quarters, with the reduction in goals in first quarter, led to the behaviour observed in the total number of goals. There were important changes in goals per quarter distribution. The first time that Brazilian teams played with the new rules was in 2019. This fact may have caused a conservative attitude in offensive actions, which may have led to a reduction in goals in first quarter, an increase in the other quarters (especially in second quarter goals) and an increase in exclusion fouls but not in penalty fouls.

Although the exclusion fouls increased with a large effect size, it seems that it was not enough to increase goals. The high performance in power-play situations could be a determining factor for scoring goals (Lupo et al., 2012a; Tucher et al., 2015). Lupo et al. (2010), comparing elite and sub-elite male WP matches, showed that the competition level has a relevant impact on the occurrence and performance of power-play situations. Lupo et al. (2010) observed a higher percentage of scored goals from power-play situations in elite-level teams than in sub-elite ones. In addition, more than half of the power-play situations in the 2014 Women's WP World Championship resulted in goals for the winners' teams (Lupo et al., 2014).

Penalty fouls did not change and presented a trivial effect size. These results indicate that the new rules may not have caused the offensive actions of entering the 6-m area by the sub-elite-level women's teams. This assumption is supported by the increase in exclusion fouls but not in penalty fouls, indicating that most exclusion fouls did not occur in penalty fouls situations. Previous studies (Lupo et al., 2010; Tucher et al., 2014) found that the sub-elite-level teams' shots are preferably inside the 5-m area and from the centre zone, indicating a reduced ability to generate other ways to score. It is likely that the Brazilian women's teams were not able to make better use of the possibilities of the new rules.

For males, goals did not change statistically and presented a trivial effect size after the new rules were imposed. For the goals in first, second, third and fourth quarters, there were no statistical differences between pre- and post-rule changes. The effect sizes were only small for all of them. However, the exclusion fouls and penalty fouls increased significantly with moderate and large rule-change effect sizes, respectively. This reveals the inability of the male Brazilian teams to take advantage of the new rules' possibilities. For the first league match after the new rules, the changes may have induced a conservative attitude or the players had not yet seen the new possibilities for goals.

The increase in exclusion fouls at the post-rule changes may have occurred due to great rigour in the application of the ruled in comparison to the pre-rule changes in order to restrain violent actions and prioritise the abilities of offensive players. This may have revealed that the short adaptation time to the rule changes did not allow players to change their technical-tactical behaviour, in which intense physical contact is predominant, both in women and men at the sub-elite level. These results corroborate Tucher et al. (2015) research, which showed that the power-play performances by Brazilian male teams, even among the winners, was only average. This performance in power play supposes a low technical quality of sub-elite teams in overcoming defences and scoring goals. Despite the increase in exclusion fouls with a consequent increase in power plays, goals remained unchanged.

The penalty fouls increase in male teams and might indicate a different technical-tactical behaviour in female and male teams regarding the offensive actions of entering the 6-m area. It seems that the sub-elite male teams have taken more 6-m area entry actions than female teams. This fact, in addition to the game characteristics involving intense physical contact, may have influenced the increase in penalty fouls. On the other hand, the short time to adapt to interpreting and applying the new rules by Brazilian referees may have influenced the increase in penalty fouls. After the 2019 Brazilian National League, some initiatives such as refresher courses for Brazilian coaches and referees were carried out to improve the interpretation of the new rules and their possibilities. This leads one to believe that the application of the rules could be suffering from bias.

The sub-elite male teams shoot preferably from the centre zone and inside the area, unlike international and elite Italian ("Serie A") teams, which presented a high frequency of diagonal shots originating outside the 5-m area (Lupo et al., 2010; Tucher et al., 2014). That indicates a lower performance level for the men's sub-elite than elite teams. This technical-tactical behaviour leads us to deduce that the increase in exclusion fouls and penalty fouls may have occurred through the increased number of offensive actions allowed by the new rules. On the other hand, the male Brazilian teams' quality performance in power play was only average (Tucher et al., 2015). That can explain why the increase in exclusion fouls did not influence goals and goals per quarter. The individual WP competitive performance depends, among other aspects, on the player's anthropometry and good physical and technical capacity (Castro et al., 2021). In this sense, it seems that the lower shot velocity of the sub-elite male teams in comparison to the elite male teams could affect decision-making (regarding the distance and location of the shots) and average performance in power plays (Lupo et al., 2010; Tucher et al., 2014, 2015).

Elite level analysis

For females, at the elite level championships no statistical differences were found between pre- and post-rule changes. The effect sizes were only from small to moderate (moderate only for penalty fouls). These results corroborate the those of Vila et al. (2011), suggesting that penalty micro situations are not a determining factor in the winning or losing status of a team. In a study conducted by Lamas et al. (2020) with World Championship teams, the women presented a lower correlation (.78) between shots and points per possession in comparison to the men (.81), although both have shown similar efficiency in creating score opportunities.

The high number of passes, great ball circulation and duration of offensive actions in situations of positional attack in female elite teams (Canossa et al., 2009) may partially explain the results of the present study. Throwing velocity tends to decrease over the course of the game due to the fatigue in female collegiate WP but not in elite junior male WP players (Royal et al., 2006; Stevens et al., 2010). Both technical-tactical, physiological and anthropometric characteristics differentiate female WP players from male players, which may justify the small effects of the rule changes for female teams in comparison to male teams (Abraldes et al., 2011). Moreover, women's WP was developed later than male WP, which can also influence performance quality and game dynamics. The first male WP team to participate in the Olympic Games (Paris) was in 1900, while female teams have only done so since 2000 (Sydney) (Lupo et al., 2014).

The elite male teams were those that showed a statistical increase in goals. This increment was due the statistical increases in goals in first and second quarters (moderate effect size) and no statistical changes in goals in third quarter (but a slight increase, moderate effect size). Exclusion fouls and penalty fouls also presented statistical increases for the elite male teams. The effect sizes were from moderate to very large. The more physically demanding game with the post-rule changes in comparison to pre, probably with more displacements, may have affected the goals per quarter distribution. The statistical increase in goals in first and second quarters (moderate effect size) may indicate a higher game intensity with the post-rule changes than pre. This hypothesis is supported by the non-significant increase of goals in third quarter (moderate effect size) and goals in fourth quarter (small effect size), indicating fatigue over the course of the game. Botonis et al. (2016) showed that handgrip strength, repeated sprint ability and ball shooting accuracy decreased after the game, which may support especially why goals in fourth quarter did not increase in this study. It seems that the increase in the two initial quarters were responsible for the increase in goals.

In the present study, the statistical increase in goals (moderate effect size) added to the increase in exclusion fouls and penalty fouls (large effect size) and may induce us to believe in the improved performance of these game situations. However, Argudo et al. (2020b) found an increase in frequency of shots per match in situations of inequality and penalty fouls but not in goals in this situation. On the other hand, in balanced games, winners engage in a larger number of attacks in power-play situations than in unbalanced games (Escalante et al., 2012; Lupo et al., 2012b). The high effectiveness of power-play situations can be decisive in defining the game's score (Tucher et al., 2015).

The increase in penalty fouls average at the post-rule changes indicated that the elite male teams may have taken advantage of the new penalty rules to explore entry movements into the 6-m area, which may have caused goals directly through penalties shots or power-play situations. The high-level teams should present conditions to score from different positions in the field (Escalante et al., 2012; Lupo et al., 2010; Tucher et al., 2014).

In this study, the sample was limited to Brazilian and European leagues referring to sub-elite and elite levels respectively. Furthermore, the different levels of rule interpretation by the Brazilian and European referees may have influenced the results. This study did not seek specific information about team's power-play performances and changes in penalty shot goals for pre- and post-rule changes. A video analysis could provide information such as the origin of shots and the actions' outcomes, as well as making it possible to rate the entry movements into the 6-m area pre- and post-rule changes (Argudo et al., 2020a; Lupo et al., 2014; Tucher et al., 2014). In addition, the present study did not compare winning and losing teams in terms of technical-tactical behaviour.

Conclusions

The 2019 WP rule changes provoked different responses according to the gender and the competitive level of the teams. At the sub-elite level, women increased exclusion fouls, goals in second, third and fourth quarters and decreased goals in first quarter. In contrast, men had practically no change in the analysed variables, presenting increases only in exclusion fouls and penalty fouls. For elite-level games, women do not seem to have changed the variables, whereas men increased goals, exclusion fouls, penalty fouls, goals in first and second quarter. According to the results of the present study, the elite-level male WP teams were the most sensitive to the rule changes, achieving one of the main objectives of the FINA rule changes, that is increasing goal frequency and providing more spectacular WP. For future studies, obtaining WP players', coaches' and referees' perceptions of the new rules could improve our understanding of the effects of the 2019 rule changes.

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Load Variability According to Specificity of Exercises. Analysis in Youth Futsal

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A young sprinter prepares herself with a track series to work on her explosiveness. @Jérome Aufort/Adobestock

Abstract

In order to determine whether the specificity of the technical-tactical tasks in training sessions affects the external load (EL) experienced by players, data were recorded for 11 players aged 15-16 years (15.55 ± 0.52) from a male futsal team during 10 training sessions using Polar Team Pro® accelerometers, analysing low-intensity accelerations (A) and decelerations (D) (m/s^2): A-1 [0.50 to 0.99], A-2 [1.00 to 1.99], D-1 [–0.50 to –0.99], D-2 [–1.00 to –1.99]; as well as high intensity ones (m/s^2): A-3 [2.00 to 2.99], A-4 [3.00 to 50.00], D-3 [–2.00 to –2.99] and D-4 [–3.00 to –50.00]. Possible relationships between the EL and approximation level III (special orientation) exercises were obtained in D-3 (r = .85; p = .03), D-4 (r = .98; p = <.01), A-3 (r = 1.00; p = <.01), TOTAL A-D 3 (r = .96; p = <.01) and TOTAL A-D 3-4 (r = .97; p = <.01). Linear regression analysis demonstrated possible causalities between EL and Level III exercises at D-3 (R^2 = .73), D-4 (R^2 = .97), A-3 (R^2 = .99), TOTAL A-D 3 (R^2 = .93) and TOTAL A-D 3-4 (R^2 = .95). The results suggested that, in this specific context, Level III exercises lead to an increase in high-intensity EL. Monitoring these aspects can be useful in programming the load according to competitive demands and squad characteristics.

Keywords: accelerometry, intensity, physical demands, RPE, volume.

Introduction

External load (EL) and internal load (IL) have been presented as parameters that allow the independent assessment of competitive demands and the effect of training on athletes (Barbero-Álvarez et al., 2008; Foster et al., 2017). It is possible to assess the physical and neuromuscular demands of exercises through the EL, while the IL reflects the player's biological response to the EL (Halson, 2014). Accelerations and decelerations, assessed using accelerometry, have been identified as parameters for the measurement of EL, as they allow its quantification and control (Caparrós et al., 2018), and from them it is possible to adjust the loads of each training session through objective data (Foster et al., 2017), thus facilitating the reduction of the possible risk of injury (Caparrós et al., 2018). In order to facilitate the programming of the load based on the objectives set, these parameters can be divided into high intensity or qualitative accelerations and decelerations ($\geq \pm 2$ m/s^2), and low intensity or quantitative accelerations and decelerations ($< \pm 2$ m/s^2) (Sánchez-Ballesta et al., 2019). On the other hand, the perceived exertion index, also known as range of perceived exertion (RPE), has been established as a useful tool for the subjective monitoring of IL in futsal (Freitas et al., 2012; Haddad et al., 2017), facilitating understanding of the response of each player in relation to the applied load (Moreira et al., 2013).

Task specificity is a fundamental principle of training (Reilly et al., 2009) that allows for the control of the athlete's adaptive responses to competition and promotes the attainment of good sporting results (Moras, 2000; Vilar et al., 2014). In order to adapt the task to the skills to be worked on, it is possible to condition the game by varying the space, the rules and/or the technical-tactical aspects (López, 2017). The exercises present in a training session can be differentiated according to their similarity to competition (Moras, 2000). In this sense, there are generic orientation exercises (Level 0 and I), which do not involve cognitive demands; directed orientation exercises (Level II), which are based on movement exercises with dynamic correspondence to the sporting movement carried out using low external resistance; special orientation exercises performed with one's own body weight (Level III and IV), where Level III exercises offer reduced but decontextualised exercises of the sport itself, and Level IV exercises are simplified situations from the real game; and, finally, competitive orientation exercises (Level V), which are exercises in which the different components of performance, such as technical, tactical, physical and psychological aspects, are combined (Moras, 2000; Vizuete, 2017).

In view of these factors, it is vitally important that coaching staff adjust the planning and design of training sessions to promote the necessary adaptations so that players can successfully cope with the demands encountered during competition (Casamichana et al., 2018). In order to achieve maximum control of these adaptations, it is necessary to understand how the EL and IL of a training session of a team interact, according to the exercises performed in that session. For this reason, the aim of the present study was based on observing the possible existence of relationships between exercise approximation levels and training load. Based on the stated objective, the main hypothesis of the research has supported the idea that a higher load will be obtained in exercises with a greater similarity to that of a competition.

Methodology

Participants

The present observational and longitudinal analytical study consisted of a sample of 11 players (age: 15.55 ± 0.52) from a boys' futsal team in the first division of the Catalan Football Federation's cadet category during the competitive period of the 2019-2020 season.

All research procedures followed the standards of the Declaration of Helsinki, as revised in Fortaleza (World Medical Association, 2013). The data were collected during the daily activity of the team, and the athletes, tutors and managers were informed that they were being used for sporting purposes and also in a scientific context. Due to the young age of the sample, the legal guardians of the players signed the corresponding informed consent form. Players were assigned an individual identification code in order to conceal their identity, thereby guaranteeing the protection of personal data in accordance with the Organic Law on Data Protection 15/1999 and the General Data Protection Regulation (GDPR) of the European Parliament (14/04/2016).

Materials and Resources

EL was measured through player accelerations and decelerations using Polar Team Pro® devices, which have an integrated MEMS (accelerometer, gyroscope and digital compass) motion sensor and 10 Hz GPS, and which have proven to be valid and reliable at measuring EL in team sports (Fox et al., 2019). Each player was assigned the same sensor (Polar Team Pro Sensor®) throughout the data collection period, with the sensor positioned on the chest using the brand's own elastic bands (Sánchez-Ballesta et al., 2019). The collected data was sent via bluetooth to a mobile device (iPad) and stored in the brand's own app for further analysis using the Polar Team Pro® software (https://teampro.polar.com; Kempele, Finland). Four levels of accelerations were recorded with these sensors (A-1 encompassed accelerations from 0.50 m/^{2} o 0.99 m/s^2; A-2 from 1 m/s^2 to 1.99 m/s^2; A-3 those from 2 m/s^2 to 2.99 m/s^2, and A-4 those from 3 m/s^2 to 50 m/s^2) and four decelerations (D-1 included those from –0.50 m/s^2 to –0.99 m/s^2; D-2 those from –1 m/s^2 to –1.99 m/s^2; D-3 those from –2 m/s^2 to –2.99m/s^2, and D-4 those from –3m/s^2 to –50m/s^2). This EL was categorised according to intensity, with level one and two (1-2) as low intensity, and level three and four (3-4) as high intensity. From these levels, the values were grouped as follows: total accelerations (Total A, sum of A-1, A-2, A-3 and A-4); total decelerations (Total D, sum of D-1, D-2, D-3 and D-4); total accelerations and decelerations (Total A-D, sum of Total A and Total D); total accelerations and decelerations level three (Total A-D 3, sum of A-3 and D-3); total accelerations and decelerations level three and four (Total A-D 3-4, sum of A-3, A-4, D-3 and D-4), and total accelerations and decelerations level one and two (Total A-D 1-2, sum of A-1, A-2, D-1 and D-2) (Sánchez-Ballesta et al. , 2019).

IL was measured using the RPE subjective rating system, which has demonstrated high validity and reliability in relation to perceived exertion (Haddad et al., 2017). The results were recorded on a record sheet and players scored according to the RPE following Borg's CR-10 scale of 0-10, where zero (0) was considered "none at all" and ten (10), "extremely high" (Borg, 1990).

Based on the adaptation of the classification of approximation levels provided by Moras (2000) and Vizuete (2017), the specificity of the exercises was determined starting from Level III, Level IV and Level V. The space used varied according to the exercise, and was performed on a 40 x 20 m (1/1), 30 x 20 m (2/3) or 20 x 20 m (1/2) track.

Procedure

Data recording was carried out over 7 consecutive weeks, during the competitive period (October-December). Within this recording period, during which the players had a training schedule of 3 hours per week, 10 training sessions were analysed, resulting in a total of 550 minutes recorded and an average time per exercise of 12 minutes. All sessions started and ended with standardised off-court actions, which have been excluded from the analysis.

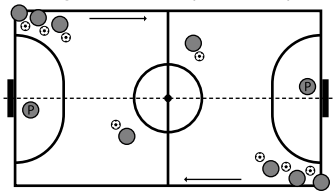
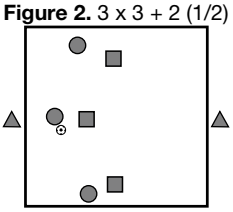
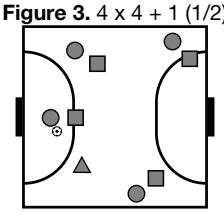
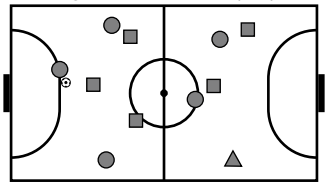
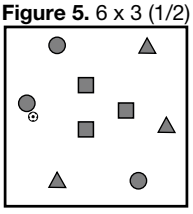
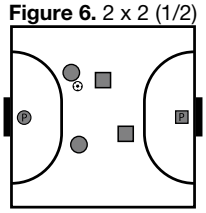
The recording of the EL started at the beginning of the on-track training and ended at the end of the training, enabling the recording of all tasks. IL, which was recorded with the RPE system, was observed 20 minutes before the start of training (Pre-RPE) and 10 minutes after the end of training (Post-RPE) (Bickelhaupt et al., 2018). In order to familiarise the players with the RPE system, they were instructed by professionals used to working with this recording system, who explained each section of the system in detail and provided support in the event that a player requested it, during four training sessions (Borg, 1990).

During the training session exercises, the groupings of partners and opponents were randomly varied. These exercises have been organised according to the adaptation of the classifications of Moras (2000) and Vizuete (2017) according to the following levels: Level III (special orientation) exercises accounted for a total of six (1 x 0 1/1, 1 x 0 2/3, 3 x 3 + 2 1/2, 4 x 4 + 1 1/2, 5 x 5 + 1 1/1 and 6 x 3 1/2); four Level IV (special orientation) 2 x 2 1/2, 2 x 2 + 2 1/2, 3 x 3 2/3 and 3 x 3 + 1 1/2); and five Level V (competitive orientation) ((3 x 2 1/1, 4 x 4 1/1, 4 x 4 - E 1/1, 4 x 4 2/3 and 5 x 4 1/2) (Table 1).

Statistical Analysis

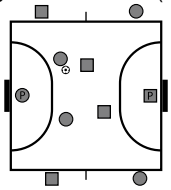
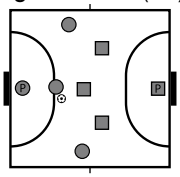
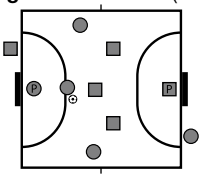
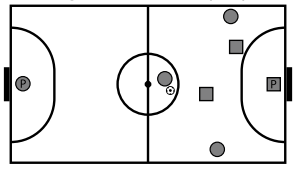
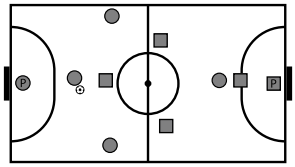
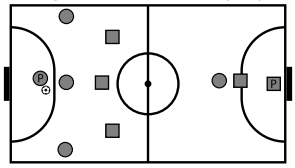
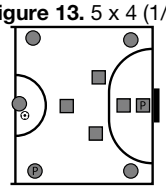
A descriptive analysis of general central tendency was performed. Subsequently, the normality of the variables studied was determined using the Shapiro-Wilk test, which revealed normal and non-normal distributions. The independence of the average values per session was analysed using the Kruskal-Wallis test for the set of variables relating to training sessions and exercises grouped according to their specificity. Independence between sessions was assessed with the Friedman test. Possible relationships among the mean values per minute per session or per exercise were determined with Pearson's r for normal data and Spearman's rho for non-normal data. Finally, multiple linear regression was used to determine the possible causality of the average values per minute per session or per exercise. The significance level in all cases was $p < .05$. Descriptive values are expressed as mean ± standard deviation. All statistical analyses were performed using JASP software (JASP Team, Amsterdam, 2019, version 0.11.1).

