



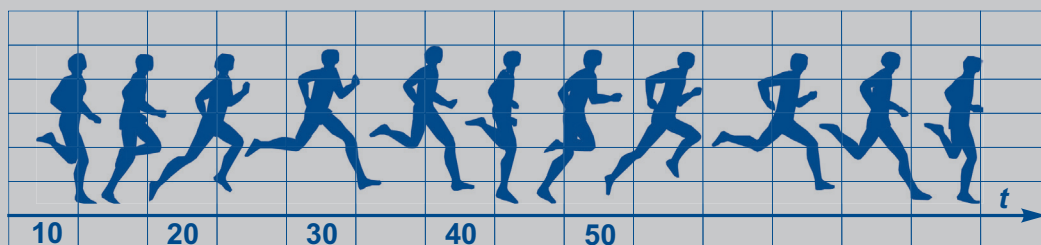
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EFFECT OF AQUATIC TRAINING PROGRAM ON PAIN AND POSTURE AMONG OBESE FEMALES WITH BILATERAL KNEE OSTEOARTHRITIS

Shinde Sandeep ^{1*}, Jain Pooja ¹

Authors' contribution:

- A. Study design/planning
- B. Data collection/entry
- C. Data analysis/statistics
- D. Data interpretation
- E. Preparation of manuscript
- F. Literature analysis/search
- G. Funds collection

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Abstract:

Background: Knee osteoarthritis (KOA) is the most common type of arthritis, causing pain, stiffness, muscular weakness, and difficulty walking, all of which discourage activity and contribute to the growing obesity pandemic as a public health concern. KOA has a considerable effect on the alignment of the spine-pelvis-lower extremity axis. Joint alignment is the main patho-physiological factor that contributes to the progression of KOA. There is little literature addressing biomechanical aspects that affect osteoarthritis and its progression, such as malalignment. The aim of this research was to investigate and compare the effects of land-based exercise (LBE) and aquatic exercise (AQE) on pain and posture in obese females with bilateral KOA.

Methods: This randomized controlled trial involved 157 obese women with bilateral KOA, of whom 7 refused to participate for various reasons. Ultimately, 150 females participated and were assigned to two different groups, Group A and Group B. They received aquatic exercise (AQE) and land-based exercise (LBE) for eight weeks. Results were evaluated using VAS, Postural Evaluation, Active Knee Extension Test (AKE), Modified Thomas Test, MMT, WOMAC, and SF-36 with statistical analysis using SPSS software.

Results: The results demonstrated a statistically significant benefit of the aquatic exercise program compared to the land-based exercise program for obese females with bilateral KOA. Pain was significantly reduced ($p < 0.0001$), whereas, posture, MMT, hip and knee flexibility, WOMAC, and quality of life were all improved ($p < 0.0001$).

Conclusion: The effect of aquatic exercise on pain and posture among obese females with bilateral KOA was found to be significant for reducing pain and improving posture, range of motion, muscle strength, and quality of life.

Introduction

Globally, lifespan has increased over time, but the rising burden of chronic illnesses suggests that a huge portion of society is living longer but in poorer health. This scenario is likely for those suffering from osteoarthritis, which is one of the primary causes of persistent pain and impaired mobility worldwide [1]. Osteoarthritis can affect any region of the body, including the hands, hips, knees, and cervical and lumbar spines [2]. The most frequent weight-bearing joint to be affected by osteoarthritis (OA), the most common type of arthritis and the primary source of disability in older persons, is the knee [3]. Over the last ten years, the prevalence of knee osteoarthritis (KOA), recognized as the tenth contribu-

tor to years spent with a disability globally, has more than doubled [4]. With a frequency that ranges from 22 to 39%, osteoarthritis is the most frequent joint condition and the second most common rheumatologic issue in India [5]. Age and weight correlate and increase the occurrence of KOA, with females being more affected than males [6].

Knee osteoarthritis (KOA) is a chronic inflammatory degenerative disease that affects the articular cartilage. The changes in the articular cartilage include increased water content, loss of proteoglycans, and breakdown of the collagen matrix. As the condition worsens, the synovium thickens, the subchondral bone alters, the cartilage fibrillates, and osteophytes form [7-11]. Although pain is the primary symptom of osteoarthritis, other symptoms include joint stiffness, increased joint discomfort, instability, and weakness. These symptoms can lead to functional limitations in day-to-day activities, difficulties completing tasks, reduced quality of life, systemic inflammation, and, ultimately, obesity [12-16]. Furthermore, persons who are obese find it more difficult and take longer to complete physical activities including walking, getting out of a chair, ascending stairs, and timed up-and-go tasks [17]. The World Health Organization (WHO) defines obesity as a body mass index (BMI) of more than 30 kg/m² that may harm a person's health. Overweight is characterized by having a BMI between 25 and 30 kg/m². Systemic contributory factors comprise age, gender, genetic predisposition, comorbidities, and obesity, whereas local mechanical risk variables include prior injuries, physical activity, occupational dangers, muscular weakness, and the amount to which body segments are aligned or misaligned [18,19].

Obesity is a major risk factor for knee osteoarthritis (KOA). According to a 2010 analysis by the International Association for the Study of Obesity (IASO) and International Obesity Taskforce (IOTF), 475 million adults globally are obese and 1.0 billion adults are overweight. Inflammatory markers such as TNF- α and leptin, which are primarily released by adipose tissue, can trigger the generation of IL-6 and C-reactive protein (CRP) and are found in higher amounts in obese individuals [20-22]. Adiponectin is an adipokine that is found in higher concentrations in individuals with osteoarthritis (OA), particularly obese women [23]. Inflammation of the hypothalamus and consequent central resistance to leptin are hallmarks of the pathophysiology of obesity. Substantial levels of leptin lead to a decrease in food consumption and an increase in energy expenditure. Furthermore, leptin stimulates the production of TNF- β , which is a stimulator of osteophyte formation. Since it can impair muscle function and reduce a person's pain threshold, the ensuing low-grade inflammation has a pathophysiological role in OA. It may also result in degenerative cartilage alterations and disrupt chondrocyte homeostasis [24-27]. OA is a chronic and persistent illness that not only lowers a person's quality of life (QOL) but also depletes financial resources and medical resources. The prevalence of OA is rising due to a confluence of factors including aging, rising rates of obesity in the world's population, and an increase in joint traumas [28].