Table 1
Characteristics of exercises carried out during the study.

Exercise (Space)	Specificity	Description	Graphic representation
1 x 0 (1/1 or 2/3)	Level III (Directed orientation)	Drills for driving and striking the ball at goal.	**Figure 1.** 1 x 0 (1/1 or 2/3) 
3 x 3 + 2 (1/2)	Level III (Directed orientation)	Ball retention with outside support.	**Figure 2.** 3 x 3 + 2 (1/2) 
4 x 4 + 1 (1/2)	Level III (Directed orientation)	Offensive and defensive actions without goalkeepers. Scoring only permitted inside the penalty area.	**Figure 3.** 4 x 4 + 1 (1/2) 
5 x 5 + 1 (1/1)	Level III (Directed orientation)	Offensive and defensive actions without goalkeepers. Scoring only permitted inside the penalty area.	**Figure 4.** 5 x 5 + 1 (1/1) 
6 x 3 (1/2)	Level III (Directed orientation)	Retention. 2 offensive and 1 defensive team. Change of role after the ball is stolen.	**Figure 5.** 6 x 3 (1/2) 
2 x 2 (1/2)	Level IV (Directed orientation)	Simulated 2 x 2 game situation on 20 x 20 m.	**Figure 6.** 2 x 2 (1/2) 

Caption: 1/1 = 40 x 20 m; 2/3 = 30 x 20 m; 1/2 = 20 x 20 m; ● = Team 1; Ⓟ = Team 1 Goalkeeper; ■ = Team 2; Ⓟ = Team 2 Goalkeeper; ▲ = Joker (support player for both teams in the offensive phase)

Table 1 (Continued)
Characteristics of exercises carried out during the study.

Exercise (Space)	Specificity	Description	Graphic representation
2 x 2 + 2 (1/2)	Level IV (Directed orientation)	Simulated 2 x 2 situation with wing backs in the offensive zone.	**Figure 7.** 2 x 2 + 2 (1/2) 
3 x 3 (1/2)	Level IV (Directed orientation)	Simulated 3 x 3 situation.	**Figure 8.** 3 x 3 (1/2) 
3 x 3 + 1 (1/2)	Level IV (Directed orientation)	Simulated 3 x 3 situation with offensive support on the baseline.	**Figure 9.** 3 x 3 + 1 (1/2) 
3 x 2 (1/1)	Level V (Competitive orientation)	3 x 2 drills with a psychological component due to limited time for completion.	**Figure 10.** 3 x 2 (1/1) 
4 x 4 (1/1 or 2/3)	Level V (Competitive orientation)	Real-life game situation.	**Figure 11.** 4 x 4 (1/1 or 2/3) 
4 x 4 -E (1/1)	Level V (Competitive orientation)	Real life game situation with each action starting from a goal kick.	**Figure 12.** 4 x 4 - E (1/1) 
5 x 4 (1/2)	Level V (Competitive orientation)	Real-life "goalkeeper-player" game situation with time limitation.	**Figure 13.** 5 x 4 (1/2) 

Caption: 1/1 = 40 x 20 m; 2/3 = 30 x 20 m; 1/2 = 20 x 20 m; ● = Team 1; Ⓟ = Team 1 Goalkeeper; ■ = Team 2; Ⓟ = Team 2 Goalkeeper; ▲ = Joker (support player for both teams in the offensive phase)

Results

A total of 382 observations were obtained during the 10 recorded sessions. The EL, expressed as the average of the total accelerations and decelerations performed per player, was 1,004.52 ± 200 m/s²; and the IL, expressed as the average RPE exhibited by each player at the end of the training, was 7.58 ± 0.37. In terms of the specificity of the exercises, six Level III exercises were performed, resulting in 135 observations; four Level IV exercises were performed, resulting in 81 observations; and five Level V exercises were performed, resulting in a total of 166 observations. In the descriptive analysis of EL, the highest value per player of Total A-D was for the 6 x 3 1/2 (26.86 ± 1.15 m/s²) and the lowest for the 5 x 4 1/2 (16.44 ± 1.81 m/s²). For Total A-D 3-4, the highest value was shown for6 x 3 1/2 (3.85 ± 0.30 m/s²) and the lowest for 1 x 0 1/1 (0.61 ± 0.13 m/s²) (Figure 14). Finally, the highest value in Total A-D 1-2 was for 6 x 3 1/2 (23.02 ± 0.86 m/s²) and the lowest for 4 x 4 + 1 1/2 (14.57 ± 1.43 m/s²) (Table 2).

The independence of the variables was observed for the approximation levels (H = 36.32; $p < .01$); as well as for the EL of each player in D-2 (H = 19; $p = .40$), D-3 (H = 48.63; $p < .01$), D-4 (H = 62.51; $p < .01$), A-1 (H = 29.83; $p < .01$), A-2 (H = 29.77; $p < .01$), A-3 (H = 66.75; $p < .01$), A-4 (H = 23.32; $p = .01$), Total A-D 3 (H = 62.08; $p < .01$) and Total A-D 3-4 (H = 62.56; $p < .01$), and for each player's IL in Pre-RPE (H = 23.79; $p = .01$) and Post-RPE (H = 41.93; $p < .01$). Similarly, EL and IL behaved independently in each specific training session (F = 159.15; $p < .01$; $\eta^2 = .96$ $\varpi^2 = .94$).

Regarding the possible relationships between EL and approximation levels, relationships were observed for Level III in D-3 ($r = .85$; $p = .03$), D-4 ($r = .98$; $p < .01$), A-3 ($r = 1$; $p < .01$), Total A-D 3 ($r = .96$; $p < .01$) and Total A-D 3-4 ($r = .97$; $p < .01$); for Level IV at D-1 ($r = –.96$; $p = .04$); and for Level V at A-3 (*rho* = –1; $p = .02$) (Table 3).

Figure 14
Total accelerations and decelerations (Total A-D) and totals 3 and 4 (Total A-D 3-4) per minute of the exercises.

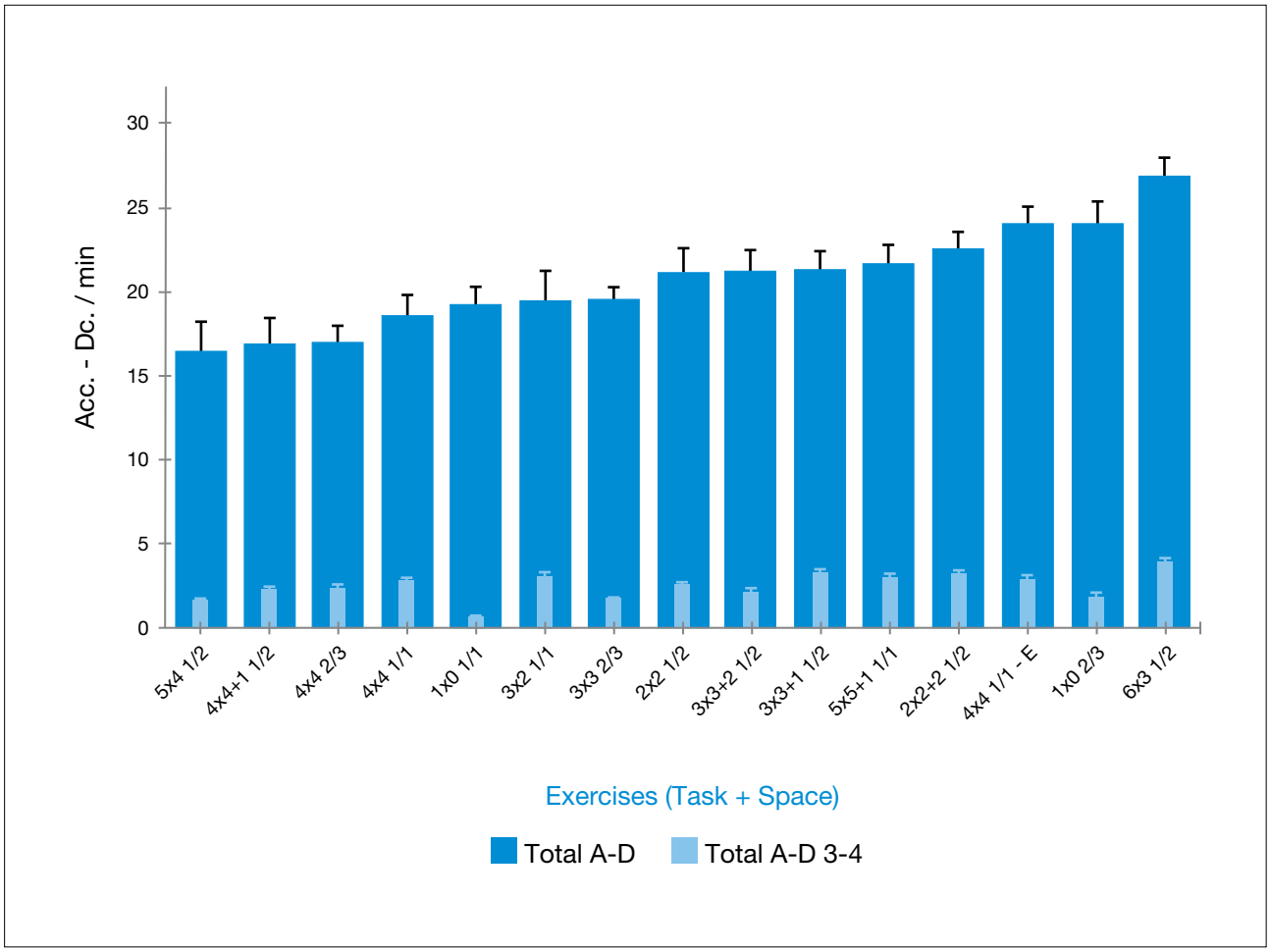


Table 2
*Total accelerations and decelerations (mean and SD) per player recorded in the training sessions, according to the level of approximation (adapted from Moras (2000) and Vizuete (2017)), intensity and exercise of the 11 training-age fustal players participating in the study (*n = 382*).*

Approximation levels	No. of observations	D-1	D-2	D-3	D-4	A-1	A-2
	n	Mean ± SD (m/s²)	Mean ± SD (m/s²)	Mean ± SD (m/s²)	Mean ± SD (m/s²)	Mean ± SD (m/s²)	Mean ± SD (m/s²)
Level III (Specific orientation)							
1 x 0 1/1	17	4.65 ± 0.24	4.71 ± 0.08	0.40 ± 0.10	0 ± 0	5.25 ± 0.42	4.03 ± 0.24
1 x 0 2/3	21	5.41 ± 0.12	5.65 ± 0.29	1.21 ± 0.25	0.03 ± 0.01	5.70 ± 0.24	5.54 ± 0.37
3 x 3+2 1/2	21	4.57 ± 0.18	5.18 ± 0.28	1.10 ± 0.19	0.13 ± 0.03	4.63 ± 0.21	4.77 ± 0.29
4 x 4 + 1 1/2	32	3.43 ± 0.36	3.86 ± 0.29	0.99 ± 0.10	0.25 ± 0.02	3.94 ± 0.39	3.33 ± 0.39
5 x 5 + 1 1/1	33	4.41 ± 0.24	4.77 ± 0.19	1.37 ± 0.17	0.26 ± 0.04	5.07 ± 0.20	4.44 ± 0.22
6 x 3 1/2	11	5.41 ± 0.15	6.14 ± 0.26	1.79 ± 0.12	0.38 ± 0.04	5.20 ± 0.17	6.27 ± 0.27
Level IV (Specific orientation)							
2 x 2 1/2	19	4.84 ± 0.33	4.65 ± 0.25	1.19 ± 0.13	0.18 ± 0.02	5.12 ± 0.33	4.01 ± 0.36
2 x 2 + 2 1/2	10	4.61 ± 0.27	5.10 ± 0.29	1.42 ± 0.10	0.31 ± 0.04	4.65 ± 0.24	4.90 ± 0.24
3 x 3 2/3	21	4.33 ± 0.10	4.42 ± 0.10	0.84 ± 0.09	0.17 ± 0.01	4.84 ± 0.27	4.29 ± 0.17
3 x 3 + 1 1/2	31	4.30 ± 0.31	4.47 ± 0.17	1.41 ± 0.13	0.38 ± 0.04	4.86 ± 0.21	4.38 ± 0.24
Level V (Competitive orientation)							
3 x 2 1/1	11	4.29 ± 0.39	4.06 ± 0.40	1.43 ± 0.14	0.20 ± 0.01	4.44 ± 0.35	3.61 ± 0.42
4 x 4 1/1	82	4.00 ± 0.27	4.00 ± 0.29	1.18 ± 0.10	0.27 ± 0.03	4.13 ± 0.23	3.65 ± 0.29
4 x 4 - E 1/1	41	4.90 ± 0.16	5.28 ± 0.20	1.50 ± 0.18	0.18 ± 0.03	5.92 ± 0.18	5.06 ± 0.27
4 x 4 2/3	21	3.70 ± 0.19	3.64 ± 0.19	0.99 ± 0.14	0.20 ± 0.01	4.41 ± 0.23	2.93 ± 0.15
5 x 4 1/2	11	3.16 ± 0.35	4.02 ± 0.35	0.87 ± 0.11	0.10 ± 0.01	4.16 ± 0.34	3.49 ± 0.63

Acceleration and deceleration data expressed in m/s². Legend: SD=Standard deviation; D-1=decelerations 1 (–-0.50 - –0.99 m/s²); D-2=decelerations 2 (–1 - –1.99 m/s²); D-3=decelerations 3 (–2 - –2.99 m/s²); D-4=decelerations 4 4 (–3 - –50 m/s²); A-1=accelerations 1 (0.50 - 0.99 m/s²); A-2 accelerations 2 (1 - 1.99 m/s²).

Table 2 (Continued)
*Total accelerations and decelerations (mean and SD) per player recorded in the training sessions, according to the level of approximation (adapted from Moras (2000) and Vizuete (2017)), intensity and exercise of the 11 training-age futsal players participating in the study (*n = 382*).*

Approximation levels	No. of observations	A-3	A-4	TOT A-D	TOT A-D 3	TOT A-D 3-4	TOT A-D 1-2
	n	Mean ± SD (m/s²)	Mean ± SD (m/s²)	Mean ± SD (m/s²)	Mean ± SD (m/s²)	Mean ± SD (m/s²)	Mean ± SD (m/s²)
Level III (Specific orientation)							
1 x 0 1/1	17	0.21 ± 0.02	0 ± 0	19.24 ± 1.10	0.61 ± 0.13	0.61 ± 0.13	18.63 ± 0.97
1 x 0 2/3	21	0.51 ± 0.11	0 ± 0	24.05 ± 1.38	1.72 ± 0.36	1.74 ± 0.37	22.31 ± 1.02
3 x 3+2 1/2	21	0.84 ± 0.09	0 ± 0	21.21 ± 1.26	1.94 ± 0.28	2.07 ± 0.31	19.14 ± 0.96
4 x 4 + 1 1/2	32	1.05 ± 0.05	0 ± 0	16.85 ± 1.60	2.04 ± 0.16	2.29 ± 0.17	14.57 ± 1.43
5 x 5 + 1 1/1	33	1.30 ± 0.09	0 ± 0	21.63 ± 1.16	2.67 ± 0.26	2.93 ± 0.30	18.70 ± 0.86
6 x 3 1/2	11	1.68 ± 0.14	0 ± 0	26.86 ± 1.15	3.46 ± 0.26	3.85 ± 0.30	23.02 ± 0.86
Level IV (Specific orientation)							
2 x 2 1/2	19	1.12 ± 0.09	0 ± 0	21.12 ± 1.50	2.31 ± 0.21	2.49 ± 0.23	18.63 ± 1.27
2 x 2 + 2 1/2	10	1.43 ± 0.11	0 ± 0	22.43 ± 1.18	2.85 ± 0.20	3.17 ± 0.24	19.26 ± 0.94
3 x 3 2/3	21	0.65 ± 0.04	0 ± 0	19.54 ± 0.78	1.49 ± 0.13	1.66 ± 0.14	17.88 ± 0.65
3 x 3 + 1 1/2	31	1.48 ± 0.07	0 ± 0	21.27 ± 1.16	2.88 ± 0.20	3.26 ± 0.24	18.00 ± 0.93
Level V (Competitive orientation)							
3 x 2 1/1	11	1.40 ± 0.16	0 ± 0	19.41 ± 1.88	2.82 ± 0.30	3.02 ± 0.31	16.39 ± 1.56
4 x 4 1/1	82	1.29 ± 0.10	0 ± 0	18.52 ± 1.31	2.47 ± 0.20	2.74 ± 0.23	15.78 ± 1.08
4 x 4 - E 1/1	41	1.15 ± 0.08	0 ± 0	23.99 ± 1.11	2.65 ± 0.26	2.83 ± 0.29	21.16 ± 0.81
4 x 4 2/3	21	1.09 ± 0.13	0 ± 0	16.95 ± 1.04	2.08 ± 0.27	2.28 ± 0.28	14.67 ± 0.76
5 x 4 1/2	11	0.63 ± 0.02	0 ± 0	16.44 ± 1.81	1.50 ± 0.13	1.60 ± 0.14	14.84 ± 1.67

Acceleration and deceleration data expressed in m/s². Caption: SD=Standard deviation; A-3=accelerations 3 (2.00 – 2.99 m/s²); A-4=accelerations 4 (3.00 – 50.00 m/s²); TOT A-D 3=Total accelerations and decelerations 3 (±2.00 – ±2.99 m/s²); TOT A-D 3-4=Total accelerations and decelerations 3 and 4 (≥ ±2.00 m/s²); TOT A-D 1-2=Total accelerations and decelerations 1 and 2 (< 2.00 m/s²).

Table 3
Relationship of EL of the exercises (n = 382) with the level of approximation.

	Approximation levels					
	Level III (*n* = 13)		Level IV (*n* = 8)		Level V (*n* = 16)	
D-1	*r*	–.02	*r*	**–.96***	*rho*	–.70
D-2	*r*	.21	*r*	–.51	*rho*	–.30
D-3	*r*	**.85***	*r*	.04	*rho*	–.70
D-4	*r*	**.98****	*r*	.58	*rho*	–.67
A-1	*r*	–.25	*r*	–.39	*rho*	–.20
A-2	*r*	.33	*r*	.17	*rho*	–.50
A-3	*r*	**1.00****	*r*	.10	*rho*	**-1.00****
A-4	*r*	.00	*r*	.00	*rho*	.00
Total A	*r*	.43	*r*	.04	*rho*	–.70
Total D	*r*	.38	*r*	–.48	*rho*	–.70
Total A-D	*r*	.40	*r*	–.27	*rho*	–.70
Total A-D 3	*r*	**.96***	*r*	.10	*rho*	–.90
Total A-D 3-4	*r*	**.97***	*r*	.14	*rho*	–.90
Total A-D 1-2	*r*	.12	*r*	-.66	*rho*	–.60

* $p < .05$; ** $p < .01$
Caption: D-1=decelerations 1 (–0.50 - –0.99 m/s²); D-2=decelerations 2 (–1 - –1.99 m/s²); D-3=decelerations 3 (–2 - –2.99 m/s²); D-4=decelerations 4 (–3 - –50 m/s²); A-1=accelerations 1 (0.5z0 - 0.99 m/s²); A-2=accelerations 2 (1 - 1.99 m/s²); A-3=accelerations 3 (2 - 2.99 m/s²); A-4=accelerations 4 (3 - 50 m/s²); Total A=Total accelerations; Total D=Total decelerations; Total A-D=Total accelerations and decelerations; Total A-D 3=Total accelerations and decelerations 3 (±2 - ±2.99 m/s²); Total A-D 3-4=Total accelerations and decelerations 3 and 4 (±2 - ±50 m/s²); Total A-D 1-2=Total accelerations and decelerations 1 and 2 (±0.50 - ±1.99 m/s²).

Table 4
Relationship between IL and training EL (n = 10).

	Perceived Effort Index			
	Pre		Post	
D-1	*rho*	–.02	*rho*	**.70***
D-2	*rho*	–.15	*rho*	.30
D-3	*rho*	–.62	*rho*	.38
D-4	*rho*	–.38	*rho*	.44
A-1	*rho*	.16	*rho*	.48
A-2	*rho*	–.29	*rho*	.36
A-3	*rho*	**–.84***	*rho*	.23
A-4	*rho*	–.17	*rho*	–.24
Total A	*rho*	–.27	*rho*	.53
Total D	*rho*	–.26	*rho*	.57
Total A-D	*rho*	–.27	*rho*	.53
Total A-D 3	*rho*	**–.80***	*rho*	.23
Total A-D 3-4	*rho*	**–.74***	*rho*	.27
Total A-D 1-2	*rho*	–.20	*rho*	.42

* $p < .05$; ** $p < .01$
Caption: D-1=decelerations 1 (–0.50 - –0.99 m/s²); D-2=decelerations 2 (–1 - –1.99 m/s²); D-3=decelerations 3 (–2 - –2.99 m/s²); D-4=decelerations 4 (–3 - –50 m/s²); A-1=accelerations 1 (0.5z0 - 0.99 m/s²); A-2=accelerations 2 (1 - 1.99 m/s²); A-3=accelerations 3 (2 - 2.99 m/s²); A-4=accelerations 4 (3 - 50 m/s²); Total A=Total accelerations; Total D=Total decelerations; Total A-D=Total accelerations and decelerations; Total A-D 3=Total accelerations and decelerations 3 (±2 - ±2.99 m/s²); Total A-D 3-4=Total accelerations and decelerations 3 and 4 (±2 - ±50 m/s²); Total A-D 1-2=Total accelerations and decelerations 1 and 2 (±0.50 - ±1.99 m/s²).

On the other hand, the IL was associated with the EL of training sessions (n = 10). Regarding the relationships between IL and EL, relationships were observed in Pre-RPE-in A-3 (rho = –.84; p < .01), Total A-D 3 (rho = –.80; p < .01), Total A-D 3-4 (rho = –.74; p = .02), and in Post-RPE, a relationship was observed in D-1 (rho = .70; p = .03) (Table 4).

Finally, from the linear regression study, possible causalities were found between the EL of Level III exercises with D-3 (R^2 = .73), D-4 (R^2 = .97), A-3 (R^2 = .99), TOTAL A-D 3 (R^2 = .93), TOTAL A-D 3-4 (R^2 = .95), and those of Level IV with D-1 (R^2 = .93).

Discussion

The main finding of the present study is the causality found between high-intensity EL and Level III (special orientation) exercises, the qualitative and quantitative nature of the exercises analysed, and the limited relationship between IL and EL for this group of training-age players.

The multifactorial and complex nature of the adaptive processes of sportsmen and sportswomen generates the need for training with varying levels of approximation (Vizuete, 2017), which can be a useful tool for load programming (Colby et al., 2014). In this context, it has been observed that the relationships have been mainly qualitative (high intensity), with significant relationships (p < .05) between qualitative EL (high intensity accelerations and decelerations) and Level III and Level V exercises (Sánchez-Ballesta et al., 2019). Based on the results obtained in the Level III exercises, and taking into account the characteristics of the sample, in the present research it has been possible to demonstrate causality (R^2 > .70) of these data through linear regression. These results suggest that it would be possible to adjust the exercise programming of training sessions towards a qualitative (high intensity) approach through the application of approximation levels.

The identification of the qualitative or quantitative nature of the different exercises proposed has provided a more objective view of the EL according to their level of approximation. Based on the results obtained, it was found that there is no clear pattern in relation to the EL and the approximation level of the exercises (Sánchez-Ballesta et al., 2019). Despite this, the results have shown that the exercises most similar to those in competition are not the ones with the highest load quality or quantity. This finding may lead to a conceptual change and allow Level III exercises to be carried out with an intensive objective as well.

IL management based on the index of perceived exertion has been found to be an effective method for intensity quantification (Freitas et al., 2012). However, based on the results obtained in this study, the RPE does not appear to be a reliable method for IL management in training age groups in futsal due to the great variability presented by the players and the limited relationship found between IL and EL. Although this assessment system has shown its usefulness and effectiveness in the evaluation of the fitness of athletes in team and individual sports (Ibáñez et al., 2020), it has also been observed that type of training can influence individualised perception, independently of physiological perception, of intensity during training (Fox et al., 2017) and competition (Brito et al., 2016), demonstrating alterations in the reliability of this method, as well as in relation to gender and experience.

The possibility of revealing relationships between the variables of EL, IL and exercise approximation levels could facilitate the planning of training sessions (Colby et al., 2014) towards a qualitative (high intensity) or quantitative (low intensity) approach (Sánchez-Ballesta et al., 2019), taking into account the accumulated stress or fatigue that the player may present regarding the proposed EL (Sansone et al., 2019), which would allow for performance improvement and reduce the potential risk of injury (Soligard et al., 2016).

The present research allows us to assess data independently (Impellizzeri et al., 2019; San Román-Quintana et al., 2014), as these results (p < .05) could indicate that the variables do not follow any particular pattern with respect to the set of exercises, just as each level of approximation is also specific in its behaviour, both for EL and IL.

The limitations of this study are mainly focused on the impossibility of comparing the data extracted in training with that obtained in competition, due to the prohibition of using accelerometers during matches in training categories. In turn, players' unfamiliarity with the RPE system for recording IL may have conditioned the result of certain ranges. Finally, it would be necessary to analyse other samples of the same age in order to be able to affirm that the results apply to all players in the category.

Conclusions

Relationships and causality have been found between the EL and planning variables related to exercise specificity, especially at Level III. Another factor observed from the results is the variability between qualitative (high intensity accelerations and decelerations) and quantitative (low intensity accelerations and decelerations) EL in the same exercise. Finally, in the present study, it was not possible to establish relationships between the RPE, as an IL variable, and the EL or the specificity of the exercises.

Practical applications

Load control is a tool used in the field of performance, injury prevention and rehabilitation (Sánchez-Ballesta et al., 2019), enabling the design of tasks/exercises for training by applying qualitative and quantitative loads according to the characteristics of the competition and the squad. To regulate the adaptive responses of such a squad, the appropriate application of the Moras (2000) and Vizuete (2017) approximation levels can be an effective tool with which to condition the qualitative (high intensity) and quantitative (low intensity) load of the session.

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Hysteresis Area of Psychobiological Variables. A New Non-Invasive Biomarker of Effort Accumulation?

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A young sprinter prepares herself with a track series to work on her explosiveness. @Jérome Aufort/Adobestock

Abstract

The hysteresis area, which reflects the history-dependency of psychobiological parameters, has been recently suggested as a new non-invasive marker of exercise stress and tolerance. However, its promising applications are still underexplored. This study aims to test if the hysteresis area of the perceived exertion (RPE), heart rate (HR), and muscle oxyhaemoglobin concentration (muscle O_2Hb) are sensitive to effort accumulation over multiple bouts of running exercise. Ten physical education students performed five consecutive running bouts at maximal aerobic velocity. The consecutive bouts started when participants reported at least an RPE ≤ 11 (Borg's 6-20 scale). The hysteresis areas of RPE, HR, and muscle O_2Hb were calculated for each bout, and their magnitude was compared using Friedman ANOVA and Wilcoxon test. Effect sizes were calculated through Cohen's *d*. The hysteresis areas of all studied variables changed between the initial and final bouts: RPE and HR increased (between bouts 1-4: $Z = -1.99$, $p = .04$; $Z = -2.19$, $p = .03$, respectively), and muscle O_2Hb decreased (between bouts 1-4: $Z = -2.80$, $p < .01$). Large effect sizes ($d = 1.22$ - 1.81) were found in HR between bouts 1-4, 1-5, 2-4, 2-5, and muscle O_2Hb between bouts 1-4 and 1-5. The results showed that the hysteresis areas of RPE, HR, and muscle O_2Hb were sensitive to effort accumulation during repeated running exercises performed at maximal aerobic velocity. Despite further research is warranted, the hysteresis area of psychobiological variables points towards being a sensitive biomarker for monitoring acute fatigue.

Keywords: complex adaptive systems, fatigue, history-dependency, recovery efficiency, sports monitoring, training.

Introduction

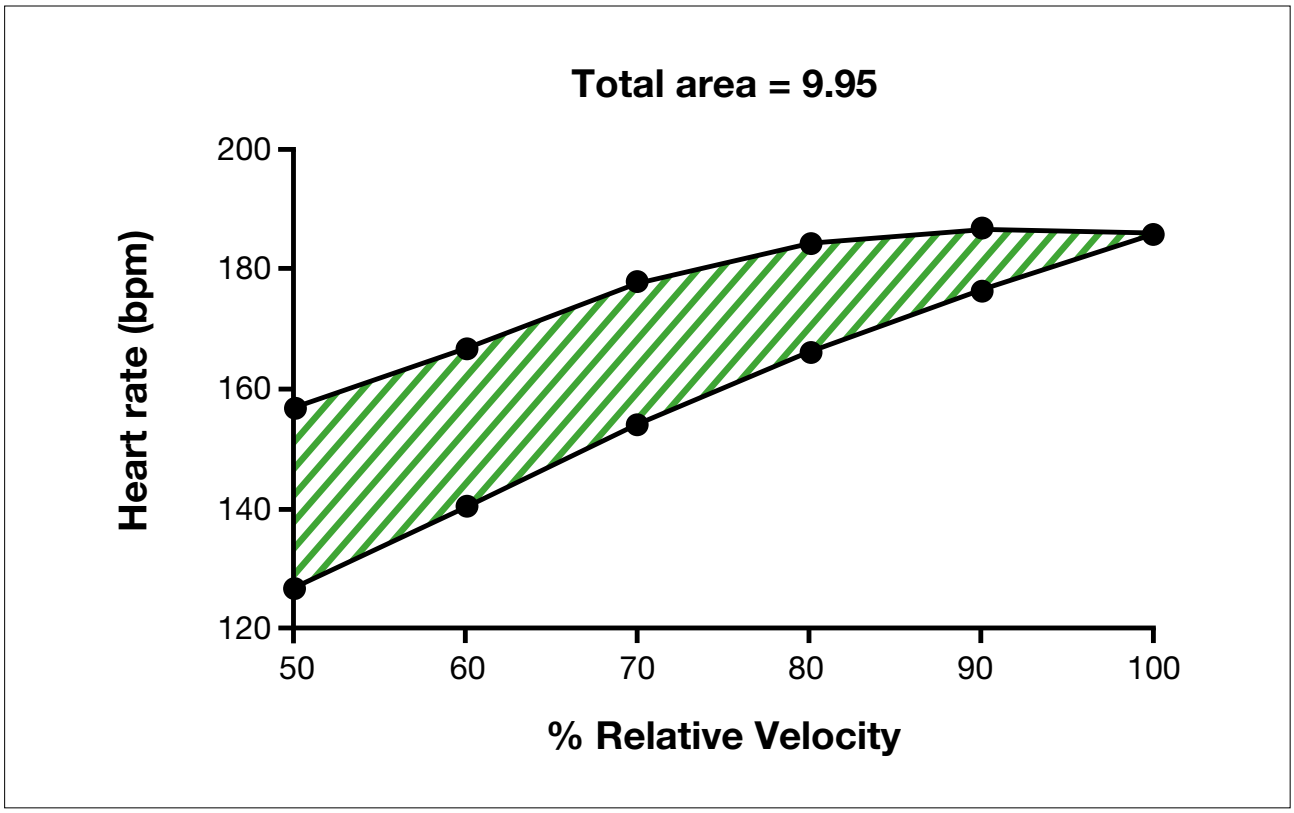
In biology, the hysteresis phenomenon refers to the history-dependency (i.e., path-dependency) of the system under study, a hallmark of its complex nature. Featured by self-organized and nonlinear dynamics (Hristovski et al., 2010, 2014), it is often ignored in exercise monitoring and exercise science (Balagué et al., 2020). It explains how the studied parameter returns to its initial state with a certain delay after being perturbed and why several states of this parameter may coexist for the same quantitative value. For instance, the same lactic acid concentration value can be found in two different physiological conditions: during exercise and at rest (e.g., during exercise recovery). The phenomenon occurs because the system depends on its history, consequently, the preferred behavioural trajectories of the studied variable are different when the control parameter is being systematically varied in opposite directions (Hristovski et al., 2014).

The hysteresis phenomenon of diverse parameters has been studied in different health-related fields such as physiology (Liu et al., 2014), biomechanics (Butler et al., 1978), and medicine (Cabasson et al., 2012). Recently, the hysteresis behaviour of psychobiological variables has been proposed as a non-invasive marker of exercise workload stress and tolerance (Montull et al., 2020) and has been applied to study the detraining effects of standardized training programs (Martín-Guillaumes et al., 2021). However, its applications and monitoring possibilities are still underexplored.

The hysteresis of a specific variable can be quantified through the hysteresis area, which reflects the amount of dissipated energy after the variable recovery (Mayergoyz, 2003). Figure 1 represents the hysteresis area by the space between the incremental and decremental phases of a pyramidal effort protocol. Montull et al. (2020) showed that a lower hysteresis area of rating of perceived exertion (RPE) and heart rate (HR) is associated with higher athlete's expertise and higher recovery efficiency. Accordingly, the authors suggested that the hysteresis area of psychobiological variables may also be sensitive to the effort accumulation, which is hardly captured through current conventional data analysis techniques and assessment protocols (Halson, 2014).

Considering fatigue as a product of multidimensional, multiscale and environmental-dependent network interactions, the commonly provided fixed quantitative

Figure 1
Example of heart rate displaying hysteresis effect provoked by the increasing and, subsequently, decreasing relative velocity (control parameter) of a pyramidal running exercise. Adapted from Montull et al. (2020), with permission.



values of isolated variables or multiple timeless metrics to define it, may be insufficient and often imprecise to inform about it (Balagué et al., 2020). This timeless assessment, based on an oversimplified and distorted conception of the organism as a complex adaptive system (CAS), ignores the nonlinear and fluctuating dynamics of athletes' behaviour and the idiosyncrasy of their dynamic responses to exercise (Nesselroade & Molenaar, 2010). For this reason, the network physiology of exercise framework promotes the assessment of CAS' properties like the hysteresis and the use of individual time series analysis for assessing physiological states (Balagué et al., 2020).

The ignorance of the hysteresis response in specific types of training like interval training may lead to an inadequate prescription of bouts of exercise and recovery times. Exercise bouts are commonly based on preestablished intensities and fixed psychobiological values (e.g., HR corresponding to the anaerobic threshold) and the recovery times on fixed metabolic-based assumptions (e.g., phosphagen system lasts 2-5 min to be recharged) (Wilmore et al., 2008).

The hysteresis response to exercise is far unknown. Only RPE, HR, and a few related variables explored for cardiovascular disease detection (Cabasson et al., 2012) have been studied. The hysteresis area of muscle oxygen saturation (muscle O_2Hb) (Hamaoka et al., 2011) may add information about how CAS compensate at microscopic level the increasing demands of an accumulated effort.

In view of the above, this study aimed to test the sensitiveness of the hysteresis area of the RPE, HR, and muscle O_2Hb to effort accumulation over multiple bouts of running exercise. The hypothesis is that RPE and HR areas will increase over the bouts, while muscle O_2Hb areas will decrease because the accumulated effort reduces oxygen saturation.

Methodology

Participants

Ten volunteer sport science students (five males and five females: 20.50 ± 2.22 years; 1.74 ± 0.08 m; 64.25 ± 11.57 kg), exercising between five and eight h/week, and following a healthy and active lifestyle participated in the study. A large effect size $\rho = 1$, $\alpha = .05$, and power $(1-\beta) = .85$ was used to determine the sample size. All experimental procedures were explained to participants before they gave their written consent to participate. The experiment was approved by the Local Research Ethics Committee of the Sports Administration of Catalonia (072015CEICEGC) and carried out according to the Helsinki Declaration.

Testing protocols

Maximal aerobic velocity (MAV) test

An incremental and maximal treadmill test (h/p Cosmos Pulsar 3p®) was performed to obtain the MAV of each participant. The test started at 8 km/h for males and 6 km/h for females, and the velocity was increased 1 km/h every 100 s until they could not keep the imposed velocity. The final velocity maintained along the 100 s was considered the MAV. This test was also used to familiarise the participants with Borg's 6-to-20 RPE scale.

Multiple bouts test

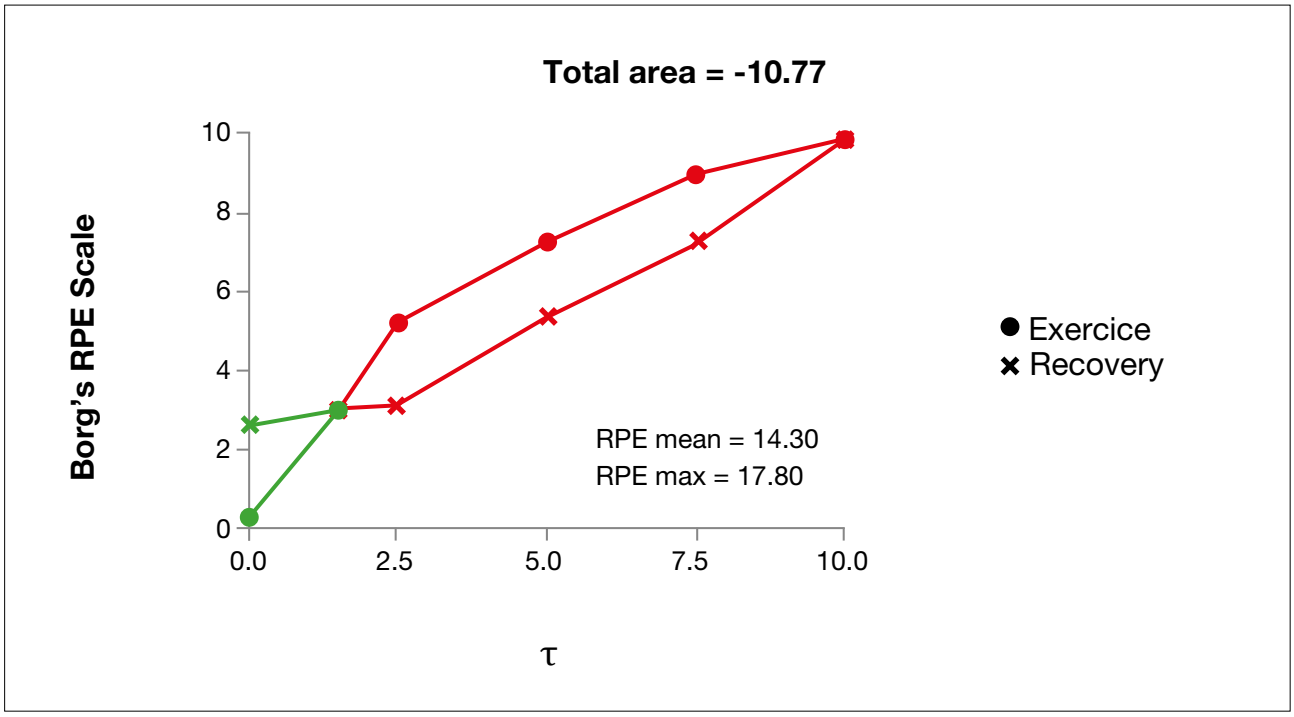
One week after performing the MAV test, they performed the multiple bouts test. After a warm-up of 5 min at 8 km/h, participants performed five consecutive running bouts of 100 s at 100% of MAV (30 to 120 s is recommended for tests of lactic anaerobic capacity, Medbo & Tabata, 1993). They rested between bouts until they recorded RPE ≤ 11 (light) in a 6-to-20 Borg scale. After each bout, they responded to the question: "What is your perceived exertion at this moment?". The Borg's 6-to-20 RPE scale was placed in a visible place.

Participants were not informed about the number of bouts they had to perform to avoid manipulations of the recovery periods. During the test, they could not talk. At the end, they were requested about their sensations and could ask questions.

Data acquisition

HR (Polar Electro Oy, Finland) and muscle O_2Hb (PortaMon, Artinis, Medical System), as one of the most direct variables of muscle oxygen saturation (McManus et al., 2018), were continuously monitored during the exercise. PortaMon (Near-infrared spectroscopy device), recording at a sampling frequency of 10 Hz, was placed on the external vast of the quadriceps of the participants (McManus et al., 2018). The values were collected every 25 s, at the same time as RPE was recorded.