Obesity can cause numerous pathological alterations to the structure of the whole knee joint, including improper joint loading, joint malalignment, and muscle weakening. The abnormal loading observed in obese individuals is mostly caused by joint malalignment and muscular weakness, which interact dynamically and therefore have a dampening effect on each other [29]. Muscle weakness in obese people leads to joint impairment, which incorporates joint misalignment. The interaction of these three mechanical variables influences joint structure, facilitating the start and development of obesity-related OA. Obesity and KOA together produce a vicious circle of discomfort, diminished function, and the advancement of the illness. The reduction of KOA symptoms is necessary to break this cycle. Thus, it is imperative to investigate strategies for impeding the disease's progression. The focus of current KOA treatment is on non-pharmacological interventions, such as physical therapy, therapeutic exercise, and weight loss [17,30]. Exercise is an excellent choice among these treatments because it is low-cost, easy to practice, and unlikely to have negative side effects [31].

Individuals who are classified as obese and have knee osteoarthritis may find it more challenging to exercise, as their arthritic symptoms may worsen with weight-bearing or rising loads, and their exercise compliance may be relatively low. According to the literature, exercise programs for KOA should be comprehensive and incorporate patient education, lower limb strengthening, cardiovascular training, gait training, flexibility, stability, and posture training, in addition to weight loss and psychosocial support. One of the primary non-pharmacological therapies recommended by the Osteoarthritis Research Society International (OARSI), the American College of Rheumatology (ACR) for managing the symptoms and preventing or delaying the onset of KOA in obese patients is aquatic exercise [13,32-36]. Aquatic exercise not only allows the patient to immerse in water and weigh up to 90% less than on land but it can also be a beneficial treatment for obese persons who struggle with weight-bearing when undertaking physical activity on land [37]. The water's natural resistance and buoyancy support the body's weight, thus minimizing the effects on bones, joints, and muscles, and facilitating movement. They also provide a comfortable training surface and may reduce pain by activating thermal receptors and mechanoreceptors. Warm water and its pressure also help to relieve stress, relax muscles, and lessen muscle stiffness. Moreover, the drag forces of the water may lessen mechanical loads on spinal joints, while the water's temperature and the hydraulic pressure may improve blood circulation [30,38-42].

Research on the beneficial effects of aquatic exercise for patients with chronic degenerative joint disease and obesity has been conducted so far. A multipurpose program is necessary for these patients, as opposed to an ordinary regimen that focuses on exercise duration and intensity, to help maintain or enhance joint function, offer stretching exercises with an advantageous impact on the muscles of the spine with KOA, reduce the risks related to stretching exercises on land, and enhance the impact of these exercises on the posture and pain of individuals with KOA when they are transferred to an aquatic environment [41,43]. Few studies have examined the effects of aquatic exercise on functional abilities, obesity, posture, and overall quality of life in this group. A pilot study was conducted to design an aquatic exercise program to relieve pain and enhance posture of obese females with KOA, and to examine the efficacy of aquatic exercise and land-based exercise on pain and posture.

Materials and Methods

Study design

The study was carried out at Krishna College of Physiotherapy, Krishna Vishwa Vidyapeeth, KIMSUDU in Karad, Maharashtra, over eight weeks. The experiment was a single-blinded and randomized controlled trial. Both aquatic and land-based training were experimental arms of this 4-month randomized controlled trial (RCT) examining obese women with osteoarthritis in their knees. Women who met the criteria for Kellgren Lawrence radiographic disease severity scale I and II and had obesity and were classified as Grade I (30–34.9 kg/m²) were among the 45–55-year-old obese individuals. The CONSORT guidelines for conducting and disclosing randomized controlled trials were met in the study and its reporting. The study procedure complies with the Declaration of Helsinki and was approved by the Krishna Vishwa Vidyapeeth, KIMSUDU, Karad Institutional Ethics Clearance Committee (Protocol No.: 579/2022/2023). Prior to enrollment, all individuals provided written informed consent.

Subject recruitment

A multiphase recruiting procedure was set in practice. This study enrolled 157 obese females with knee osteoarthritis (KOA). Out of 157 females, 2 refused to participate due to personal issues, 3 rejected due to scheduling constraints, and 2 declined due to reluctance to visit the clinic. Finally, 150 obese females decided to take part in this research. The participants were verified using the inclusion and exclusion criteria. The selection criteria were obese females aged 45 to 55 years, with Grade I obesity (30–34.9 kg/m²) and meeting the Kellgren Lawrence radiographic disease severity scale I and II criteria. Meanwhile, the exclusion criteria were a history of surgery, skin illness, open wounds, water phobia, unstable medical conditions, or having undergone hip/ knee replacement surgery, participants who had had knee surgery within the six months prior to the study, participants who had undergone any knee injection within the previous three months, and participants who were unable to safely enter or exit the pool.

Randomization and blinding

In this study, participants were randomly assigned to one of two groups using a computer-generated random number generator. Each participant received a sealed envelope containing a group identification number (1 = land-based exercise, 2 = hydrotherapy). The patient opened the sealed envelope when they were examined and included in the study. The group assignment was concealed from the assessors who measured the patient's variables. The study involved three steps: (1) measurements taken before the intervention, (2) the experimental group undergoing an 8-week aquatic exercise program, while the control group undergoing a land-based exercise program, and (3) measurements after the intervention.

Study intervention

Both groups received hot moist pack electrotherapy for 10–15 minutes, interferential therapy (4VP) for 15 minutes, and ultrasonic therapy (0.8–1.2W/cm²) for 7 minutes. After that, the two groups followed different protocols. Group A, which was the experimental group or aquatic training group, underwent an 8-week aquatic exercise program, while Group B, which was the conventional group, engaged in land-based exercise (LBE) (Table 1).