Figure 2
Example of a total hysteresis area (sum of positive "green" and negative "red" areas) of the rescaled rating of perceived exertion (RPE) in function of the time on/off task (τ) (0 = initial, 10 = maximal). It corresponds to a participant performing the first bout at the maximal aerobic velocity for 100 s (time on task) and resting for another 100 s (time off task). Mean and maximum RPE values (at the originally reported 6-to-20 scale) are also included.



Data analysis

Hysteresis areas calculation

Hysteresis areas of the studied psychobiological variables were calculated according to Montull et al. (2020). The space between the exercise and the recovery phases was considered for each variable and bout. Given that the workload was constant in all bouts of exercise and null during the recovery, the control parameter selected was the effort-recovery length (τ). It corresponded to the current time of exercise or recovery divided by the total time of exercise (100 s). The studied variables and the τ were normalized from 0 to 10 to relativize them in the same scale before calculating the areas. We calculated the total hysteresis area as the sum of positive and negative partial areas. While positive areas were considered when the recovery phase values were higher than in the exercise phase, the negative areas were considered when the recovery phase values were lower than in the exercise phase (see Figure 2 as an example). In case the recovery phase was longer than the exercise phase, we applied the same logic: until the recovery values were not lower than the initial exercise value, the area was not considered negative. Matlab R2020a was used for this calculation.

Statistical analysis

After demonstrating a non-normal distribution, Friedman ANOVA, and then, Wilcoxon test were applied to compare the differences of a) hysteresis areas among all bouts (for each variable), b) initial values of variables between the consecutive bouts, and c) hysteresis areas among the three studied variables. Cohen's *d* was also calculated for hysteresis areas and initial values of each variable between the initial (1-2) and final (4-5) bouts. According to Cohen's (1988) guidelines, $d \geq .2$, $d \geq .5$, $d \geq 0.8$, represent small, intermediate, and large effect sizes, respectively. The level of significance was set at $p \leq .05$ throughout the study. Statistical analyses were performed with SPSS v.15 (SPSS Inc., Chicago, USA).

Results

Table 1 shows the values of the hysteresis areas and initial values of RPE, HR, and muscle O_2Hb for each bout of exercise. Also, it displays how the resting recovery time between bouts increased with effort accumulation. Table 2 shows the effect sizes and significant differences in the hysteresis areas and initial values of RPE, HR, and muscle O_2Hb between the initial and final bouts.

Table 1
Median and interquartile values of the total hysteresis areas (sum of positive and negative areas) and initial values of rating of perceived exertion (RPE), heart rate (HR), and muscle oxyhaemoglobin (O_2Hb) for the five-consecutive bouts. Median and interquartile of recovery time between the bouts is also included.

Bouts	RPE		HR		Muscle O_2Hb		Recovery time (s)
	Areas	Initial values (6-to-20)	Areas	Initial values (bpm)	Areas	Initial values (μmol)	
1	–16.1 (18.07)	7.5 (1.75)	–25.42 (28.55)	147 (4.5)	58.44 (6.95)	7.11 (19)	87.5 (25)
2	–15.07 (33.2)	10.75 (1)	–11.06 (18.1)	136 (29)	43.85 (11.45)	21.44 (29.32)	100 (43.75)
3	–8.07 (35.6)	11 (0)	–3.06 (23.41)	131.5 (16.75)	47.54 (28.07)	20.05 (27.51)	112.5 (62.5)
4	0.6 (27.2)	11 (0)	8.43 (11.3)	141.5 (23.5)	38.48 (15.24)	20.26 (21.81)	125 (68.75)
5	4.5 (33.71)	11 (0)	15.63 (8.89)	132 (14.5)	43.81 (17.62)	22.85 (22.46)	125 (87.5)

Note: Areas represent the calculated hysteresis behaviour between the exercise and recovery phases. Initial values are those collected at the beginning of the bouts.

Table 2
Differences between the initial and final bouts of hysteresis areas and initial values of rating of perceived exertion (RPE), heart rate (HR), and muscle oxyhaemoglobin (O_2Hb). Cohen's d *is represented in values, while significant differences from the Wilcoxon test are marked (*p < .05).*

		Bouts 1-4	Bouts 1-5	Bouts 2-4	Bouts 2-5
RPE	Areas	0.68*	0.61	0.44	0.37
	Initial values	From bout 2 participants had to start the exercise when RPE ≤ 11			
HR	Areas	1.37*	1.71*	1.25*	1.81*
	Initial values	0.67	1.06	0.26	0.03
Muscle O_2Hb	Areas	1.52*	1.22*	0.36	0.19
	Initial values	0.16	0.48	0.01	0.32

Note: Areas represent the calculated hysteresis behaviour between the exercise and recovery phases. Initial values are those collected at the beginning of the bouts.

The HR areas increased over the bouts ($\chi^2 = 14.16$, $p < .01$), and the muscle O_2Hb areas decreased ($\chi^2 = 9.84$, $p = .04$). The differences were significant between the initial (1 and 2) and final bouts (4 and 5): HR (1-4: Z = –2.19, $p = .03$; 2-4: Z = –2.09, $p = .04$; 1-5: Z = –2.29, $p = .02$; 2-5: Z = –2.60, $p < .01$) and muscle O_2Hb (1-4: Z = –2.80, $p < .01$; 1-5: Z = –2.19, $p = .03$). As shown in Table 2, large effect sizes (d = 1.22 – 1.81) of hysteresis areas were found in HR between bouts 1-4, 1-5, 2-4, 2-5, and in muscle O_2Hb between bouts 1-4 and 1-5. RPE increased only between bouts 1 and 3 and bout 4 (Z = –1.98, $p = .04$; Z = –1.99, $p = .04$, respectively), with small and intermediate effect sizes between initial and final bouts.

All areas showed a large interquartile and displayed high differences among the variables ($\chi^2 = 59.08$, $p < .01$). Concretely, between muscle O_2Hb with both HR (Z = –6.11, $p < .01$) and RPE (Z = –6.00,$p < .01$).

On the other hand, there were non-significant differences between the initial values of the consecutive bouts (see Tables 1 and 2). Only RPE and muscle O_2Hb were different between bouts 1 and 2 (Z = –2.35, $p = .02$; Z = –2.80, $p < .01$, respectively). In addition, small and intermediate effect sizes were displayed between initial and final bouts of such initial values (except for HR between bouts 1-5).

Discussion

This research, assessing the hysteresis areas of RPE, HR, and muscle O_2Hb during repeated running bouts, found an increase in RPE and HR areas, and a decrease in muscle O_2Hb areas, in the last bouts compared with the first ones.

The muscle O_2Hb hysteresis areas decreased as effort accumulated, reinforcing the hypothesis of the hysteresis area as a possible biomarker of exercise stress and tolerance

(Montull et al., 2020). It informed about the differences between internal and external load (MAV was kept in all bouts) in function of effort accumulation. This difference was also reflected by the increase in the recovery time over the bouts.

In contrast to the hysteresis areas, the initial values of RPE, HR, and muscle O_2Hb before the bouts were quite similar. These results support the assumption that fixed quantitative values of RPE, HR, and muscle O_2Hb cannot be sufficiently reliable as indicators of internal load (Montull et al., 2020, 2022).

The degeneracy property of CAS (Edelman & Gally, 2001; Montull et al., 2020) may explain why participants could keep the same velocity along the bouts despite the psychobiological effects of effort accumulation. Different psychobiological synergies should be activated when effort accumulates to compensate the fatigue effects and satisfy the task goal.

According to the results, psychobiological synergies were highly individual and contextual. The hysteresis areas of RPE, HR, and muscle O_2Hb were notably different over the bouts, as shown by their high statistical dispersion. These findings support previous results studying RPE and HR (Montull et al., 2020) and the non-proportional relations found between internal and external loads (Impellizzeri et al., 2019).

Although the recovery time increased as running bouts progressed, the hysteresis areas of RPE and HR also increased, switching from negative to positive values after the third bout. This transition indicates that RPE and HR recovery values were higher than exercise values until RPE decreased below 11. This phenomenon informs about the impending instability of psychobiological synergies (Hristovski et al., 2014), which can be used as an early warning signal (Scheffer et al., 2009) to help "forecast" the exhaustion and task disengagement provoked by acute fatigue effects. Accordingly, the possibilities to capture and anticipate such effects seem possible using the hysteresis area of psychobiological variables.

Monitoring the hysteresis area has also been effective in capturing the efficacy of training interventions (Martín-Guillaumes et al., 2021) and increasing the diagnostic accuracy in cardiac diseases (Zimarino et al., 2016). Thus, these findings reinforce its potential for monitoring sports and medical interventions. In sport, it may help to manage the recovery during exercise and post-exercise with more precision (Montull et al., 2020). The access to instantaneous values of the hysteresis area of psychobiological variables during an intervallic training may allow athletes and coaches to control more adequately the training workloads (frequency, duration, intensity, recovery). This is in line with recent proposals pointing towards avoiding preestablished working/resting exercise times (i.e., recipes), but promoting a continuous adaptation of training workloads to the changing fitness states of athletes and teams (Balagué et al., 2019, 2020; Pol et al., 2020).

Despite its potential, the hysteresis area of physiological variables may not provide accurate information about the effort accumulation. Subjective perceptions, able to compress multiple information of interoceptive and exteroceptive channels and, therefore, reflect the internal workload in a more integrated manner, maybe a good monitoring complement (Montull et al., 2022).

This study used only the RPE to control the recovery time. Future research is warranted to add other variables like HR to control the recovery period. Further research is also warranted to study the hysteresis area of psychobiological variables in populations with different health and training/fitness states. Finally, this study stresses the importance of developing some technology with the capacity to monitor and assess the hysteresis response during exercise instantaneously.

Conclusions

This study showed the sensitiveness of the hysteresis area of RPE, HR, and muscle O_2Hb to effort accumulation during repeated running exercises performed at MAV. The hysteresis area of psychobiological and physiological variables promises to be a new biomarker for monitoring acute fatigue and assessing health and performance states.

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Anthropometry, Tactical Position, Performance Parameters and Experience in Water Polo: Network Analysis

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A young sprinter prepares herself with a track series to work on her explosiveness.
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Abstract

This study aimed to verify, in water polo (WP), the networks formed with anthropometry, tactical position of the players, and performance in WP specific tests, by experience in the modality. It was aimed, as well, to comparing the variables of the net between the less (group 1 - G1, 24 players) and more (group 2 - G2, 25 players) experienced players. The study included WP players from four teams. Body mass, height, and arm span were measured and tests for agility (AGIL), vertical jump (VJ) and throw speed (TS) were applied. Comparison between groups was performed with Student's *t* test for independent data and the effects size were verified with Cohen's *d*. Three measures of centrality, in z-score, were used: expected influence (EI), closeness centrality (CC), and strength centrality (SC). Network figures demonstrated the relationships between variables in each group. Experience effect sizes were moderated for body mass and for VJ. Arm span and experience had the highest EI values (1.70 and 1.32, respectively), which indicates that the variables are most susceptible to interventions. For G1, tactical position and VJ presented the highest values of CC (1.23 and 1.75, respectively), which indicates that the variables are most quickly affected by interventions, and SC (1.14 and 0.77, respectively), which indicates they have the strongest relationships in the system. For G2, height and arm span had the highest EI values (1.05 and 0.91, respectively). Arm span and body mass had the highest CC values (1.57 and 0.91, respectively). Arm span and experience had the highest SC values (2.16 and 0.69, respectively). G2 formed a more stable network and fewer relationships than G1 players. In general, G1 had a more complex network and G2 a less complex network between variables; anthropometry and experience influence (i) the performance of the WP player to perform specific actions (agility, jumping and throwing) and (ii) the definition of the player's tactical position in the team.

Keywords: aquatic sport, assessment, performance.

Introduction

Water polo (WP) is a team and invasion sport, whose main objective is to invade the sector defended by the opponent, reaching the opposite goal to score and protect, simultaneously, the own goal. Because it is practiced in water, the environment presents uncertainties to practitioners; therefore, it should require permanent motor adaptation (Lamas et al., 2014). Specific and vast skills are required, so the requirements go beyond classic swimming techniques, i.e., the four swimming strokes. It is essential to acquire an extended motor repertoire that includes changes in the direction and rhythm, accelerations, braking, jumping, rotations, eggbeater, and ball handling (Canossa et al., 2009). These skills, which are expressed in a complex way in tasks related to agility, shooting, blocking, and passing, are also crucial to the game tactics.

Anthropometric characteristics present important correlations with specific actions of WP, such as throwing speed, for example, and indicate characteristics that must be considered when determining the different tactical positions of players, as center offensives are commonly higher and heavier than wings, for example (Idrizović et al., 2013). The time of experience exerts an important influence on the performance in WP, in relation to the mastery of the aquatic environment, the perception of competence and the mastery of technical-tactical fundamentals (Iturriaga, 2015). In this way, the initiation in WP, in the most traditional countries, takes place before the age of 10, and in the main international competitions the teams have players with an average age over 25 years old (Canossa et al., 2009).

In sport in general, performance parameters can be evaluated in specific tests (Platanou, 2005). The evaluation is important to control training and performance and by systematically evaluating it is possible to predict individual and collective performance (Quevedo et al., 2015; Menescardi et al., 2019), which will result in valuable information for coaches and athletes (Canossa et al., 2009). Often in WP, tests are applied empirically or in some cases of unclear relevance; therefore, tests that can assess specific motor skills individually, and in combination, are needed (Veale et al., 2010). Agility, throw speed, and vertical jump are considered the main abilities that determine the success of a WP player, as previously reported (Alcaraz et al., 2011; Platanou, 2005). Those tests present, as main objectives, respectively, to evaluate the agility (AGIL) of the line players, the throwing speed (TS), and the vertical jump (VJ) with the execution of the propulsive eggbeater kick.

Bivariate correlation analyses predominate in the investigation of the relationships between performance parameters in WP (De Castro et al., 2021). However, their results often do not point to theoretically expected correlations. Thus, such analyses do not seem to show the best picture of the relationships between the various variables that influence performance. In this case, a possibility of study is the analysis of networks, which allows exploring performance parameters individually, collectively and their interactions (Lusher et al., 2010). In this perspective, players and evaluated characteristics can be seen as network nodes connected through performance-relevant variables, sustaining complex patterns of interaction between teammates. In this way, it becomes possible to obtain detailed information on all analyzed variables (Ribeiro et al., 2017), without excluding them from the analyses. In sports performance, small contributions of variables to performance can modify the entire network and change performance. In this way, it is possible to identify which variables are most influential for changes from interventions. Considering the complexity of WP, three measures of centrality were selected for this study: (i) the Expected Influence (IE) indicates the variables most susceptible to intervention, as well as indicating which variables are more difficult to access, those more resistant to change; (ii) the Closeness Centrality (CC) indicates which variables have the shortest path among the others, that is, which variables could be affected by interventions more quickly, and (iii) the Strength Centrality indicates which variables, in the current pattern of the network, have the strongest relationships.

Considering (i) the broader possibilities of analyzing networks in sport, (ii) the need of understanding the possible relationships among different parameters that influence performance in WP, and (iii) the possible effect of practical experience on performance, the goals of this study were: to verify the networks formed with anthropometry, tactical position of the players, and performance in specific tests, by experience in the modality, as well as to compare the variables of the network between the more and less experienced players.

Methodology

Forty-nine male WP players, from four different teams, participated in this study. They were divided into two groups by the 50th percentile of experience (years) in WP training championships. The tactical positions were identified by the performance of athletes in games and training, so they were classified as central positions (center back and center offensive) and peripheral positions (wings and flats). Group I (less experienced, G1) consisted of 24 players (3 center players and 21 peripheral players). Group 2 (more experienced, G2) consisted of 25 players (6 center players and 19 peripheral players). Participants trained at least three times a week, between 90 and 120 min per session, in the last 6 months prior to collection, and used to participate in regional and national championships. Table 1 shows the frequencies (absolute/relative) of the tactical game positions of the participants in each group.

Table 1
Absolute (and relative) frequency of the preferred positions of the participants in each group (G1: less experienced; G2 more experienced).

Players	G1, *n* = 24	G2, *n* = 25
Center	3 (12.5 %)	6 (24 %)
Peripheral	21 (87.5 %)	19 (76 %)

This research was evaluated and approved by the Local Research Ethics Committee (36758920.3.0000.5347). Participants over 18 years old and parents or guardians of participants under 18 years old signed a consent form and participants under 18 signed a consent form to participate in the study.

Data collection and analysis

Anthropometric data and information regarding experience and tactical position were obtained before testing in the pool. The athletes were instructed not to train 24 hours before the tests. In addition, they were asked to avoid, 72 hours before the tests, consuming any product with caffeine or alcohol. Height, body mass and arm span were obtained using standard procedures, with a measuring tape and scale, and players were barefoot and wearing only swimming suits. The tests were applied over three days, separated by at least 24 hours, always with a standard warm-up for the WP training session.

Tests

Agility

To obtain AGIL data, the Functional Test for Agility Performance (FTAP) was applied (Tucher et al., 2014, 2015, 2016). The players followed the trajectory of the ball after passes made by the players positioned at the vertices of the area established for the test (9 m²). At each vertex, a ball was placed in a floating arch. Three passes were performed between players positioned at the vertices. The assessed players knew only the direction of the first pass executed, thus, for the second and third pass, a quick displacement was necessary for the removal of the ball from the arc of the respective player from the vertex that received and executed the next pass. After the second ball was removed, the timer was stopped, and the agility time recorded. Two stopwatches (Casio, JS-9006P, Japan) were used by two experienced trainers. The evaluators and test players were informed in advance about the test procedures and were properly familiarized with the protocol. To avoid interfering with test performance, athletes did not receive information about the result during the FTAP application.

Throw speed

The test was adapted from the one proposed by Vila et al. (2009). A 5-minute warm-up was given to the participants, who performed passes and throws. The evaluated players threw to the goal at 5 m, simulating a penalty kick, without the goalkeeper. In the test, each athlete evaluated performed five shots with 1 min interval between attempts. In situations where the ball went out, bounced in the water before reaching the goal, or hit the post, it was necessary to repeat the attempt. A radar (26.5-40 gHz; Bushnell, United States) located behind the goal was used to measure the speed of the ball after the throw, as described by Skoufas et al. (2003).

Vertical jump

The players remained in a vertical position performing eggbeater and sculling with one hand, while the other arm remained extended above the headline (defensive position for blocking) for 5 s, in an area whose height was previously calibrated at 200 cm (further transformation of pixels into cm). After that, they sculled with both hands and prepared to execute the vertical jump as high as possible, performing a high-intensity leg movement and touching with one hand (dominant arm) the plate as

much as possible (De Castro et al., 2021; Platanou, 2006). Each player performed three attempts at a 5 min interval. A video camera (60 Hz; VPC-WH1, Sanyo, Japan) was used on a tripod. The images of the tests were analyzed in the Kinovea open-source software (www.kinovea.org) and the result of the vertical jump in centimeters was obtained.

Statistical analysis

Data normality was verified with the Shapiro-Wilk test. Means, standard deviations, and means confidence limits (95%) were calculated for the scalar variables. Absolute and relative frequencies were calculated for categorical variables. Comparison of scalar variables, between G1 and G2, was performed using Student's *t* test for independent data (alfa ≤ .05). Effect size of experience (group effect) on scalar variables were verified with Cohen's *d* and categorized according to: 0 to 0.19, trivial; 0.2 to 0.59, small; 0.6 to 1.19, moderate; 1.2 to 1.99, large; 2.0 to 3.99, very large, and > 4.0 almost perfect (Hopkins, Will G., 2002).

To verify the possible associations among anthropometry, tactical position and tests performances, the Machine Learning Technique called Network Analysis was applied. Centrality measures were generated and transformed into z-scores to understand the role of each variable in the system. In the present study, three measures were used (Epskamp et al., 2012):

(i) Expected influence (EI): estimated from the magnitude of the negative and positive edges that connect one node to the others.

(ii) Closeness centrality (CC): determined from the inverse of the distances from one node to all others.

(iii) Strength centrality (SC): the sum of all the weights of the paths connecting one node to the others.

Regarding centrality measures, the farther from zero, the greater the relevance of the variable within the system. In this study, the "pairwise Markov" random field model was used to improve the accuracy of the partial correlation network. The estimation algorithm used assumes the highest order interaction of the true graph. The algorithm includes an L1 (regularized neighborhood regression) penalty. Regularization is achieved by a least absolute selection and contraction operator (LASSO) that controls the model's dispersion (Friedman et al., 2008). The Bayesian Extended Information Criterion (EBIC) was used because it is more conservative to select Lambda from the regularization parameter. EBIC uses a hyperparameter (y) that determines how much EBIC selects sparse models (Chen, 2008; Foygel & Drton, 2011). The y value is usually set between 0 and 0.5. Higher values indicate more parsimonious models with fewer edges. A value closer to 0 indicates an estimate with more edges. A y value of 0.25 is potentially a useful value for exploratory networks. This value was used in the present study (Foygel & Drton, 2011). The LASSO regularized algorithms to obtain the precision matrix, which, when standardized, represents the associations between the network variables. The positive relationships in the network are expressed by green and the negative ones by the red color. The thickness and intensity of the colors represent the magnitude of the associations. The SPSS v.20.0 and version 0.14.1.0 programs were used for the analysis and construction of the networks.

Results

Descriptions and comparisons of time of experience, age, anthropometric characteristics, and performance parameters, as well as the experience effect sizes are in Table 2. Time of experience presented: (i) large effect size on age, (ii) trivial on height and arm span, and (iii) moderate on body mass. Regarding performance parameters, the effects of the experience groups were: (i) moderate on vertical jump and (ii) small on agility ball and throw speed. G2 were older, had more experience, were heavier, and reached higher VJ than G1.

Figures 1 and 2 show the networks formed for, respectively, G1 and G2 using the variables experience (EXP), age (AGE), height (HEI), arm span (SPAN), total body mass (TBM), tactical position (POS), vertical jump (VJ), agility (AGIL), and throw speed (TS). Blue lines indicate positive relationships, reddish lines indicate negative relationships. The thickness of each line indicates the relation strength.[1]

[1] Complementarily, the correlation matrix is in Appendix of this manuscript.

Table 2
Means, standard deviations, means confidence limits (95%), comparisons and Cohen's d *and respective category of effect of groups for experience time, age, anthropometric characteristics, and performance parameters (G1: less experienced; G2 more experienced).*

	G1, *n* = 24	G2, *n* = 25	*t* *p*-value	Cohen's *d* Effect
Experience time (years)	4.7 ± 1.0 4.3 to 5.2	13.0 ± 6.7 10.2 to 15.7	–6.0 <.001	1.7 large
Age (years)	17.9 ± 5.7 15.4 to 20.3	26.5 ± 8.6 22.5 to 30.1	–4.1 .001	1.8 large
Height (cm)	180.0 ± 5.8 177.5 to 182.5	179.1 ± 5.8 177.5 to 182.5	0.51 .60	0.15 trivial
Arm span (cm)	185.6 ± 5.2 183.4 to 187.8	185.0 ± 7.2 182.0 to 188.0	0.31 .75	0.09 trivial
Total body mass (kg)	74.6 ± 8.2 71.1 to 78.1	81.0 ± 13.4 75.4 to 86.6	–1.9 .05	0.82 moderate
Agility (s)	3.8 ± 0.2 3.7 to 3.9	3.7 ± 0.3 3.5 to 3.8	1.61 .11	0.39 small
Throw speed ($m \cdot s^{-1}$)	17.8 ± 1.2 17.2 to 18.3	18.2 ± 1.6 17.5 to 18.9	–1.0 .31	0.28 small
Vertical impulsion (cm)	132.1 ± 10.9 127.4 to 136.7	141.0 ± 16.0 134.4 to 147.7	–2.2 .027	0.65 moderate

Figure 1
Network formed in G1 (less experienced players): EXP (experience), AGE (age), HEI (height), SPAN (arm span), TBM (total body mass), POS (position), VJ (vertical jump), AGIL (agility) and TS (throw speed). Blue lines indicate positive relationships, reddish lines indicate negative relationships. The thickness of each line indicates the strength of the relationship; n = *24.*

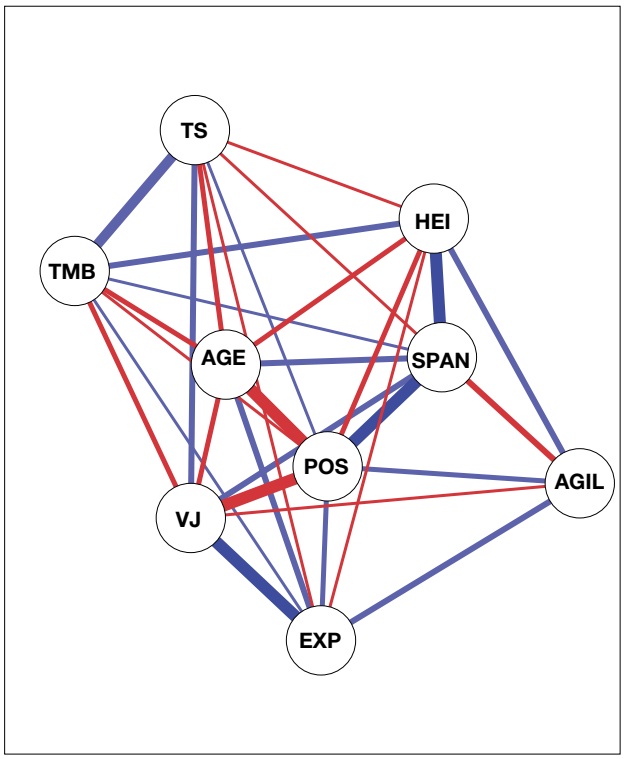

Figure 2
Network formed in G2 (more experienced players): EXP (experience), AGE (age), HEI (height), SPAN (arm span), TBM (total body mass), POS (position), VJ (vertical jump), AGIL (agility) and TS (throw speed). Blue lines indicate positive relationships, reddish lines indicate negative relationships. The thickness of each line indicates the strength of the relationship; n = *25.*

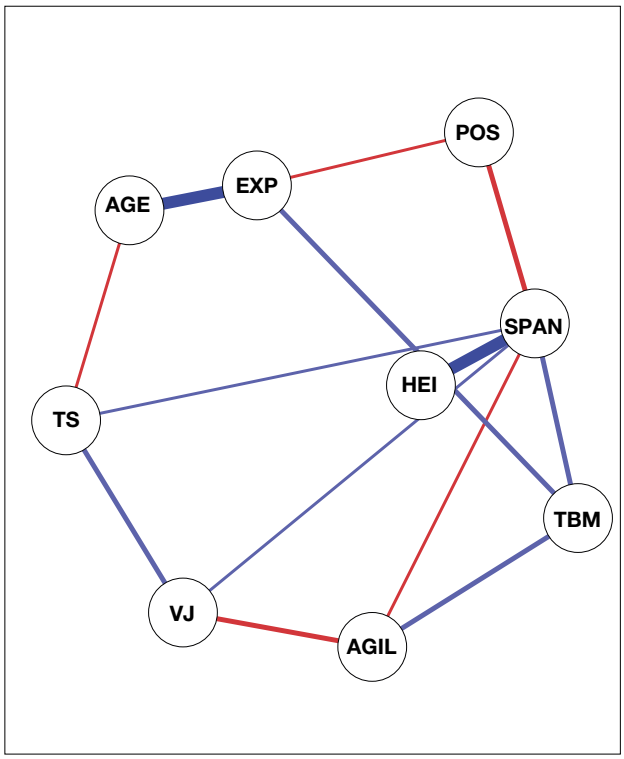

Table 3
Centrality measures for G1 (less experienced; n = *24) and G2 (more experienced;* n = *25).*

	EI		*CC*		*SC*	
	G1	G2	G1	G2	G1	G2
POS	–1.00	–1.77	1.23	0.56	1.75	–0.40
EXP	1.32	0.86	–0.13	0.38	–0.43	0.69
AGE	–1.21	0.30	0.21	–0.15	0.31	0.65
HEI	–0.02	1.05	0.48	0.13	0.21	–0.20
SPAN	1.70	0.91	0.66	1.57	0.64	2.16
TBM	0.35	0.65	–1.02	0.91	–0.85	–0.65
VJ	–0.81	–0.57	1.14	–1.54	0.77	–0.79
AGIL	–0.08	–1.07	–1.20	–0.96	–1.19	–0.49
TS	–0.22	–0.38	–1.38	–0.91	–1.19	–0.94

EI: Expected influence (EI); CC: Closeness centrality (CC); SC: Strength centrality.

The centrality measures, for G1 and G2, in relation to tactical position, experience, age, height, arm span, total body mass, VJ, AGIL, and TS are shown in Table 3.

Discussion

This study verified the networks formed among anthropometry, tactical position of players, and performance in WP specific tests by experience in the modality, as well as compared the variables of the network between the more and less experienced groups. Among the results of this study, the ones that stand out are: (i) the graphical analysis of the networks illustrated the greater connectivity of the variables for G1 and indicated a lower level of complexity between the variables for G2; and (ii) the influence of EXP on anthropometry and performance parameters indicated in moderate effect sizes for body mass and VJ, respectively. When compared, G2 had higher values for age, total body mass, and VJ than G1.

To reach a good technical level in WP, it is required at least 15 years of competitive experience. This statement is based on the analysis that the best international teams have players with an average age over 25 and initiation in WP, in the most traditional and winner countries, occurs even before the age of 10 (Canossa et al., 2009). So, experience exerts a preponderant influence on performance in the modality. In this study, we could find just moderate experience effect size in total body mass and in VJ. Yet, regarding the interpretation of the effect size (Cohen, 1988) indicated that a moderate effect size represents a magnitude evident to the naked eye to a careful investigator; in this way, somehow the influence on the observed variable must be considered (Espírito Santo & Daniel, 2017). The VJ presents itself as a decisive parameter for the outstanding performance in WP, as it influences the ability to execute passes, offensive throws, and blocks (Platanou, 2005). In this case, experience indicates that it is relevant to such a capability.

Different studies seek to investigate factors that may influence performance in WP with correlation analysis. For example, in the study by De Castro et al. (2021) three performance parameters were analyzed in Brazilian WP players: AGIL, VJ, and TS. The results indicated a positive correlation of AGIL with VJ and TS. However, it was not possible to identify a pattern for the best athletes in the three variables analyzed together. In the study by Zinner et al. (2015), with German national team players, the performance in the execution of the eggbeater, isometric and dynamic strength tests, and WP specific tests were assessed. Positive correlations were observed for muscle strength for high performance in eggbeater execution, with consequences for greater speed in the throw.

Sports games, teams, and athletes have recently been seen as complex adaptive systems whose behavior is influenced by environmental, individual, and task constraints (Pol et

al., 2020). From this perspective, WP can be understood as a complex phenomenon as it contains variables of different natures that influence performance: anthropometric, tactics, techniques. Thus, they must be sensitive to changes and exhibit behaviors that are not linear. To interpret the different variables in relation to performance in WP, network analysis seems to best translate these interactions, that is, in an integrated way, to be able to observe all the relationships that may influence behavior for different levels of performance.

In this study, through the graphic analysis of the networks, it was possible to identify the relationships between the variables in each experience group. Furthermore, differences between groups were identified: the first one concerns the network pattern presented for the group of less experienced athletes (G1) compared to the group of more experienced athletes (G2). Figure 1 indicates a network with a higher level of complexity (G1), with close and multiple interactions, a scenario that suggests that athletes with less experience have a greater number of variables sensitive to changes. Figure 2, on the other hand, indicates a network with a distinct pattern for more experienced athletes (G2), with greater distance between the performance variables, which seem to be more fixed. Consequently, they seem to be more resistant to change. Such results, considering the possible responses of young players to training, seem to reinforce the possibility that experience plays an important role, especially when it comes to provide countless and diverse practices in young athletes.

The EI values, regarding the performance parameters, indicate that, for G2, AGIL (-0.08) is the most difficult variable to be accessed and with the least capacity to undergo direct interventions. In G1 it was possible to identify the importance of experience for all variables in the network (1.32). Regarding the anthropometric parameters, for G2 the main variables were arm span (1.05) and height (0.91). For G1, the highlighted variable indicated was the arm span (1.70). As for the CC, considering the performance parameters, the values indicate that for G1, the VJ (1.14) is the closest variable to the other in the network. Consequently, from a possible intervention, VJ can take effect quickly. Regarding the tactical position, G1 and G2 presented, respectively, 1.23 and 0.56. The values suggest that for G1 the tactical position is more sensitive to changes. Such result may indicate the low specialty of action in relation to the role that less experienced players should have. As for the anthropometric parameters, the highlight is the value presented for arm span (1.57) and body mass (0.91) in G2. The SC values, in the performance parameters, indicate that for G1, VJ (0.77) has more strong relationships in the current network standard. In relation to the tactical position, G1 and G2 presented, respectively, 1.75 and -0.40. For experience, there was also a difference between the groups. G1 and G2 presented, respectively, -0.43 and 0.69. Regarding the anthropometric parameters, the highlight is the value presented for the span (2.16) in G2. This result indicates the magnitude of the relationships between the span and the other variables. Thus, anthropometric parameters can be considered essential for coaches to determine the tactical positions of their athletes on their teams.

The integrated analysis with several variables, seeking to verify the complex relationship of different parameters that can influence performance in WP, is only possible with analyses such as the one used in this study. In WP, earlier, isolated relationships between anthropometric parameters and performance have already been demonstrated (Platanou & Varamenti, 2011) and with performance parameters (De Castro et al., 2021), for example. However, such analyses are limited to the elimination of joint analysis of selected parameters that could, in some way, interfere in performance. The results of the present study, in an initial way, allow this analysis to be made based on the complexity of the modality. Although, it is possible to indicate some limitations of the present study: the participation of a small number of players who have a central position, the lack of more specific anthropometric analyses, and the lack of analyses carried out in game situations.

Conclusion

Through network analysis, it was possible to visualize the level of complexity and magnitude of interactions between anthropometric and performance variables in WP for groups with different years of experience. For the less experienced group (G1), the greater intensity between the relationships (i.e., the formation of a more complex network with greater connectivity between nodes), indicated that players in training have more variables sensitive to interventions and changes than more experienced players. For the more experienced (G2), the less connectivity between nodes (less complexity), indicated more fixed and resistant variables to changes. In general, anthropometry and experience influence (i) the performance of the WP player to perform specific actions (agility, jumping and throwing) and (ii) the definition of the player's tactical position in the team.

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Offensive Performance Indicators of the Spanish Women's Handball Team in the Japan 2019 World Cup

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A young sprinter prepares herself with a track series to work on her explosiveness. @Jérome Aufort/Adobestock

Abstract

The main objective of this study was to identify the positional attack performance indicators of the Spanish handball team during the World Championship in Japan 2019, in which they were runners-up. Using an idiographic, observational, follow-up and multidimensional design, positional attacks played with equal numbers of 6 vs. 6 were recorded and analysed, excluding attacks carried out with an empty goal. The polar coordinates technique made it possible, on the one hand, to identify behavioural patterns and, on the other, performance indicators related to: the continuity of attack, the situations used to generate imbalances in the opposing defence, and the actions involved in the completion of the attack. For this purpose, two levels of analysis were carried out: each match independently and all matches together. The results obtained show that each match presented its own specific game dynamics, as different behavioural patterns were triggered and different performance indicators emerged depending on the match. These findings highlight the variability and dynamic nature of the offensive behaviours and performance indicators of the World Cup runners-up team. The need to study performance indicators through research that respects their specific and changing nature is emphasised.

Keywords: behavioural patterns, handball, polar coordinate analysis, performance indicators.

Introduction

Performance indicators are game variables that are associated with victory in a match or championship (Hughes & Bartlett, 2002). In the field of handball, the compilation of performance indicators is a matter of great interest for coaches and researchers, as they provide performance profiles that teams aim to approximate, and provide information on game development from one championship to the next (Prieto, 2015).

Two research approaches are identified in handball: static and dynamic (Prieto et al., 2015). The static approach is the most common and also the least complex. It mainly analyses actions performed during attack, such as shots or turnovers, focusing on events that occurred and paying limited attention to how they happened (Sampaio et al., 2013). The dynamic approach is less common. It focuses more attention on the context in which actions occur (Prieto et al., 2015), studying the influence of game systems (Lozano et al., 2016) or how the presence of a certain player conditions the development of the game (Flores & Anguera, 2018). In addition, actions are studied in the chronological order in which they occurred, which provides insight into the changes that occur in the game within a single match (Lames, 2006; Lames & McGarry, 2007).

Whether using the static or the dynamic approach, most performance indicators give a fixed snapshot, a kind of general rule of thumb that winning teams always follow. These indicators are derived from the analysis of data obtained at the end of one or several matches, whether they are performed by a single team or by all the teams participating in the competition (Gruić et al., 2006; Melekatos & Bayios, 2010; Meletakos et al., 2011; Montoya et al., 2013; Ohnjec et al., 2008; Rogulj et al., 2004; Srhoj et al., 2001; Volossovitch et al., 2010; Vuleta et al., 2003).

However, the fixed snapshot of performance indicators can be problematic: (a) Teams change the way they play during the course of a championship and also within a single match. Coaches vary their strategic approach depending on the opposing defensive system, the characteristics and form of their players or the refereeing style (Chow et al., 2015). (b) Obtaining equally valid performance indicators for all teams can be a difficult task: do all teams have the same ability to pivot, score from the wing or shoot from distance? (Lames & McGarry, 2007). (c) Furthermore, the study of performance indicators must have regard to variability, understood as the ability to solve the same game situation in different ways, which is characteristic of high-level athletes (Corrêa et al., 2020; Correia et al., 2018).

Consequently, it is necessary to search for dynamic performance indicators that take into account the peculiarity of each match and are specific to each team, as sporting success can be achieved by different ways of playing (Laporta et al., 2021). For this reason, the main objective of this study was to identify the positional attack performance indicators of the Spanish women's handball team during the World Championship in Japan 2019, in which they were runners-up. For this purpose, behaviours were studied specifically in each match and also in general in the championship.

Methodology

Research design

This study was developed according to the observational follow-up/idiographic/multidimensional (F/I/M) design (Anguera et al., 2011): (a) idiographic, because the behaviour of several handball players who, as members of the same team, functioned as a unit, was studied; (b) follow-up, because several matches were analysed, also carrying out intrasession follow-up within each match that provided the frequency and sequence of the behaviours recorded, and (c) multidimensional, because several levels of response, collected in the observation instrument, were studied.

Participants

Seven matches played by the Spanish national handball team during the Women's Handball World Championship Japan 2019, in which they finished runners-up, were analysed. Two of the five first-phase matches: Montenegro-Spain and Spain-Hungary; all second round matches: Spain-Sweden, Japan-Spain and Spain-Russia; the semi-final, Norway-Spain; and the final, Netherlands-Spain. Thus, seven of the 10 matches played by the Spanish national team in the championship were analysed, excluding three matches from the first phase due to the considerable difference in points scored: Kazakhstan-Spain (16-43), Spain-Senegal (29-20) and Romania-Spain (16-31).

The study was conducted in accordance with the ethical principles set out in the Declaration of Helsinki and, in accordance with the Belmont Report (1978), informed consent and review by the relevant ethics committee was not required because: (a) the study involved the observation of individuals in a public setting (sports venue); (b) the individuals and groups observed had no reasonable expectation of privacy (the matches were broadcast worldwide); and (c) the study did not involve intervention by the researchers or direct interaction with the individuals studied.