Group A: aquatic exercise training group (AE)

The aquatic exercise program was conducted at the Outpatient Physiotherapy Department of Krishna Hospital in Karad. The program lasted for eight weeks and included three sessions per week. Each session consisted of a 5-minute warm-up, 45–50 minutes of main aquatic exercise, and a 5-minute cool-down. The intensity and frequency of

the exercise were adjusted to the participants' abilities, such as their self-selected walking pace and self-selected repetition rate (rpm), and were progressively increased over a period of two weeks. The intensity of conditioning was considered to be 13-17 Borg scale (60-70%) of their maximal heart rate. The height of the aquatic treatment pool was modified to ensure that every part of the leg was immersed throughout the activity. Participants were usually under the supervision of an aquatic exercise therapist and in warm water (36°C) at a level that reached the medium sternum (1.2 m). Furthermore, two competent physiotherapists who had received training to educate this program led small groups of 5-6 individuals through the intervention. Attendance was recorded. The exercise instructors employed behavioral techniques to support social interaction amongst participants, encourage frequent contact throughout all phases of the intervention, establish specific behavioral goals, provide opportunities for feedback on accomplishments, and assist participants in self-monitoring their pain and exercise intensity in order to finish the activity. Table 1 provides a full description of the AE program (Table 1).

Group B: land-based exercise (LBE) group

The same treatment protocol as for Group A was administered by the physiotherapist at the gym adjacent to the aquatic pool where the AQE program was conducted. Participants were assigned to an 8-week program, with each session lasting 40-50 minutes, including 5 minutes of warm-up and 5 minutes of cool-down (Table 1).

Table 1. Exercise Protocol [17,30,41,44-46]

Type of exercise	Exercises	Distance/ Repetitions/ Hold × Sets							
		W1	W2	W3	W4	W5	W6	W7	W8
Warm-up (5 minutes)	Forward, backward, and side walking with the use of buoyancy and then with a dumbbell (meters)	16×2	20 × 2	16 × 3	20 × 3	16 × 4	20 × 4	16 × 4	16 × 5
Flexibility exercises (10 minutes)	Stretching and flexibility exercises of pectorals, peroneals, paraspinals, spinal erectors, quadriceps, hamstrings, gastrosoleus, and plantar fascia.	10×3	10×5	15×3	10×5	20×3	20×5	30×3	30×5
Upper and lower body training (10 minutes)	Exercises for arms, elbows, wrists, hands, and fingers. Leg lift, small squats, Side to Side weight shift, Front Lunge Weight shift, Ankle circles, Toe curls, Inversion-Eversion.	10×2	10×4	10×6	10×8	12×10	13×8	13×10	13×12
Aerobic and Endurance training (10 minutes)	Straight leg kick (front, corner, across, side and back) Heel Jacks, Rocking Horse, Elbow to Knee, Jump Jack, Cossack Shuffle and Four Square Waltz Step	8 × 2	8 × 2	10 × 2	8 × 3	10 × 3	8 × 3	10 × 3	10 × 3
Strength training (10 minutes)	Hip flexion-extension, hip abduction-adduction, knee flexion-extension, double leg squat (resistance used was water, ankle weights)	10 × 3	10 × 4	10 × 5	10 × 6	10 × 7	10 × 7	12 × 3	12 × 3
Balance and proprioception training (10 minutes)	Marching on the spot	10 × 3	10 × 4	10 × 5	10 × 6	10 × 7	10 × 7	12 × 3	12 × 3
	Gait training in anterior-posterior, lateral-lateral, and diagonal (meters)	16×2	20 × 2	16 × 3	20 × 3	16 × 4	20 × 4	16 × 4	16 × 5
	Knee chest, cross-country ski	10 × 3	10 × 4	10 × 5	10 × 6	10 × 7	10 × 7	12 × 3	12 × 3
	Walking in figure 8 holding a noodle, without the noodle, and then with eyes closed	16×2	20 × 2	16 × 3	20 × 3	16 × 4	20 × 4	16 × 4	16 × 5

	Balance on one leg with eyes open and then with eyes closed (hold, seconds)	4 × 2	4 × 2	5 × 2	5 × 2	4 × 3	4 × 3	5 × 3	5 × 3
Cool down (5 minutes)	Lying down on a pool corner and slowly cycling with legs in the water.					–			

Outcome Measurements

Visual Analogue Scale

It is a tool for measuring a quality that is believed to comprise a range of values and is difficult to assess directly. VAS is a single-dimensional method of measuring pain that has already been widely applied to adults. The validity of VAS was examined by intraclass correlation score, which was 0.97 (95% CI = 0.96 to 0.98) [47].

Western Ontario and McMaster’s Universities Osteoarthritis Index (WOMAC)

The WOMAC is a disease-specific self-assessment for individuals with knee and hip OA that consists of 24 items divided into three dimensions: pain, function, and stiffness. It can be used to examine people with OA treated conservatively. Its inter-rater and intra-rater reliability are 0.91 and 0.81, respectively, with acceptable ICC. Pain, stiffness, and function have ICC values of 0.74, 0.58, and 0.92, respectively [48,49]

Manual muscle testing (MMT)

MMT is the most often used method for measuring muscle strength deficits. With the application of force to the subject’s resistance, the examiner assesses the muscle groups being tested as subjectively ‘weak’ or ‘strong’ on a five-point scale. The levels of agreement attained were high, ranging from 82% to 97% for inter-examiner reliability and from 96% to 98% for test-retest reliability [50].

Active knee extension test (AKET)

It is used to determine the length of the hamstring muscle with the hip flexed 90 degrees using goniometry. It is recognized as the most reliable method for measurements of hamstring flexibility because it depends on a database of currently known knowledge. The patient was positioned supine, lying with 90 degrees of hip and knee flexion. The test was conducted on both the right and then the left extremities. For the location of the fulcrum of the universal goniometer, the lateral femoral condyle was recorded. The patient was then instructed to bend the knee until a slight stretch could be felt in the back of the leg. The average of three successive measurements was used as the final value for the popliteal angle as the AKET outcome measure. For determining hamstring tightness, these cut-off values vary for each gender. The active knee extension angle for men should be less than 33.0, whereas the angle for women should be less than 23.4 [51,52].