Resources

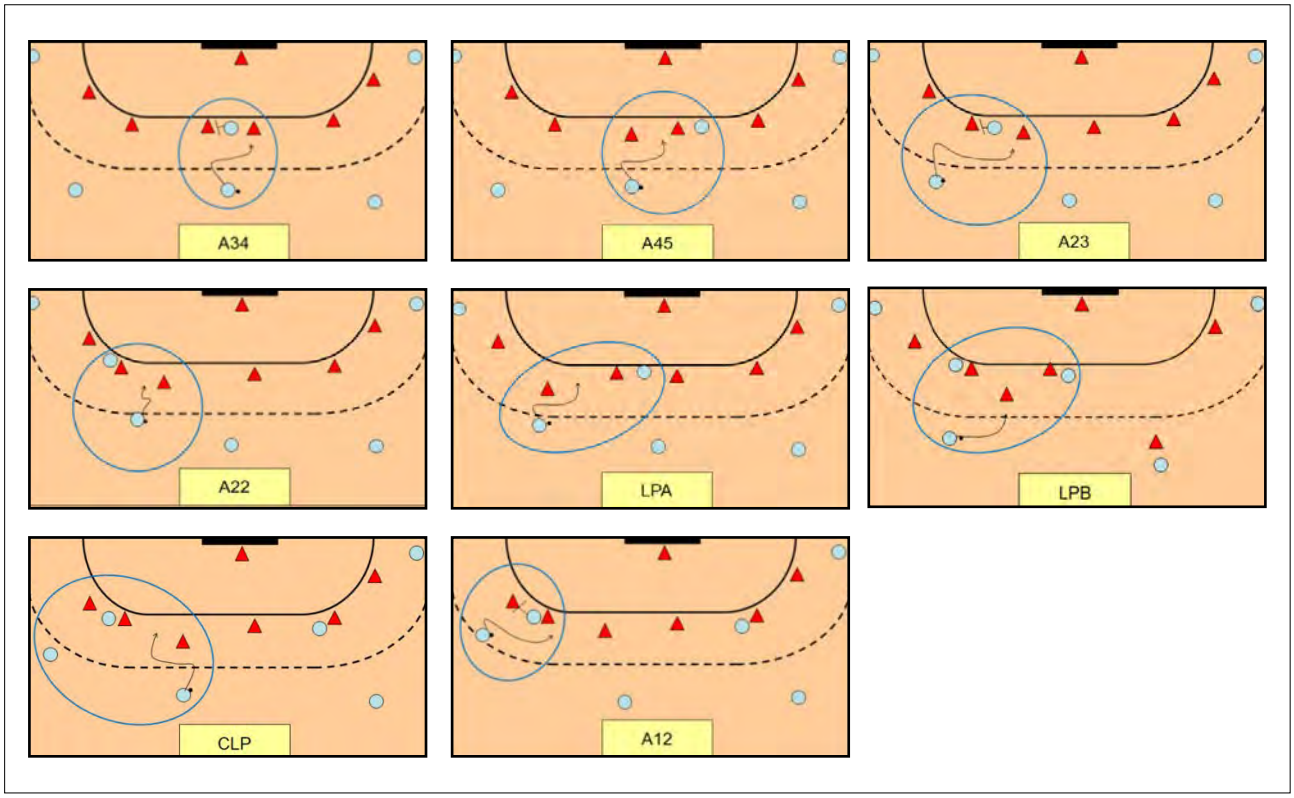
Observation instrument

In order to record the most relevant actions related to the proposed objective, an *ad hoc* observation instrument was designed (Table 1). A design that combined the field format with comprehensive and mutually exclusive category systems was chosen. This combination exploits the strengths of both instruments; on the one hand, the category system offers theoretical consistency while the field format provides flexibility in recording the specific behaviours to be studied (Anguera & Hernández-Mendo, 2013).

Table 1
Observation instrument

Criterion	Categories
Number (NUM)	Six against six (6v6) / Seven against six (7v6) / Six against six with an empty goal (E6v6) / Six against five (6v5) / Six against five with an empty goal (E6v5) / Other numerical ratio (XvX).
Defensive System (DEF)	Defensive system facing the attack: 6:0 (SIX) / 5:1 (AVN) / 4:2, 3:3 or individual defence (ABI) / Mixed defence (MIX).
Offensive system (ATT)	Offensive system implemented: 3:3 (T33) / One of the wingers leaves his position to become a second pivot (DEX) / A front row player leaves his position to become a second pivot (T24).
Sequence (SEQ)	Number of sequences in a single ball possession. A new attempt is considered to have begun after play is stopped (e.g. free kick signal) and possession is not lost: first attempt (SQ1) / second attempt (SQ2) / third attempt (SQ3) / four or more attempts (S4M).
Type of strong attack (TSA)	Situation in which two or three players intervene in an attempt to create imbalances in the opposing defence (Figure 1): two against two centre-pivots, with the pivot positioned between the centre defenders (A34) / two against two centre-pivots, with the pivot positioned between the centre and wing defenders (A45) / two against two wing-pivots, with the pivot positioned between the wing and centre defenders (A23) / two against two wing-pivots, with the pivot paired with the outside defender (A12) / two against two wing-pivots, with the pivot paired with the outside defender (A12) / two against two wing-pivots, the pivot between the wing and outside defenders (A22) / situation played by the players occupying the centre, wing and pivot positions, after the winger has moved to the pivot position (CLP) / initiated by the player occupying the wing position with the pivot positioned between the centre defenders (LPA) / three against three initiated by one of the two wingers together with two players in the pivot position (LPP) / a strong attack different from the previous ones (ANO) is carried out.
Location of the strong attack (LSA)	Place where the strong attack occurs: left (LZ) / right (RZ) / centre (CNZ).
Player who carries out the strong attack (SAP)	The player who carries out the strong attack is: Alexandrina Cabral (ALE) / Nerea Pena (NER) / Mireya González (MIR) / Almudena Rodríguez (ALM) / Alicia Fernández (ALI) / other player (OP).
Number of passes after strong attack (PSA)	Number of passes made after the strong attack and before completion: zero to one pass is made (P01) / two to three passes are made (P23) / four or more passes are made (P4M).
Crosses and/or swaps after strong attack (XSA)	Number of crosses and/or swaps made after the strong attack: zero (X00) / one (XP1) / two (XP2) / three or more (X3M).
Place of completion (PC)	Zone where the attack ends: left (LZ) / right (RZ) / centre (CNZ).
Completion player (CP)	Front row player who finishes the attack or passes to a player on the wing or pivot: Alexandrina Cabral (ABA) / Nerea Pena (NPE) / Mireya González (MGL) / Almudena Rodríguez (ARO) / Alicia Fernández (AFD) / Other player (OP).
Completion Action (CA)	Individual action in which the attack ends: action of the pivot (PIV) / action of the winger / feint or breakthrough by a front row player (J6M) / long range throw-in or action performed in the vicinity of nine metres (J9M).
Development of attack (DA)	Attack ends in: goal, seven-metre throw-in signal or two-minute suspension of a defender (G72) / a throw-in that does not result in a goal (MIS) / turnover (PER) / free kick or other stoppage of play signal that does not result in a change of possession (NOL).

Figure 1
Graphic representation of the categories of the criterion "Type of strong attack" (TSA)



The observation units were the Spanish team's positional attacks developed in a numerically equal 6 vs. 6 situation, excluding attacks carried out with an empty goal. The positional attack together with the counter-attack constitute the two offensive phases of handball. The positional attack is developed in an organised manner against an organised defence. Therefore, each observation unit began with the start of the positional attack and ended when the Spanish team lost possession of the ball (after a throw-in or defensive recovery) or after a referee signal with no change in possession of the ball, such as a free kick or throw-in (Lozano et al., 2016). A total of 439 attacks were analysed in the seven recorded matches.

The development of the observation instrument was carried out in three phases: 1) Two level IV coaches (highest federation qualification in Spain) with previous experience in observational studies designed an initial version, with the work of Flores and Anguera (2018) and Lozano et al. (2016) proving particularly useful. The purpose was to record the most relevant actions in the different sub-phases of positional attack: initiation, development and completion (Montoya et al., 2013). 2) Subsequently, the instrument was subjected to a precautionary test, which consisted of recording three matches not included in the sample (Anguera, 2003). The precautionary test was designed to in order to add, modify and delete criteria and categories from the initial version of the instrument. The precautionary test was passed when no new patterns of behaviour were detected in any of the criteria. 3) The instrument was judged by five experts, university handball teachers and level IV coaches. The experts filled in a rating form in which they had to mark their approval or disapproval of each criterion and category. Ultimately, all the criteria and categories that comprised the observation instrument obtained an approval rating of 80% or more, i.e. at least four of the five experts gave their approval: 100% for the criteria NUM, DEF, ATT, SEQ, LAF, SAP, PAF, LIF, JIF and 80% for the criteria TSA, XSA, AFI, DIF. The final version of the observation instrument consisted of 13 criteria and 58 categories.

Recording instruments

For the recording and classification of behaviours, the observation instrument was inputted into Dartfish 5.5 software, which thereby acted as a recording instrument. Polar coordinate analysis was carried out with HOISAN 1.2 software (Hernández-Mendo et al., 2012). Prior to

the calculation of polar coordinates and as a prerequisite, sequential delay analysis was conducted using GSEQ 5.1 software (Bakeman & Quera, 2011). Finally, after polar coordinate analysis, the significant relationships were plotted using Snowflake 0.2.

Procedure

The recording and classification of behaviours was carried out by two observers. Both were involved in the development of the observation instrument and had experience in observational studies, so they were familiar with the recording instrument. To optimise the reliability of the observations, observers participated in a training process in which matches that were not included in the sample were recorded. The training process was concluded when approval levels above .80 were obtained for Cohen's kappa statistic for all criteria, both at the intra-observer level, a single session recorded by the same observer at two different times (after 16 days), and at the inter-observer level, a single session recorded by the two observers. Once the training phase was over, the behaviours observed in each of the seven matches that made up the study sample were recorded and classified. Intra-observer and inter-observer concordance levels were calculated, both with Cohen's kappa index above .95 for all criteria. According to Landis and Koch (1977, p. 165) the approval level shown in both tests can be considered "almost perfect".

Polar coordinate analysis

Polar coordinates analysis enables information to be obtained on the behavioural patterns that emerge during the course of the match, and has been used in research in the field of team sports (Castañer et al., 2017). This analysis enables the graphical representation of the relationships, of activation or inhibition, existing between the behaviours studied. In polar coordinate analysis, the behaviours analysed have two roles: focal behaviour, the behaviour that is considered to generate the relationships, and conditioned behaviours, the rest of the behaviours analysed.

As a prerequisite for its calculation, it is necessary to perform the sequential analysis of prospective and retrospective lags (Sackett, 1980). For this purpose, the same number of lags are considered in both scenarios, from 1 to 5 for prospective and from -1 to -5 for retrospective. The prospective perspective provides information on the conditioned behaviours that are activated or inhibited once the focal behaviour is performed. The retrospective perspective provides information on the conditioned behaviours that activated or inhibited the occurrence of the focal behaviour (Anguera et al., 2011).

Once the prospective and retrospective sequential analyses have been carried out, the polar coordinate analysis integrates the two by applying Zsum statistic (Sackett, 1980), a powerful data reduction technique. Each prospective and retrospective Zsum can have a positive or negative character. Thus, the combination of the characters will determine in which of the four possible quadrants (I, II, III, IV) the significant relationships obtained between the focal behaviour and the conditioned ones will be located. Quadrant I indicates a relationship of mutual activation between the focal behaviour and the conditioned behaviour; quadrant IV indicates that the focal behaviour activates the performance of the conditioned behaviour, while it is inhibited by it; quadrant III indicates a relationship of mutual inhibition between both behaviours; and finally, quadrant II indicates that the focal behaviour inhibits the performance of the conditioned behaviour, while the conditioned behaviour activates the occurrence of the focal behaviour (Anguera et al., 2011).

Results

The significant relationships found, those with a radius greater than 1.96 ($p < .05$), after polar coordinate analysis, are presented below. Each match was analysed independently and the observations from all matches were also analysed together, thus providing insight into patterns of behaviour and performance indicators for each match and in the championship as a whole.

Behaviour patterns

Figure 2 and Table 2 display the patterns of behaviour that emerged during the positional attacks developed in a 6 vs. 6 situation. Category 6v6 acted as the focal behaviour; the other categories of the observation instrument acted as conditioned behaviours. Relationships located in quadrants I and IV are presented, i.e. those behaviours that were activated by the focal behaviour.

With regard to the type of strong attack carried out, the A34 strong attack (two against two centre-pivots, with the pivot positioned between the centre defenders) was implemented in the matches against Montenegro, Russia and the Netherlands; the A23 type (two against two wing-pivots, with the pivot positioned between the wing and centre defenders) was implemented in the matches against Sweden

and the Netherlands; the CLP type (played by the players occupying the centre, wing and pivot positions, after the winger has moved to the pivot position) was implemented only against Japan; the A12 attack type (two against two wing-pivots, with the pivot paired with the outside defender) was implemented against Japan and Russia; the A45 attack type (two against two centre-pivots, with the pivot positioned between the centre and wing defenders) was implemented against Russia and the Netherlands.

In the matches against Montenegro, Japan and Russia, their strong attacks were implemented from the central zone (CNZ). In contrast, in the match against Sweden, strong attacks were launched from the left side of the attack (LZ). In reference to the strong attacking players, the strong attacks made by Alexandrina Cabral (ALE) were implemented in all matches except those against Sweden and Japan, where the strong attacks were made by Alicia Fernandez (ALI).

On the other hand, in relation to completions, those featuring Alexandrina Cabral (ABA) were executed in the matches against Hungary, Russia and the Netherlands, those performed by Alicia Fernández (AFD) were executed in the matches against Russia and the Netherlands, and those performed by Nerea Pena (NPE), in the matches against Hungary and Japan. Regarding the action used in attack completions, 9-metre actions (J9M) were used in the match against Russia, actions from the wing against Sweden, and in the match against Russia the pivot position completions (PIV) and six-metre actions (J6M) were used.

Finally, analysing the records from all matches together revealed the strong attacks: A23, A22, A12, CLP, LPA, A45 and A34; and those made by players Alexandrina Cabral (ALE) and Alicia Fernández (ALI). In terms of completions, the 9-metre shots and those made by Alexandrina Cabral (ABA) were the key ones.

Figure 2
Patterns of behaviour in positional attacks carried out in a six-on-six situation.

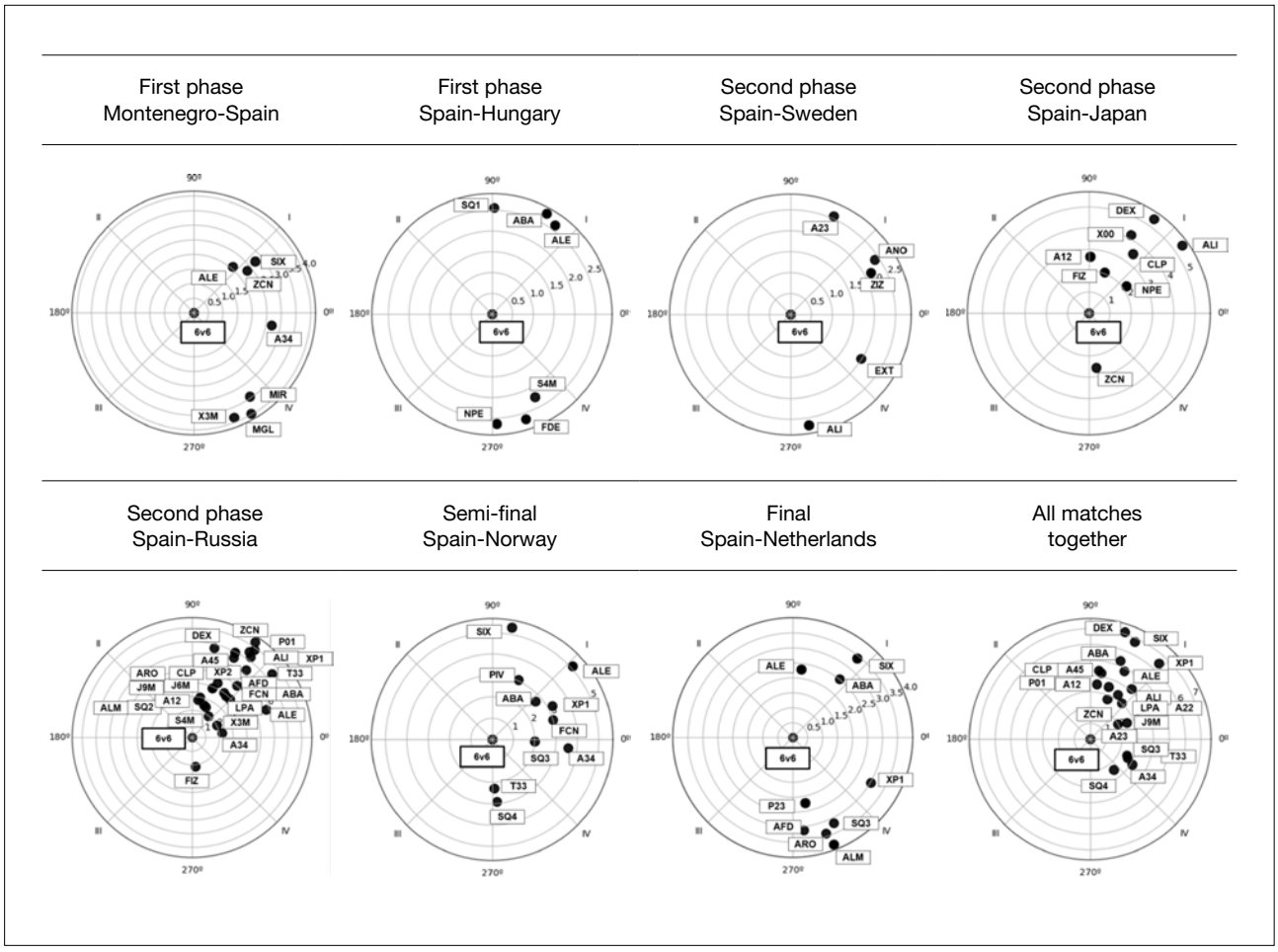


Table 2
Patterns of behaviour in positional attacks carried out in a six-on-six situation.

First phase Montenegro-Spain				First phase Spain-Hungary				Second phase Spain-Sweden				Second phase Spain-Japan			
C.	Q.	R.	A.	C.	Q.	R.	A.	C.	Q.	R.	A.	C.	Q.	R.	A.
SIX	I	2.74	39.98	SQ1	I	2.56	89.09	EXT	IV	1.98	328.14	DEX	I	5.38	55.49
X3M	IV	3.84	291.08	S4M	IV	2.24	297.73	ALI	IV	2.67	279.52	X00	I	4.19	62.06
ALE	I	2.07	49.88	ALE	I	2.76	61.58	LZ	I	2.16	27.63	ALI	I	5.44	36.12
MIR	IV	3.45	303.82	RC	IV	2.65	288.04	A23	I	2.57	66.57	CNZ	IV	2.57	277.77
CNZ	I	2.33	38.74	ABA	I	2.63	54.48	ANO	I	2.40	33.26	LC	I	2.06	68.77
MGL	IV	3.97	299.75	NPE	IV	2.63	272.23					NPE	I	2.18	35.71
A34	IV	2.69	351									A12	I	2.67	88.95
												CLP	I	3.46	53.46

Second phase Spain-Russia				Semi-final Spain-Norway				Final Spain-Netherlands				All matches together			
C.	Q.	R.	A.	C.	Q.	R.	A.	C.	Q.	R.	A.	C.	Q.	R.	A.
SQ2	I	2.55	70.02	SIX	I	5.32	79.92	SIX	I	5.01	61.87	SIX	I	6.78	65.44
S4M	I	1.98	52.73	SQ3	IV	1.99	357.77	SQ3	IV	3.16	295.60	SQ3	IV	2.51	336.19
DEX	I	6.75	76.43	SQ4	IV	2.89	274.06	XP1	IV	3.01	329.82	SQ4	IV	2.43	308.25
T33	I	7.44	38.52	T33	IV	2.28	272.25	EXT	I	2.51	51.68	DEX	I	7.13	72.05
XP1	I	7.24	54.23	XP1	I	3.24	29.12	ALE	I	2.31	82.79	T33	IV	2.62	333.63
XP2	I	6.29	51.64	PIV	I	3.06	66.51	ALM	IV	3.82	290.94	XP1	I	6.47	48.09
X3M	I	1.99	26.93	ALE	I	5.09	42.27	P23	IV	2.22	280.48	J9M	I	2.54	23.97
J6M	I	3.02	78.84	CNZ	I	3.01	18.16	ABA	I	3.42	51.15	ALE	I	4.84	63.43
J9M	I	3.92	51.46	ABA	I	2.69	41.50	AFD	IV	3.12	276.75	ALI	I	4.13	51.02
ALE	I	5.79	20.98	A34	IV	3.57	353.83	ARO	IV	3.39	288.96	CNZ	I	3.03	49.48
ALI	I	7.53	56.29					A23	IV	3.13	295.80	P01	I	3.52	71.15
ALM	I	2.46	65.82					LPA	I	2.48	50.01	ABA	I	5.32	69.24
CNZ	I	8.32	56.67					A45	I	3.28	85.21	A23	I	1.98	28.68
P01	I	7.85	54.48					A34	IV	2.89	301.02	A22	I	2.76	67.30
LC	IV	2.10	276.24									A12	I	3.51	82.92
CNZ	I	4.99	49.48									CLP	I	4.26	80.45
ABA	I	4.00	54.96									LPA	I	3.32	58.13
AFD	I	6.55	62.67									A45	I	4.39	83.11
ARO	I	4.40	65.31									A34	IV	3.09	328.66
A12	I	2.80	81.44												
CLP	I	3.91	68.18												
LPA	I	3.93	45.34												
A45	I	6.96	63.55												
A34	I	2.20	8.54												

Note. C: category; Q: quadrant; R: radius; A: angle

Performance indicators

Figure 3 and Table 3 show the performance indicators, those actions whose prior occurrence was significantly associated with subsequent success (G72), in attacks that pitted six attackers against six defenders (6v6). Therefore, the combination of categories 6v6 and G72 (6v6_G72) served as focal behaviour and the rest of the categories in the observation instrument acted as conditioned behaviours. Relationships located in quadrants I and II are displayed, i.e. those behaviours that were performed earlier and triggered success.