Modified Thomas test

This test was used to examine the hip joint flexibility by proper placement and to reveal the tightness of the hip flexors. Two participants were asked to sit at the edge of the testing sofa after being informed about the procedure, and they were requested to roll back onto it while pulling both knees to their chests. This was ensured with the pelvis oriented posteriorly and the lumbar spine in the proper position on the testing couch. The participant then brought one limb to the ground while maintaining maximum hip flexion with their arms on the other side. Two angles were measured on each side using a goniometer. The first angle was the hip flexion angle. The second one was the knee flexion angle. The stationary arm of the goniometer was aligned with the horizontal plane. Readings obtained using this procedure were obtained and documented. Test-retest reliability for this modified Thomas test ranges from 0.91 to 0.94 [53,54].

Quality of life

The Short Form 36 (SF-36) was used to assess health-related quality of life. The eight domains of the SF-36 include functional ability, physical aspects, pain, general state of health, vitality, social aspects, emotional aspects, and mental health. It is a widely used generic instrument for assessing health status. Every questionnaire item is assigned a score between 0 and 100, where 0 represents the worst overall health and 100 represents the best health.

Posture

Posture was assessed by the observation method. A vertical plumb line was suspended over the center of the body and any asymmetrical variations were checked that might be a sign of poor posture. The patient wore as minimal clothing as possible to allow the examiner to clearly see the anatomical landmarks and bony prominences from the front (anteroposterior view), back (posteroanterior view), and side (lateral view). The patient was instructed to stand straight and face forward [55]

Statistical Analysis

SPSS statistical software (version 23.0) was used for all statistical analyses, including calculating the mean and standard deviation of pain, ROM, manual muscle testing, WOMAC, active knee extension, and the Thomas test. The paired t-test was employed to analyze the pre- and post-intervention data within the group. The unpaired t-test was employed to compare the groups prior to and following intervention. In the intent-to-treat (ITT) analysis, subjects who dropped out during the interventions were included. The final observation was performed using the last observation carried forward method to assess outcome measurements in the ITT population. The outcome measures were evaluated at the commencement of the study and eight weeks later.

Results

The 157 females who undertook the initial evaluation were divided randomly into two groups: 77 were assigned to the AE group and 80 to the LBE group. Two participants dropped out of the AE group due to a lack of willingness to visit the clinic and one participant due to schedule constraints. Four participants from the LBE group dropped out owing to personal reasons. Finally, 75 participants from each of the AQE and LBE groups completed the interventions and follow-up examinations. Based on the statistical analysis, the aquatic exercise program had a substantial positive effect on knee osteoarthritis (KOA) in obese females. The average values of age, body height, body weight, and BMI were compared. The mean ages for groups A and B were 52.09 ± 2.472 and 50.76 ± 2.832 , respectively, whereas the mean BMI was 32.10 ± 1.208 and 31.66 ± 0.9124 , respectively (Table 2).

Table 2. Demographic details

Variables/Group	Experimental Group	Control Group
Age (years)	52.09 ± 2.472	50.76 ± 2.832
Height (cm)	155.82 ± 5.626	157.14 ± 5.221
Weight (kg)	77.88 ± 3.452	77.00 ± 3.731
Body Mass Index (kg/m ²)	32.10 ± 1.208	31.66 ± 0.9124

The mean values of the WOMAC and VAS for patients with KOA within and between the groups were compared and showed a significant difference with $p < 0.0001$. The post-test mean values are presented in Table 3, with p-value between the groups at <0.0001 .

Table 3. Comparison of mean scores of VAS and WOMAC within and between the groups

WOMAC	Pre test	Post test	p-value	t-value
Group A	68.64 ± 1.035	50.2 ± 0.8054	<0.0001	118.46
Group B	66.01 ± 0.762	61.62 ± 0.8970	<0.0001	30.636
Interference	17.697	82.086		
Visual Analogue Scale				
Group A				
At rest	4.82 ± 0.76	2.16 ± 0.65	<0.0001	22.991
On activity	6.26 ± 0.60	3.04 ± 0.72	<0.0001	46.136

Group B				
At rest	4.56±0.8094	2.68±0.5964	<0.0001	25.605
On activity	6.90±0.8411	3.54±0.5994	<0.0001	47.925

The mean values of MMT scores within the groups were compared and group A had $p < 0.0001$ for hip flexors and extensors, knee flexors and extensors, and ankle plantar flexors and dorsiflexors, for both right and left side. The post-test mean values between the groups of MMT for all the muscles had $p < 0.0001$ except for right and left knee extensors, with $p = 0.0036$ and 0.0030 , respectively (Table 4).

Table 4. Comparison of mean scores of Manual Muscle Testing within and between the groups

MMT	Pre test	Post test	p-value	t-value
Right hip flexors				
Group A	3.10±0.48	4.08±0.6098	<0.0001	10.938
Group B	3.04±0.4172	3.26±0.4452	0.0025	3.128
Interference	0.9064		9.329	
Left hip flexors				
Group A	3.05±0.4619	4.02±0.6773	<0.0001	9.872
Group B	3.17±0.3811	3.4±0.5199	0.0025	3.128
Interference	1.736		6.356	
Right hip extensors				
Group A	3.18±0.45	4.04±0.5560	<0.0001	10.130
Group B	3.02±0.56	3.34±0.50	0.0006	2.973
Interference	1.901		7.983	
Left hip extensors				
Group A	3.09±0.4979	4.06±0.5022	<0.0001	12.445
Group B	3.05±0.5670	3.8±0.5452	<0.0001	7.421
Interference	0.4591		3.115	
Right knee Flexors				
Group A	3.16±0.4943	4.2±0.5452	<0.0001	11.316
Group B	3.10±0.5087	3.70±0.5139	<0.0001	8.447
Interference	0.6512		5.702	
Left knee flexors				
Group A	3.09±0.4403	4.10±0.6057	<0.0001	12.090
Group B	3.02±0.4925	3.29±0.4584	0.0012	3.374
Interference	0.8740		9.273	
Right knee extensors				
Group A	3.06±0.5022	4.17±0.5544	<0.0001	12.853
Group B	3±0.4650	3.88±0.6568	<0.0001	9.674
Interference	0.8435		2.956	
Left knee extensors				
Group A	3.10±0.3881	4.13±0.4746	<0.0001	13.977
Group B	3.04±0.5051	3.86±0.6003	<0.0001	9.207
Interference	0.9064		3.018	

Right ankle plantar flexion				
Group A	3.04±0.4484	4.2±0.5927	<0.0001	13.650
Group B	3.01±0.4189	3.24±0.4603	0.0025	3.128
Interference	0.3763		11.078	
Left ankle plantar flexion				
Group A	3.04±0.4316	4.09±0.5244	<0.0001	13.119
Group B	3.02±0.4341	3.72±0.6485	<0.0001	7.309
Interference	0.3772		3.877	
Right dorsiflexion				
Group A	3.08±0.3587	4.12±0.5685	<0.0001	13.512
Group B	3.02±0.4642	3.66±0.6224	<0.0001	8.027
Interference	0.7873		4.657	
Left dorsiflexion				
Group A	3.05±0.3991	4.13±0.5534	<0.0001	13.135
Group B	3.02±0.4341	3.26±0.4452	0.0011	3.398
Interference	0.3916		10.567	

The mean AKE score values within the group for these patients revealed that Group B for the right and left sides, had p-values of 0.0376 and 0.0004, respectively, whereas Group A had a p-value of 0.0001. The post-test mean values between AKE groups were $p < 0.0001$. When the mean values of the Thomas test score were compared within the group for these patients, Group B had p-values of 0.0011 and 0.0013 for right hip flexion and left knee flexion, respectively, whereas Group A had $p < 0.0001$ for left hip flexion and right knee flexion, and $p < 0.0001$ for all movements. The post-test mean values of the Thomas groups were $p < 0.0001$ (Table 5).

Table 5. Comparison of mean scores of Active knee extension and Thomas test within and between the groups

Active Knee Extension (AKE)(degrees)	Pre test	Post test	p-value	t-value
Right				
Group A	34.72±1.68	51.05±0.9986	<0.0001	78.459
Group B	36.024±5.46	37.36±0.8643	0.0376	2.117
Inference	1.971		89.794	
Left				
Group A	35.256±2.013	50.01±0.8563	<0.0001	62.361
Group B	35.07±1.309	35.73±0.6844	0.0004	3.747
Inference	0.6444		112.81	
Thomas test (degrees)				
Right hip flexion				
Group A	107.90±1.117	112.06±0.9492	<0.0001	25.642
Group B	105.37±0.6529	105.74±0.8557	0.0011	3.384
Inference	16.956		38.519	
Left hip flexion				
Group A	103.37±0.7671	109.37±0.6733	<0.0001	46.602
Group B	105.65±0.6876	107.01±0.5325	<0.0001	13.159
Inference	19.167		23.808	

Right knee flexion				
Group A	110.96±0.9070	116.61±0.7515	<0.0001	38.290
Group B	108.38±0.7333	110±0.7166	<0.0001	14.818
Inference	19.107		55.157	
Left knee flexion				
Group A	105.12±0.7345	113.33±0.8436	<0.0001	64.289
Group B	104.82±0.8116	105.30±1.052	0.0013	3.339
Inference	2.321		51.539	

The mean values of the SF-36 for patients with KOA within and between the groups were compared and showed a significant difference at $p < 0.0001$. The p-value between the groups was $p < 0.0001$ (Table 6).

Table 6. Comparison of mean scores of Short form-36 (SF-36) within and between the groups

SF-36 dimensions	Pre test	Post test	p-value	t-value
Functional capacity				
Group A	53.8±0.56	67.32±0.46	<0.0001	147.36
Group B	56.62±0.65	62.46±0.50	<0.0001	54.35
Inference	<0.0001		<0.0001	
Physical aspects				
Group A	62.44±0.72	73.29±0.69	<0.0001	87.50
Group B	60.8±1.16	68.02±1.02	<0.0001	49.32
Inference	<0.0001		<0.0001	
Pain				
Group A	52.98±0.64	67.76±0.43	<0.0001	132.35
Group B	55.65±0.72	62.98±0.64	<0.0001	76.75
Inference	<0.0001		<0.0001	
General state of health				
Group A	69.77±0.78	78.6±0.47	<0.0001	108.71
Group B	68.48±0.77	74.26±0.77	<0.0001	35.60
Inference	<0.0001		<0.0001	
Vitality				
Group A	70.46±1.03	80.89±0.55	<0.0001	80.83
Group B	71.26±0.68	78.13±0.79	<0.0001	49.07
Inference	<0.0001		<0.0001	
Social aspects				
Group A	78.82±0.94	88.37±0.48	<0.0001	114.49
Group B	80.08±0.86	84.88±0.77	<0.0001	52.72
Inference	<0.0001		<0.0001	
Emotional aspects				
Group A	77.7±0.80	83.16±0.77	<0.0001	49.05
Group B	74.64±0.69	79.74±0.77	<0.0001	91.87
Inference	<0.0001		<0.0001	

		Mental health		
Group A	75.85±0.71	81.8±0.40	<0.0001	51.44
Group B	76.18±0.72	75.92±0.65	<0.0001	35.29
Interference	<0.0001		<0.0001	

Posture was assessed before and after the intervention, and percentages were calculated and compared within each group for anterior, posterior, and lateral perspectives. In all three views, Group A showed a 33.3% increase in thoracic kyphosis, scoliosis, anterior spinal inclination angle, and knee flexion, a decrease in lumbar lordosis, posterior pelvic tilt, knee varus, ankle everted, and foot pronated, and approximately 66.6% of participants had no postural deviations. Group B showed a 25.33% increase in these postural deviations and approximately 74.66% of participants had no postural deviation. The post-test measurements of Group A revealed 6.66% of participants with postural deviations, whereas approximately 93.3% had no postural deviations. Group B showed 12% with and approximately 84% without postural abnormalities.