In reference to the type of strong attack that triggered success, in the match against Montenegro it was the CPL situation, in the match against Hungary it was A23, in the match against Japan, A34 and in the match against Russia it was A45. Strong attacks made by Alexandrina Cabral (ALE) were associated with success in the matches against Hungary and Russia; those made by Alicia Fernández (ALI) were associated with success in the match against Japan and Russia, while those made by Nerea Pena (NER) were associated with success in the match against Montenegro.

On the other hand, in terms of completions, those made by Alexandrina Cabral (ABA) were associated with success in the matches against Montenegro and Russia, those made by Alicia Fernández (AFD) against the Netherlands and Russia, and those made by Nerea Pena (NPE) against Norway. Regarding the action used in the completion of attacks, 9-metre actions (J9M) against Hungary, actions from the pivot position (PIV) against Sweden and six-metre actions (J6M) against Russia and the Netherlands acted as performance indicators. In reference to the completion location, for the match against Montenegro from the left (LC) and for the match against Russia from the right (RC).

Finally, when analysing the records from all the matches together, it was observed that the use of the DEX offensive system (one of the players occupying the winger position moving to the second pivot position) triggered the occurrence of success. With regard to the strong attacks, those made from the central zone (CNZ) and those made by the players Alexandrina Cabral (ALE) and Alicia Fernández (ALI) were particularly effective. They also triggered the completion of attacks through actions from the central area (CNZ) and those by Alexandrina Cabral (ABA).

Figure 3
Performance indicators in positional attacks developed in a six-on-six situation.

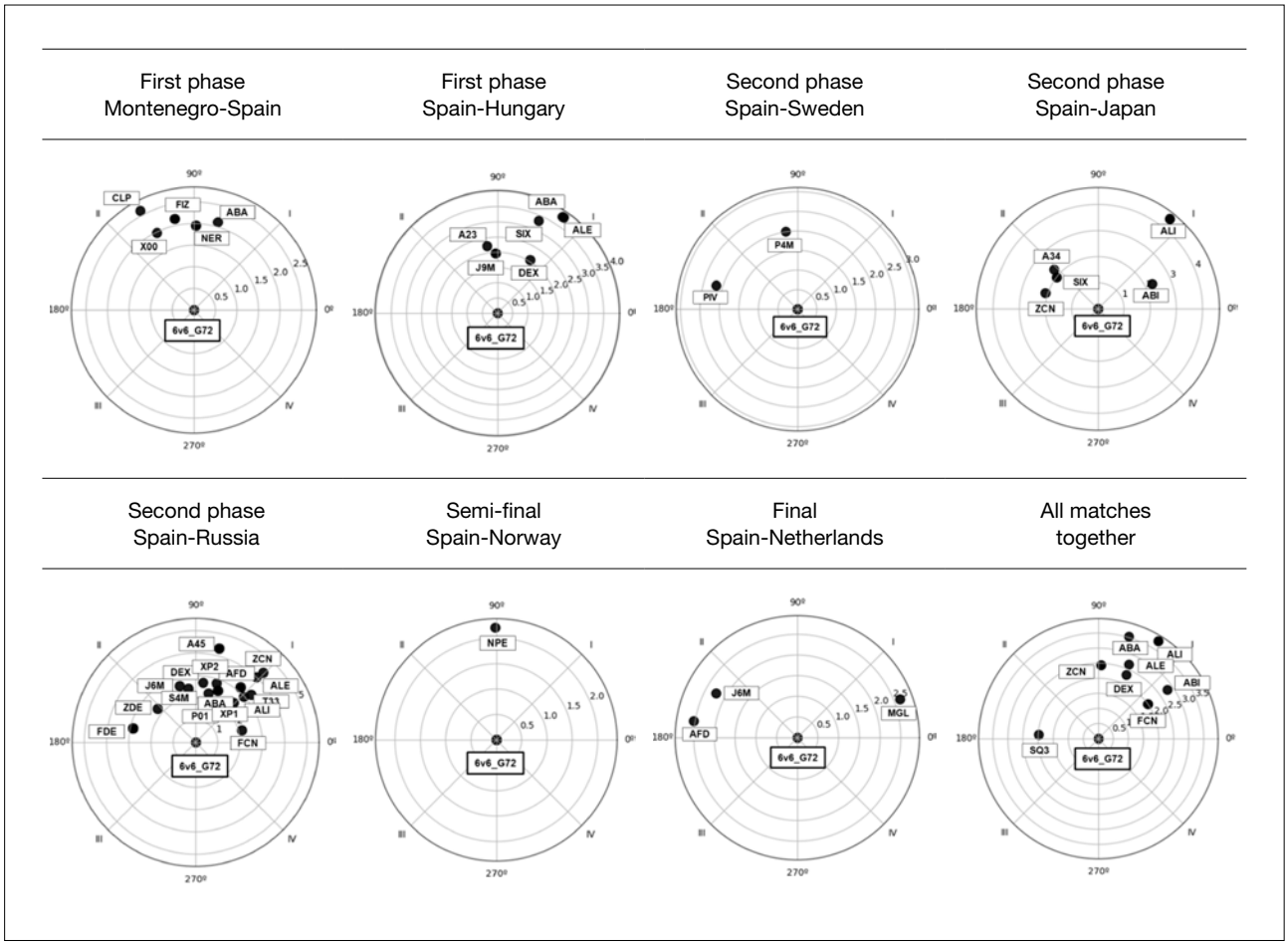


Table 3
Performance indicators in positional attacks developed in a six-on-six situation.

First phase Montenegro-Spain				First phase Spain-Hungary				Second phase Spain-Sweden				Second phase Spain-Japan			
C.	Q.	R.	A.	C.	Q.	R.	A.	C.	Q.	R.	A.	C.	Q.	R.	A.
X00	II	1.99	115.93	SIX	I	3.32	66.02	PIV	II	2.18	163.57	ABI	I	2.27	25.23
NER	I	1.97	88.70	DEX	I	2.06	58.55	P4M	II	2.01	98.87	SIX	II	2.11	162.90
LC	II	2.16	101.78	J9M	II	1.97	92.02					ALI	I	4.43	51.57
ABA	I	2.11	74.83	ALE	I	3.84	55.36					CNZ	II	2.01	142.52
CLP	II	2.61	118.37	ABA	I	3.82	56.02					A34	II	2.26	138.01
				A23	II	2.25	99.19								

Second phase Spain-Russia				Semi-final Spain-Norway				Final Spain-Netherlands				All matches together			
C.	Q.	R.	A.	C.	Q.	R.	A.	C.	Q.	R.	A.	C.	Q.	R.	A.
S4M	II	2.43	97.53	NPE	II	2.21	90.53	J6M	II	2.25	151.25	AVN	I	2.31	66.20
DEX	I	2.71	83.17					AFD	II	2.54	170.67	ABI	I	2.80	35.50
T33	I	3.28	40.50					MGL	I	2.65	20.44	SQ3	II	1.98	176.23
XP1	I	2.47	46.61									DEX	I	2.66	67.48
XP2	I	2.82	70.44									ALE	I	3.79	58.66
J6M	II	2.63	105.57									CNZ	I	2.44	88.18
ALE	I	4.01	46.90									CNZ	I	1.99	34.96
ALI	I	2.97	43.72									ABA	I	3.54	73.45
CNZ	I	4.36	46.21												
ZDE	II	2.30	138.60												
P01	I	2.27	75.39												
CNZ	I	2.13	14.68												
RC	II	2.89	167.44												
ABA	I	2.52	66.59												
AFD	I	3.19	51.24												
A45	I	4.35	75.83												

Note. C: category; Q: quadrant; R: radius; A: angle

Discussion

The main objective of this study was to identify the positional attack performance indicators of the Spanish women's handball team during the World Championship in Japan 2019, in which they were runners-up. For this purpose, behaviours were studied specifically in each match and also in general in the championship. The results provided by the polar co-ordinate analysis indicated that the Spanish handball team achieved success through different routes or ways of playing, depending on the demands of each match.

Lozano et al. (2016) noted that the use of different offensive systems helped to overcome opposing defences. In this study it was found that, even within the same offensive system, variability in group and individual behaviour is characteristic of the World Cup runner-up team. This was reflected in the different types of strong attack (those situations involving two or three players that are intended

to create an imbalance in the opposing defence) that were implemented: in the games against Montenegro, Russia and Norway the pivot was placed between the central defenders (A34); in the game against Japan the pivot was paired with the outside defender, using situations A12 and CLP; and in the games against Sweden and the Netherlands the pivot was placed between the side and central defenders (A23). Not only in the type of strong attack, depending on the match analysed, did the Spanish team exhibit different patterns of behaviour in other criteria, such as the area in which the strong attack took place, the scoring area or the action carried out to score. As already pointed out by Correia et al. (2018), behavioural variability, understood as the ability to score a goal through different routes, is characteristic of high-level athletes. In view of the results of the Spanish national team, it appears that Spanish coaching staff selected the elements of their game model that they considered most suitable in order to exploit the weaknesses of each opponent.

Continuing to look at the types of strong attack, those that acted as performance indicators (their prior realisation enabled the achievement of subsequent success) also changed according to the match: in the match against Montenegro it was CLP, in the match against Hungary it was A23 and in the matches against Japan and Russia it was the A45 situation. These findings highlight two issues: 1) the importance of playing with the pivot to generate imbalances in the opposing defence is highlighted, something that was previously pointed out by Meletakos et al. (2011) in their analysis of three men's world championships. However, it should be noted that in this study it was found that the placement of the pivot was different in each of the above-mentioned situations. 2) The types of strong attack used in the analysis of behavioural patterns in a given match do not necessarily coincide with the types of strong attack that acted as performance indicators in that same match. The importance of alternation in offensive behaviour and the influence exerted by previous actions on subsequent success is highlighted, as they condition defensive behaviour. Imagine that an attack ends in a goal after a certain player passes to the pivot. It is likely that, in the next action, when the player who made the pass intervenes again, the defenders will try to block to prevent another pass to the pivot, running the risk of receiving a shot from distance.

However, variability is not present to the same extent in all criteria, as observed in the criterion relating to the player who carried out the strong attack: in four of the seven matches analysed, strong attacks by Alexandrina Cabral (ALE) were made. This result, from the point of view of the theory of complex non-linear dynamical systems, could be understood as an attractor state or general tendency of the system (Balagué & Torrents, 2011). This is possibly due to the fact that the coach wanted to take advantage of this player's skills to create imbalances in opposing defences. However, when teams have very strong attractor states they become more predictable (Balagué & Torrents, 2011), facilitating the anticipation and strategic approach of the opposing defence.

To date, most research has offered performance indicators obtained from the joint analysis of a large amount of data, pertaining to several matches from the same or different championships. These indicators present a fixed, stable and presumably valid reality for all matches. However, in the present work, analysing the data for all matches together has yielded results that do not allow for an understanding of the specific dynamics of each match. For example, the joint analysis revealed that goals from the central zone were associated with success, consistent with the findings of Srhoj et al. (2001). In contrast, when each match was analysed independently, this result only appeared in two of the seven matches, against Japan and Russia. In other criteria as well, both in the analysis of behavioural patterns and in the analysis of performance indicators, the results for each match differ from those obtained when analysing all matches together. These findings may call into question the usefulness of performance indicators obtained from the analysis of large volumes of data, as in line with previous research (Lames, 2006; Lames & McGarry, 2007; Russomanno et al., 2021), each match offered its own game dynamics.

The analysis of behavioural patterns and performance indicators can be very useful, as they provide specific information on the behaviour of a particular team in certain situations in the competition: what kind of situations they look for to create imbalances in the opposing defence, in which areas, which players are involved in them, etc. This information is very valuable and can be very useful in the day-to-day practice of a particular team, so that the coaching staff can reflect and draw conclusions about the team's performance. Subsequently, these conclusions can be taken into account in the planning of the training process and in the strategic preparation of the competition.

Although this study provides valuable information on the variability of the behaviour and offensive performance indicators of the World Cup runners-up team, it has some

limitations. It does not allow analysis of the intrinsic dynamics of each match and, therefore, of the changes in strategies that take place during the match: within each match there are different games. Nor is the behaviour analysed according to the players who are on the court at that moment, occupying key positions, such as centre-back, which conditions the play of the whole team, as demonstrated by Flores and Anguera (2018). For future research that aims to explore the inherent variability of handball performance indicators, taking these aspects into account could help to capture their dynamic and changeable characteristics.

Conclusions

In relation to the objective of this research and taking into account the results obtained, the following conclusions can be drawn:

- The Spanish national team does not play the same way throughout the tournament, its behaviour varies depending on the match.
- The performance indicators of the Spanish national team are dynamic and variable, changing according to the match analysed.
- The performance indicators obtained from the joint analysis of several matches, while providing general behavioural trends, do not explain the specific dynamics of each match.
- The situations used in order to create imbalances in the opposing defensive system that were associated with achieving success include players occupying the pivot position.
- The scenarios involving the pivot that were associated with success were different in each match.
- Although variability is a characteristic of the Spanish team's attacking play, some behaviours were very consistent and were repeated in different games, such as the strong attacks by Alexandrina Cabral (ALE).

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Service-Learning and Motor Skills in Initial Teacher Training: Doubling Down on Inclusive Education

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A young sprinter prepares herself with a track series to work on her explosiveness. @Jérome Aufort/Adobestock

Abstract

The diversity present in classrooms requires teachers to be prepared to provide an adequate educational response to all students. However, in the field of Physical Education, teachers do not feel adequately prepared to work with students with functional diversity. Initial teacher training is essential in moving towards inclusive motor sessions, and more research is needed to analyse what practices can improve training in this regard. This study examined how participation in a service-learning programme developed future teachers' knowledge of inclusive education. The participating students were taking a subject in the field of motor skills and body expression as part of the Early Childhood Education Teacher Training Degree, and designed and implemented sessions aimed at children with functional diversity. This research was approached through a qualitative research design by analysing reflective notebooks. The results reveal that service-learning applied in the field of training future teachers through Physical Education is a suitable tool for developing knowledge related to changing the vision of functional diversity, understanding the problems they face, challenging preconceived ideas and developing positive skills and attitudes. This knowledge enhances their education and is highly relevant if inclusive education is to be encouraged in the future.

Keywords: inclusion, motor skills, qualitative research, service-learning, teacher training.

Introduction

The diversity present in classrooms requires teachers to be prepared to provide an adequate educational response to all students, regardless of their differences. In this sense, if progress is to be made towards inclusive education, initial teacher training is crucial. With regard to students with functional diversity, different studies show that teachers do not feel adequately prepared to work with this group in the field of Physical Education (PE), highlighting the lack of initial training in this area (Apelmo, 2022; Tant & Watelain, 2016; Wilhelmsen & Sørensen, 2017). In this respect, the literature calls for more research aimed at developing teaching competences related to working with individuals with functional diversity in the field of PE and analysing which practices can improve the training of future teachers (Hernández et al., 2011; Hutzler et al., 2019).

In order to address these issues, service-learning (SL) emerges as a possibility, because there are different research studies in the field of PE providing a service to groups with functional diversity that offer relevant learning in order to advance towards educational inclusion, including technical learning and improving attitudes towards the group (Capella et al., 2014; Case et al., 2021). SL is an educational experience whereby students participate in service activities that benefit the community, and reflect on developing a greater understanding of content, personal values and civic responsibility (Bringle & Clayton, 2012). For practical purposes, SL is usually implemented within the framework of a specific subject and the students who take it apply subject-related learning in such a way that they improve skills and attitudes in the academic, social, personal and civic spheres.

Butin (2003) identifies four major perspectives of learning generated by SL: technical, cultural, political and post-structural. This study focuses on the cultural perspective, which includes the knowledge developed by students in relation to a greater understanding of the group with which they work. In other words, by interacting with the context and the target group, learners generate an understanding of their needs and challenges which promotes a better understanding of society. This shared experience could lead to an improvement in university students' skills and attitudes regarding inclusive education (McCracken et al., 2020). Following the aforementioned model and within the field of PE, Gil-Gómez et al. (2015) provide an extension of the subcategories that comprise the cultural learning dimension: (1) understanding diversity issues and (2) diversity as a source of learning. The aim of this study is to analyse knowledge related to the cultural perspective developed by university students after participating in an SL programme.

Methodology

Research design

This research was undertaken using a qualitative research design (Flick, 2015), which aims to understand the complexity of social phenomena based on the perspective of its participants (Pérez-Juste et al., 2012), as it allows for a holistic and in-depth analysis of a phenomenon in this context (Yin, 2009).

Participants

The participants (N = 123) were part of a regular group formed by the group-class in the subject "Fundamentals of Body Expression; Motor Games in Early Childhood Education" on the Degree in Early Childhood Education Teaching at the Jaume I University.

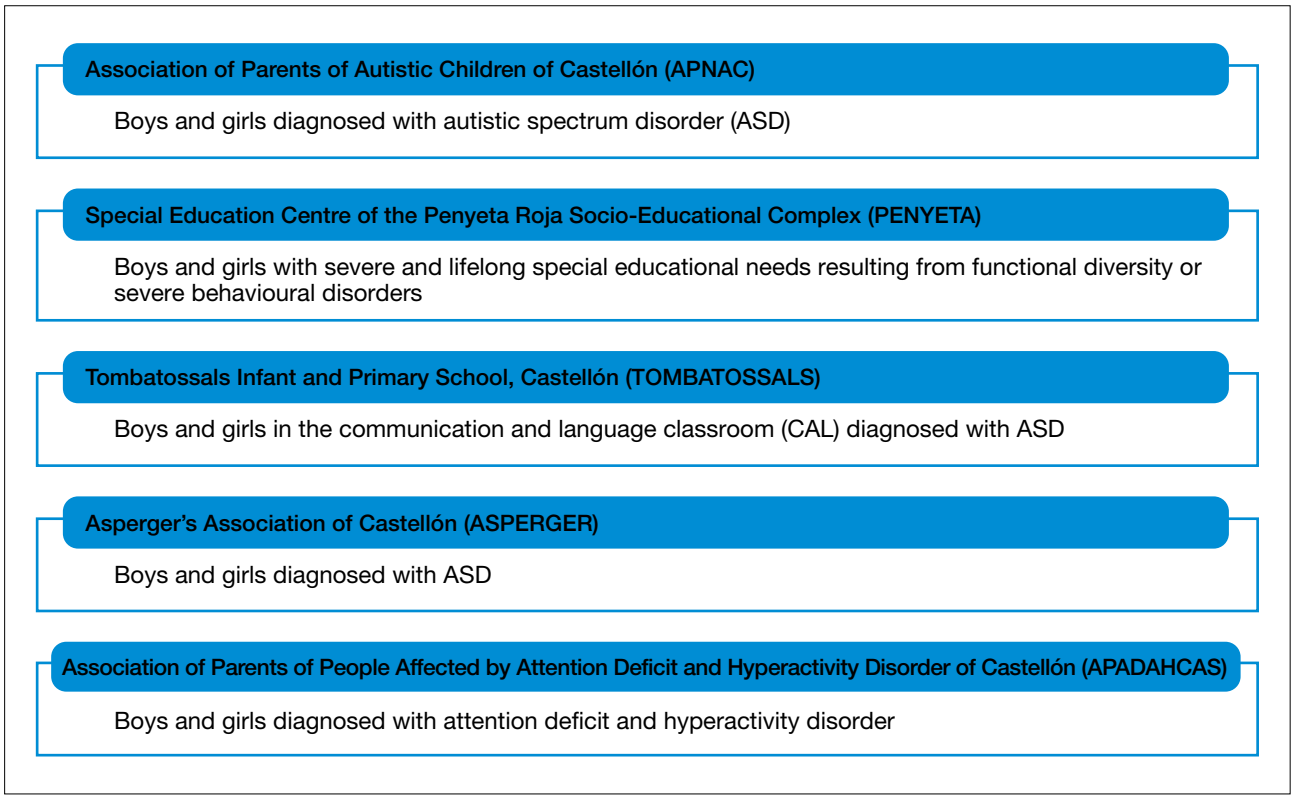
Resources

The research instrument used was the reflective monitoring notebook, a well-established tool in SL research (Chiva-Bartoll et al., 2020). It consisted of a group and an individual component, which all students had to complete during the project. The group part recorded both the body expression activities and motor games carried out in each session and the modifications that were introduced in their practice. The individual section included reflections related to their experience and learning related to personal skills (vision on diversity, civic and social skills put into play...).