Discussion

This study was conducted to examine the effect of aquatic exercises on pain and posture among obese females with knee osteoarthritis (KOA). It was conducted in women aged 45 to 55 years with bilateral KOA, with Grade I obesity (30-34.9 kg/m²) and meeting the Kellgren Lawrence radiographic disease severity scale I and II criteria. Osteoarthritis commonly affects middle-aged to elderly populations. 150 females were enrolled in the study and were divided into two groups randomly using simple random sampling. The pre-evaluation of pain threshold, muscle strength, muscle length, Thomas test, postural assessment, and WOMAC scale was then performed. Group A consisted of 75 obese KOA females who participated in an 8-week aquatic fitness program, while Group B participated in a land-based exercise (LBE) program. Following that, the effectiveness of both groups was compared. The aim of this research was to investigate the effect of an aquatic exercise program on pain and posture in obese females with KOA.

According to Weng J et al., osteoarthritic knee deformity results in a different gait and weak hip muscles [56]. Because of this, people with KOA suffer maladaptive kinematic stresses and loads while standing and walking, which results in morphological changes to the lower extremities and the trunk in the sagittal, frontal, and transverse planes [56]. A study showed a connection between overall spinal variables and the prevalence of radiographic KOA in aged patients [57]. Numerous studies have shown how posture in the lower body and the spine influences OA of the knee joint. However, there is no study showing how effective posture correction is for treating obese females with KOA, and hence this study was conducted. This study found that at the end of week 8, Group A experienced significantly less discomfort, improved strength, range of motion, flexibility, and corrected posture than Group B.

According to Matsumura et al., several studies have investigated truncal alterations in KOA [58]. Individuals with KOA had a posterior pelvic tilt, knee flexion and varus, and pronated feet [58]. Riegger-Krugh et al. showed that adaptive foot pronation can emerge from genu varum malalignment to achieve a plantigrade foot position during weight bearing [59]. Additionally, the consequences of increased scoliosis may be due to the varus-valgus deformity of KOA that causes compensatory mechanisms [60]. Similar findings were seen in our study; group A participants exhibited similar postural abnormalities in about 33.3% of cases, compared to group B participants in about 25.33% of cases. Pain, reduced functionality, and a general decline in QOL are just a few of the problems that this trend can cause [61]. To improve mobility and prevent KOA from developing, it is critical to address these concerns right away and to put the proper intervention methods into place.

Exercise serves as one of the therapeutic approaches that aids in reducing the harmful effects of aging on the musculoskeletal system while promoting weight management, enhancing quality of life, correcting posture, reducing pain, and increasing functional capacity. Lehnert-Schroth created an exercise regimen for patients with scoliosis focused on isometric tension exercises and stretching activities [62]. The program aimed to correct muscle tension and improve patient perceptibility. It involved training previously inactive muscles and re-educating the patient into an upright posture. The exercise effectively targeted the weakened and stretched muscles on the "thick" side and the tightened muscles on the constricted side, restoring their natural muscle tone and readiness for function [62]. Through a series of workouts, Moon et al. addressed the muscle imbalance brought on by genu varum [63]. These exercises, according to their theories, improved static stability and strength in the pelvis and lower extremities, al-

leviated muscle imbalances possibly by strengthening the quadriceps femoris and rectus femoris, two key muscles in the lower extremities, and significantly decreased knee pain during movements by integrating the dynamic stress within the knee joint [63].

A systematic study “Effectiveness of Exercises in individuals with Overweight or Obesity Suffering from KOA” was conducted in 2022, with 64 articles included [64]. According to this study, quality of life (QOL) can be improved with exercise therapies. The present research found that interventions involving physical activity are helpful in enhancing QOL in overweight or obese KOA patients, thus lowering pain and improving physical function. However, for the obese population, land-based exercise might exacerbate joint contact stress and pain [64]. In a research study conducted in 2022, Abadi et al. compared the effects of aquatic and theraband workouts on pain intensity and endurance in obese persons with KOA [44]. The 45 obese individuals in this study were randomly assigned to one of three groups: the control group, the aquatic exercise group, or the theraband exercise group. According to this study, progressive aquatic and theraband exercises are further recommendations to reduce pain intensity, and aquatic exercise may be more beneficial to recovering endurance in obese patients with KOA [44]. Lim et al. conducted a study with the goal of designing an aquatic exercise (AQE) and land-based exercise (LBE) program to improve knee function and reduce body fat in obese and KOA patients, as well as investigating the impact of these exercise programs on body fat and functional status. This study concluded that AQE had an advantage in minimizing pain-related interference with activity. AQE may be an effective strategy for obese patients who have difficulty with KOA physical activities [41].

Water exercise seems to increase the strength of the muscles around the knee, such as the quadriceps and hamstrings, with gentle resistance while reducing the compression force and load of the joint thanks to the special properties of water, including turbulence, viscosity, hydrostatic pressure, and buoyancy. In this manner, when a person dives deeper into the water, less weight-bearing pressure is exerted on their joints and intervertebral discs, resulting in more stable joints. Compared to land-based exercise, water-based exercise produces a more attractive and enjoyable environment for obese persons to exercise [17,65]. Previous research demonstrated that four to eight weeks of warm pool water (34 °C) treatment can help with pain relief, edema reduction, ease of mobility, muscle relaxation, joint protection, and releasing tight muscles [44]. Similarly, in our study, an aquatic exercise program was found to be effective for pain relief, muscle relaxation, improving range of motion, facilitating changes in muscle tension for correction, activating previously inactive muscles, and continuously training them to reeducate the deviated posture into a corrected upright posture.

A new study of individuals with ankylosing spondylitis (AS) compared the impact of water stretching exercises and pilates on pain, function, spine posture, and quality of life (QOL) in AS patients. Forty patients were randomly assigned to three groups: aqua stretch, aqua pilates, and control. This study concluded that aqua stretch and aqua pilates had the same effect on improving pain, function, QOL, and spinal range of motion (ROM) [43].

In 2021, a study titled “Postural impairments in primiparae women after one year after delivery” was conducted, involving 100 primiparae women ranging in age from 20 to 30 years [66]. Postural evaluation, a muscle length and strength test, and outcome measurements were performed. According to the findings of this study, primiparae women are more inclined to have postural abnormalities, muscle stiffness, and muscle weakness [66]. Similar findings were observed in the current investigation, which showed that KOA patients have a significant amount of postural impairment. Furthermore, the active knee extension test revealed significant tightness in the hamstrings and hip flexors along with weakness in the abdominal and gluteal muscles. Thus, the present research indicated that a water exercise program had a clinically favorable effect on pain, strength, range of motion, and posture correction in obese females with KOA. In Group A, the experimental group, the results for pain, range of motion, strength, and posture correction were determined to be statistically significant. As a result, this study accepts the alternative hypothesis, according to which an aquatic exercise program has a significant impact on pain and posture correction in obese females with knee osteoarthritis.

The aquatic training protocol is simple and convenient to learn and requires only minimal equipment, which facilitates learning and adherence to the training program, and this is a major strength of our study. Rigorous training and full attention to the patients during the therapy session are two other factors that increased the credibility of our results by ensuring research quality.

Limitations of study

The first limitation was the very small number of participants. Second, the age range was narrowed. Future studies should be conducted with a bigger sample size and more significant results, such as gait analysis for obese people.

Conclusion

Based on the study results, it was determined that aquatic and land-based treatments had equivalent effects on pain and self-assessed knee stiffness (WOMAC). However, compared to land-based exercises, aquatic exercise sessions had a greater impact on knee stiffness, lower limb muscle strength, and range of motion compared to land-based activities. As a result, the findings of this study suggest that an eight-week aquatic exercise program can be more beneficial, at a statistically significant level, in reducing pain, range of motion, muscle strength, and posture, and improving other sub-domains of quality of life such as symptoms, ADL, and knee-related quality of life in obese people suffering from KOA. Furthermore, the physical features of water allow the obese females to work out effectively and safely in water-based settings. Therefore, aquatic exercise programs can be recommended for obese females as a feasible approach for KOA patients to recover.

Institutional Review Board Statement

The study was accepted by the institutional ethical committee of Krishna Vishwa Vidyapeeth, KIMSDU (Protocol No.: 579/2022/2023) in Karad, Maharashtra. The Helsinki Declaration of 1964 and its subsequent amendments, as well as the ethical requirements of the relevant organizational and national research committees, were followed in all procedures carried out in studies involving human participants.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data availability statement: The data presented in this study are available on request from the corresponding author.

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COACHES' PERSPECTIVES OF THE USE OF SMALL-SIDED GAMES IN THE PROFESSIONAL SOCCER TRAINING ENVIRONMENT

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- B. Data collection/entry
- C. Data analysis/statistics
- D. Data interpretation
- E. Preparation of manuscript
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Abstract:

Background: The utilization and variation of small-sided games (SSGs) in team sports have garnered increased attention in recent years. This study aimed to explore the application of SSGs in high-performance soccer using qualitative methods.

Methods: Five high-performance soccer coaches participated in semi-structured interviews. A reflexive thematic analysis was conducted, revealing six key themes: 1) the relevance of SSGs, 2) variations in SSGs, 3) the role of SSGs in planning and periodization, 4) the diverse functions and meanings of SSGs within a high-performance team, 5) decision-making and creativity in SSGs, and 6) the emphasis on tactical development through SSGs.

Results: The findings highlighted the integral role of SSGs in the coaches' training routines, particularly on microcycle days -4 and -3, and for both substitute and starting players. Coaches identified the number of players and pitch dimensions as primary constraints to manipulate. The leadership of SSGs was typically delegated to assistant coaches to enhance the physical and enjoyment aspects. SSGs were predominantly used to develop positional play, with specific playing positions constrained in various pitch areas to elicit targeted behaviors. Furthermore, SSGs were employed to enhance players' decision-making and creativity by providing game-like scenarios that encourage spontaneous problem-solving.

Conclusion: This study underscores the critical importance of SSGs in high-performance soccer training, offering practical insights for coaches and theoretical implications for researchers. Coaches can leverage SSGs to replicate match demands, foster tactical understanding, and enhance player engagement.

Introduction

A wide range of research have emerged over the last two decades emphasizing the use of game-based situations as a coaching method to enhance players' performance [1]. It has been argued that the use of game-based situations would help the players to develop and refine their motor skills in accordance with the environmental information [2], such as the teammate and opponents positioning [3,4], the ball location, and in relation to the game rules, through an ecological approach [5].

Small-sided games (SSGs), also known as skill-based conditioning games, game-based training, or small-sided and conditioned games, are modified training formats played in adjusted areas, with adapted rules and/or involving a reduced number of players in relation to the competition [6]. Such formats are typically employed on the premise that it allows to concomitantly develop players' physical, technical, and tactical behaviours [7]. One advantage is that coaches can plan and emphasize the players' running demands, motor skills, and space exploration as result of modifying different task constraints [2].

These practices tend to be representative of the match scenarios because they expose players to dynamic and unpredictable situations through teammates' cooperative behaviours and opponents' competitive interactions under specific game rules [8]. Consequently, the interest in the use of SSGs has been growing, leading to the emergence of a wide scope of original investigation and reviews exploring the effects of different rules, playing area dimensions, number of players, goals, or touches, among others, on the physical, technical, and tactical behaviours of soccer players [5,9,10].

A few studies have attempted to explore the coach's perceptions on the use of SSG in the team preparation through semi-structured interviews [11–13]. Coaches consider SSGs to be important in the process of preparing their team for competition [12] and to allow concurrent development of tactical and physical skills [11]. Particularly, coaches reported that SSGs are essential in their training methodology to establish direct association with specific game moments and the competition [11]. As such, SSGs are adopted in the daily training routines and throughout the season [13].