Context of application

The SL programme was developed in collaboration with organisations from the socio-educational network of the city of Castellón de la Plana (Figure 1) that cater for groups of children with different disorders, all with motor, social and communicative impairments.

Figure 1
Specification of collaborating entities and the groups they support.
Source: in-house production.



It should be pointed out that the service provided resulted from the lack of recreational and sporting activities aimed at children with functional diversity, both in the public and private spheres, in which they can be adequately cared for and which provide a space for improvement (non-clinical) in the areas they are affected by.

SL Programme

The general SL programme was implemented in the subject "Fundamentals of Body Expression; Motor Games in Early Childhood Education". This subject works on content related to corporal expression, motor skills and play, which are included in the curriculum of the second cycle of the Infant Education programme.

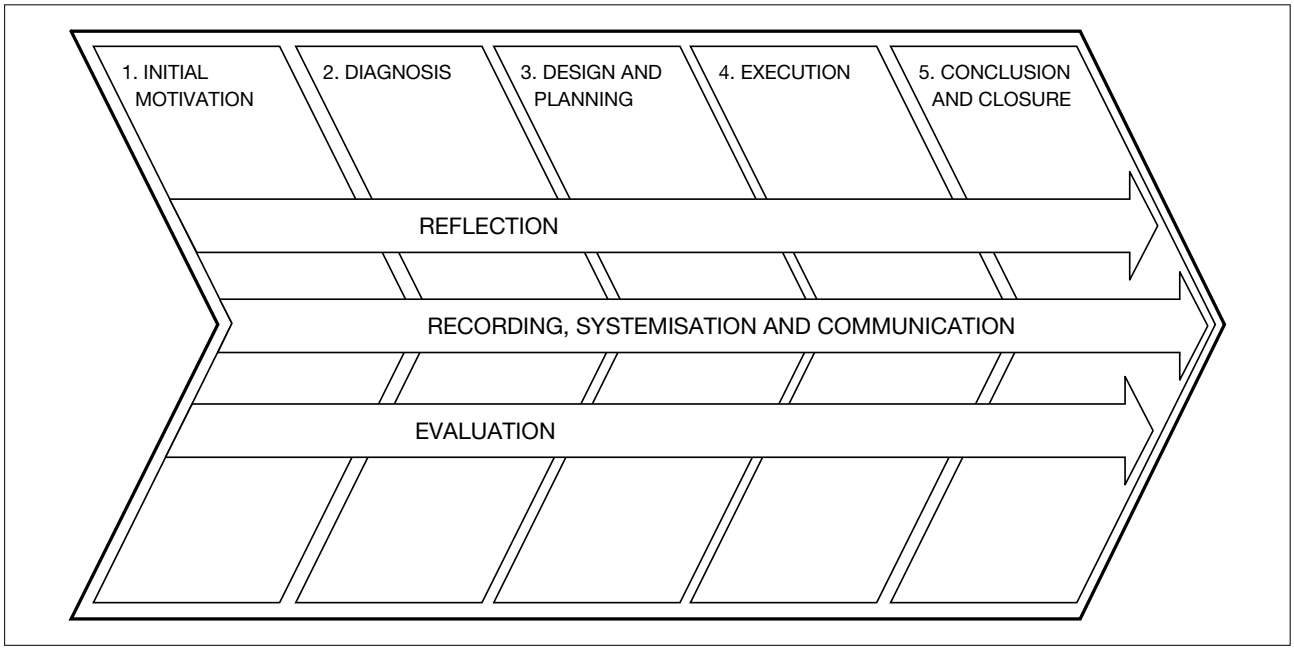
The students were organised into working groups of four to six members in order to design and implement game sessions and corporal expression activities aimed at improving the motor and socialisation skills of the participating children. In order for an SL project to develop properly, it is important to follow predetermined phases. Each group developed a project on a reference entity following the model (Figure 2) proposed by CLAYSS (2016). Within the assessment system of the subject, the SL project is included in the section on the preparation and/or presentation of work, with a weight of 30% of the total mark.

In the diagnosis stage, each group detected the motor and corporal expression needs presented by the specific group of their reference entity. These contents had been previously worked on in class, both theoretically and practically.

As can be seen in the figure, reflection should be encouraged transversally throughout the process, as it contributes decisively to consolidating and deepening learning. The reflection system carried out is summarised below:

- Group tutorials. The university faculty guided the students through group tutorials, reviewed their work and shared some feedback.
- Post-session reflection. At the end of each session, the group had to carry out a final, shared reflection, in which the staff of the organisation and the university teaching staff could also participate.
- Group reflections in the university classroom. Each group shared their experiences in leading the PE sessions in the entities.
- Reflective monitoring notebook. Students had to fill this in throughout the whole process and hand it in at the end.

Figure 2
Phases of a service-learning project.
Source: model proposed by CLAYSS (2016).



Statistical Analysis

This research was approached using the interpretative paradigm and took the research of Gil-Gómez et al. (2015), who identified two categories for cultural dimension (understanding the problems of diversity and diversity as a source of learning), which are analysed in this study, as a reference.

The information analysis was carried out through a multi-phase approach, based on an initial phase of open coding and a second phase of axial coding, from which different subcategories were created. The reflection notebooks were anonymised and coded for analysis based on the entity in which the SL was conducted and the number of the notebook from which each fragment was extracted. For example, (APNAC_3). In addition, ethical criteria specific to the research were followed, including the collection of informed consent, researcher triangulation and member checking (Flick, 2015).

Results

This section presents the results related to the cultural perspective (Butin, 2003) following the categories proposed by Gil-Gómez et al. (2015). Examples of quotations are provided to demonstrate the learning acquired through the textual transcription extracted from the notebooks. The selection of quotes was based on relevance (comments of most interest in relation to the research objectives) and depth (focus on comments that reflect the most insight into the respondents' thoughts/ideas regarding their experiences).

The first category addresses the understanding of diversity issues, which reflects the personal learning that emanates from understanding the characteristics of children with functional diversity. This category was grouped into the subcategories: capacities and interests of the collective, legitimate needs and aspirations.

In this sense, after the games and corporal expression sessions, the pupils understood that the spectrum is very broad and, although they share similarities, each child has different interests, motivations, abilities, characteristics... that make a personalised response necessary.

> "It's true that autistic children are very different from each other, they share very few similarities, each one has different interests and you can't use the same resources to calm them down, for example. You can hug some of them to calm them down, but others don't like contact and it wouldn't be appropriate, it would be better to take them to a quiet place." (APNAC_3)

As the sessions developed, they realised the importance of working on the basis of their interests in order to achieve the proposed didactic objectives and, consequently, they modified their sessions to include their interests and likes.

> "As the sessions went on, we adapted the activities to suit each of them, based on their interests. For example, in order for X to do the activities, you had to play music for him." (APNAC_4)

On the other hand, they became aware of the problems or repercussions that can arise as a result of preconceived ideas, expectations or social prejudices about this group. Thus, they also alluded to the change in these expectations.

"Working with students with special educational needs has made me realise that we should not label children or prejudge them, as having certain expectations of them only limits them. Furthermore, any expectation you have of them is invalid, as they always surprise you and show you that, despite their disabilities, they can achieve more than we usually think, even with their limitations." (PENYETA_10)

Thus, students pointed out that misinformation about functional diversity is one of the factors that cause preconceived ideas or prejudices and that this conditions their own attitudes and behaviours. This information is useful for teaching and can be extrapolated to any type of group.

"I am sure that the perception I have of this collective is the same one that society has, and it includes all the prejudices we have about what people with autism are like (...) Before doing the SL I thought that it would be very difficult to work with children with Asperger's, that I wouldn't understand them, that they would get angry most of the time, that they wouldn't listen to me... When the time came for me to work with them, I realised that all my concerns were unfounded." (ASPERGER_10)

In another area, the students became aware of the needs that may arise in relation to their care and attention.

"It seems to me that for families and close friends (...) it must be a very hard and sacrificial way of life, they have to be very strong people to endure so much, not only the extra work they are able to do, but also emotionally." (ASPERGER_8)

Finally, students developed learning related to the legitimate aspirations of the collective. They reflected on the need to adapt the educational process to the students and not the other way around, a basic concept in the promotion of inclusive education.

"Now I know that if I have a student with Asperger's in my classroom, I don't have to separate him or her because I think that he or she cannot do the activities at the same pace as the rest, but I need to adapt the activities so that he or she can do them, just as I would do with the rest of the students. Since all pupils have different needs and learning paces, it is the teacher who has to adapt to the pupils and not the other way round." (ASPERGER_10)

"In my capacity as the teacher I want to be, I do not entertain the idea of having to adapt a game for one child, no, what I would do is adapt the game for everyone. Things can be done without excluding anybody. Games for all. For this reason, I think it is necessary to focus on inclusive education that addresses all the specific characteristics of the classroom." (TDAH_8)

By interacting with the group, the students understood that not only should their limitations be taken into account, but they also saw the importance of focusing on the capabilities of these individuals. In this sense, students consider that the aforementioned prejudices emerge as an obstacle in progressing towards inclusion.

"In my view it is our own prejudices that make their inclusion more difficult, as we only see their weaknesses and never what they excel in. I used to be like that, but after three months at Penyeta Roja, I discovered that yes, they might have difficulties in some academic tasks, but I met students who excelled in painting, swimming or gardening. And this is what we have to focus on (...) their multiple skills and not their weaknesses, which is something we all have, regardless of whether we have functional diversity or not." (PENYETA_2)

The second category is called "diversity as a source of learning." This encompasses different personal knowledge that the future teachers have gained in relation to the diversity present in the sessions.

Given the breadth of types of learning that can be developed within this category, the following subcategories were grouped together: teaching competence, enriching diversity and social and educational inclusion.

In the first category, learning related to teaching competence is included. The students valued learning developed as a result of interaction with the group, as they considered that it will be useful in their future.

"It has been an experience that will be very useful for me in the future when dealing with children and for understanding the basic guidelines on how to react if any of them have these difficulties." (APNAC_3)

After their experience, they realised that, given the diversity in the classroom, it is essential that they are trained and prepared to be able to provide an adequate educational response for all students, regardless of their abilities and characteristics.

"This opportunity has helped me to understand that when I work as a teacher in the classroom I will have students with many different abilities and limitations, since each

child is different and has his or her own needs, so it is very important that I start training, researching, practising, etc." (APNAC_11)

Secondly, learning related to the recognition of diversity as beneficial is grouped together. As a result of the experience, the students reflected on the differences between individuals and developed a concept of diversity that is considered positive and beneficial, as well as a source of learning. This led them to further deepen their understanding of the characteristics, needs, etc. of the group and thus improve their understanding of diversity and society.

"It has helped me a lot to better understand people with educational difficulties and to appreciate differences as something positive for learning. In the future, whether I work with pupils with educational support difficulties or pupils in mainstream schools, I know that I will know how to use the differences between them as another educational tool." (PENYETA_1)

"I have seen, through this experience, that there are big differences between individuals, but this is what enriches us as individuals and as a society. We are all different, but we are all people with rights and we can all learn a lot from this great diversity." (PENYETA_6)

Moreover, university students became aware that it is necessary to see the learner instead of the diagnosis. This issue is relevant in teaching, as such a diagnosis may be accompanied by preconceived ideas.

"I have learned not to pay attention to whether a child has ADHD or not (referring to not labelling and having different expectations); when I was working on the project I only saw children, some of them requiring more activity, some of them less activity, etc." (TDAH_2)

Finally, derived from the positive conception and consideration of diversity as a learning tool, references relating to social and educational inclusion were brought together. The students considered that the way to avoid exclusion is through coexistence. They concluded that, in order to teach values or behaviours, real interaction is need to develop meaningful learning.

"I think it would be very positive for both disabled and non-disabled children to be able to coexist and learn from each other. I find it very difficult to try to teach them what it means not to discriminate against people because of their different characteristics if they don't have the opportunity to encounter them. I believe that discrimination arises from fear of the unknown and ignorance; we should try to ensure that in our classrooms children can share experiences with other children and learn to get to know them, to really understand that diversity is not negative but positive." (PENYETA_2)

Students felt that schools should interact, so that "neurotypical" students become aware that all people have rights and should therefore have equal opportunities.

"I think it is essential that, from an early age, pupils with a disability interact with others who are neurotypical because the latter realise that we are all equal and we all have the same rights and that we should all have the same opportunities." (TOMBATOSSALS_5)

Discussion

This study attempts to respond to one of the courses of action proposed by Hernández et al. (2011), who call for the implementation of teacher training programmes that allow for an approach to adapted and inclusive motor practice, while analysing the learning generated through it. The interest in the object of study is reflected in the increase of studies related to inclusion in PE (Marín-Suelves & Ramón-Llin, 2021).

The literature in the field of PE indicates that there is a lack of training, knowledge and experience regarding attention to diversity (Apelmo, 2022) and, in fact, teachers indicate that they do not feel adequately prepared with regard to educational inclusion, highlighting insufficient initial training in this regard (Tant & Watelain, 2016; Wilhelmsen & Sørensen, 2017). Clearly, a change in initial teacher education aimed at improving inclusive education is necessary (Apelmo, 2022).

In this sense, the SL programme presented in this study seems to have been a good way to start encouraging this change, as it has combined both academic preparation and experiences through which university students have been able to interact directly with children with functional diversity; key factors in the construction of positive attitudes towards inclusion (Hernández et al., 2011; Van Mieghem et al., 2018). Therefore, SL emerges as an appropriate way to improve attitudes towards individuals with functional diversity among trainee teachers (Case et al., 2021).

The first category analysed presents student learning related to the understanding of diversity issues. Previous literature on SL applied in the field of motor skills has already highlighted its contribution to bringing about changes in perceptions, understandings and beliefs about the target group (Seban, 2019). The results of the present study indicate that the participating trainees were able to perceive that the

motivations, interests, characteristics and abilities of the children they worked with needed personalised responses. At the same time, according to Ashton and Arlington (2019), this increased understanding of diversity could increase self-confidence in working with diverse learners in their future teaching. Moreover, university students have become aware of the impact that social prejudices can have, as they can reinforce the assumption of negative stereotypes. In this way, it appears that the SL programme has led to an improvement in university students' attitudes towards inclusion and inclusive practices through direct experience (McCracken et al., 2020).

Another relevant aspect of learning within this category is understanding the legitimate aspirations of the groups targeted, as PE teachers sometimes prefer segregated classes, i.e. separate provision for pupils with special educational needs (Slee, 2018), which has a negative impact on the motor experiences of these children (Apelmo, 2022). In this sense, therefore, the SL programme seems to have helped trainee teachers to realise the need to tailor the educational process to the learners, a key aspect in promoting inclusive education. Similarly, university students appear to have reconfigured their view of diversity by shifting from a focus on limitations to a focus on the capabilities of the children they have worked with; demonstrating an appreciation for the multiple ways of moving, being healthy and physically active and showing a strong commitment to this diversity, issues that are also required to support inclusive (physical and motor) education (Apelmo, 2022; Penney et al., 2018).

The second category analysed deals with university students' perceptions of diversity as a source of learning. This is key, as a lack of teacher training on inclusion leads to the perception of diversity as a problem, and so risks seeing children with special educational needs as separate from the rest, thus tending to marginalise them (Apelmo, 2022). In this sense, Gil-Gómez et al. (2015) argue that SL is capable of generating learning of various kinds in those who implement it, including aspects such as improved teaching competence, the perception of diversity as a source of benefit and an improvement in social and educational inclusion, the three subcategories to which the students participating in our study alluded.

Increasing teaching competence is relevant since, when specialist PE teachers do not feel sufficiently prepared to deal with diversity, they tend to become frustrated, nervous and frightened when they encounter students with special educational needs in class (Apelmo, 2022). Therefore, being able to develop inclusive practices with the guidance and mentoring of the university faculty (through SL) can not only enhance the development of teaching competence, but also provide teaching experiences that can reshape views on inclusion and develop greater self-confidence in working with children with special educational needs (Ashton & Arlington, 2019; Van Mieghem et al., 2018). In this way, SL emerges as an ideal tool in the construction of a remodelled motor and physical education, which is committed to educational inclusion and which perceives differences in bodies and minds as a source of learning (Apelmo, 2022). Ultimately, SL is a potentially appropriate method by which to support inclusive education, as it enables trainee teachers to gain a new perspective on the educational experience by promoting attitudes, values and practices that support inclusive educational approaches in schools (Carrington et al., 2015).

Conclusions

It is necessary to address initial teacher training if progress is to be made towards inclusive education. After participating in the SL programme, students have altered and developed their view of functional diversity, better understanding the issues they face, challenging preconceived ideas, developing skills and positive attitudes towards diversity and the group.

On the one hand, the results obtained suggest that the participating students have developed knowledge that will be of great help to them in their professional future to promote inclusive education, in line with the general literature on SL (Carrington et al., 2015).

On the other hand, the novelty of the present research lies in the fact that SL applied in the specific field of PE is postulated as an appropriate tool for improving initial teacher training in relation to the group with functional diversity, in line with the needs identified in the literature in this field (Hernández et al., 2011; Hutzler et al., 2019).

However, limitations of the study could be identified regarding the specificity of the environment, situation and sample in which the research was carried out, making it difficult to transfer the results to other educational contexts, and the lack of variety in the data collection strategy, which restricts the consistency of the findings presented. Taking this information into account, as future research prospects, it is proposed that multiple case studies be carried out, as well as the triangulation of the information obtained with other agents involved in the programme and/or instruments. In addition, the results obtained in this study may encourage the research team to gather more data to further the objective of the study.

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LITERATURE REVIEW

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Book review: Camerino, O., García-Castejón, G., Valero-Valenzuela, A. & Castañer, M. (2023). *Innovar en Educación Física y Deportes. El Modelo Pedagógico de Responsabilidad Personal y Social (MRPS)*

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Front cover:
A young sprinter prepares herself with a track series to work on her explosiveness. @Jérome Aufort/Adobestock

The authors of this text address the challenge of clarifying the new pedagogical and didactic trends in physical education and sport. Its approach updates the theoretical foundation and offers new innovative pedagogical and didactic strategies to be applied progressively in practical sessions, following the premise of "theorising practice and practising theory" (Castañer & Camerino, 2022).

The content of the book is focused on professionals who promote and want to innovate and apply new pedagogical and didactic strategies in physical education and sport and are not satisfied with a traditional approach.

The structure of its content guarantees a pleasant, orderly and rigorous reading, which includes scientific and current references, as well as orientations and practical applications, reflections and dilemmas to be discussed with the students in relation to each type of innovation proposed.

The first introductory theme is key in dealing with different perspectives of 21st century renewal pedagogy. The text then delves into the pedagogical innovation of physical activity and sport, showing the professional new methodological approaches and encouraging them to adopt a guiding role that gives the lead role and responsibility to the participants and seeks to develop the different motor behaviours together with the cognitive, relational and emotional dimensions.

The book explores the new pedagogical models, offering a theoretical and practical orientation of each of them, as well as a reflection on the evidence and results of the application of each model.

Finally, the authors focus on the Model of Personal and Social Responsibility (MRPS) provided by Hellison (2011), which seeks to develop levels of autonomy to prepare participants to be effective in transmitting values of responsibility towards themselves and others in a social environment.

It is undoubtedly a book that offers a pedagogical and didactic vision with an innovative, reflexive, applicable and tangible approach in its professional environment.