While the effects of SSGs on various aspects of team sports (such as physical fitness, technical skills, tactical understanding, and psychological components) are well-documented, there remains a significant gap in understanding how professional soccer coaches perceive and implement these tasks within their training routines. Coaches' perspectives are crucial as their experiences, beliefs, and strategic decisions directly influence the practical application of SSGs, impacting their effectiveness. As well, despite the relevant scientific insights with a practical implication, previous research has mainly been conducted at the academy level or semi-professional environments through quantitative methods. It remains unclear how high-performance soccer coaches perceive and manipulate the use of SSGs in their practise. Therefore, using a qualitative approach can provide valuable insights about how coaches envision their own practices and their rationale for decision making [14]. Such line of inquiry may help coach education programs, sport organizations and high-performance coaches reflect on the influence of experiential, social, and cultural factors on planning and periodisation, which subsequently may provide solid grounds for more effective reflexive practices and better learning opportunities for players.

Said that, this study aims to explore coaches' insights to uncover the rationale behind their use of SSGs, the specific methods and variations they employ, the challenges they encounter, and the perceived benefits and limitations of SSGs from a coaching perspective. Addressing this gap is essential to bridging the divide between theoretical benefits established in research and the practical realities faced by professional soccer coaches, thereby informing best practices, and contributing to the development of more effective coaching education programs. Specifically, the study seeks to understand how coaches define SSGs and the perceived benefits these games offer in training sessions [11]. It aims to investigate the timing and frequency of SSG implementation throughout the training calendar and how coaches adapt these games to develop specific fitness components and tactical aspects of play [13]. Additionally, the study intends to examine the constraints and rules coaches manipulate within SSGs to achieve desired training outcomes and the role of SSGs in fostering decision-making and creativity among players [12]. By addressing these questions, the study aspires to fill existing gaps in the literature and provide a comprehensive understanding of the practical applications and theoretical underpinnings of SSGs in high-performance soccer coaching.

Materials and Methods

Researchers' Positioning

Considering the purpose of the present study, the research team adopted a relativist ontology and constructionist epistemology, highlighting the importance of perceived experiences and the pivotal role played by social interactions. This is a co-constructed process, engages researchers and participants, involves events, and captures how individu-

als perceive knowledge and how these perceptions are grounded on social interactions [15]. Therefore, the present study results from a reflexive and collaborative process between researchers and coaches, all with their unique identities, beliefs, experiences, and critical awareness [14].

To help readers critically reflect on the present study, it is important to stress that all authors of this research have a Higher Education degree. Particularly, authors 1, 2, 3, and 4 completed a PhD in Sports Science, while author 5 has a MSc. From a coaching experience, authors 1, 2, 3 and 5 completed UEFA soccer courses and have been engaged in the coaching process, including planning, and delivering sessions, and performance analysis. Author 4 is an innovative soccer researcher, attending conferences worldwide. Specifically, author 5 works as Head of Fitness in a high-performance club that regularly participates in the Asian Champions League, with previous experience in different worldwide clubs and leagues/tournaments, including FIFA Club World Cup and UEFA Champions League. Authors 1, 2, 3, and 4 are university lecturers, teaching modules to BSc and MSc university students, and delivering workshops and continuous professional development courses to different soccer associations.

Participants

Five male soccer coaches participated in this investigation (Table 1). The number of participants was determined based on theoretical saturation [16]. All coaches possessed the UEFA Pro Football (Soccer) Coaching qualification and have numerous years of experience in high-performance soccer across different environments. At the time of data collection, all individuals were employed as Head Coaches in Professional Soccer (adult male contexts) or at the Professional Development Phase (Under-23 and Under-19) across different countries. The participants' diverse experiences, beliefs, values, and cultures facilitated a completer understanding about SSGs through a multitude of lenses and ontologies [16,17]. After ethics approval by the local Institutional Research Ethics Committee, written and informed consent was provided by the coaches before the beginning of data collection. All participants were notified that they could withdraw from the study at any time. To ensure anonymity, participants were given a number (e.g., Coach 1).

Table 1. Professional soccer coaches' characterisation

Coach 1	Ex-professional soccer player with international playing experience in different countries. Represented a South American Soccer Confederation (CONMEBOL) National Team as player. Soccer Head Coach in different divisions and countries, with experience managing in international competitions. National Team Head Coach in a Union of European Football Associations (UEFA) country. 16 years playing experience. 17 years coaching experience.
Coach 2	Ex-professional soccer player in the United Kingdom. Previous experience as Head of Academy and 1 st Team Head Coach in the United Kingdom. Head Coach in the Scottish Premiership. Soccer coach educator. 17 years playing experience. 10 years coaching experience.
Coach 3	BSc in Sports Science and Physical Education. Career started as Academy Coach and Assistant Head Coach. Head Coach, with experience in different countries and continents. Previous Asian Football Confederation (AFC) champion. 25 years coaching experience.
Coach 4	Ex-professional soccer player in the United Kingdom, but never played in the highest league. Early career finisher. Previous experience as a younger Academy Manager, 1 st Team Assistant Manager and Head of Academy. Currently Under-23 Head Coach in an English Premier League soccer club. 5 years playing experience. 9 years coaching experience.
Coach 5	Ex-professional soccer player in the United Kingdom. Under-19 Head Coach in an English Championship soccer club. National Team Head Coach in a Confederation of North, Central America and Caribbean Association Football (CONCACAF) country, with also experience representing it as soccer player. 13 years playing experience. 7 years coaching experience.

Procedures

Data was collected using an individual semi-structured interview guide with 27 questions (Table 2). Questions were shared with a group of soccer coaches and researchers, and the final amended interview guide was attained after suggestions for minor corrections (e.g., how do you manipulate SSGs in accordance with the microcycle day?) and additions (e.g., what constraints do you usually manipulate to develop your topics? Can you provide any examples?). Due to the geographical distance between the interviewer and the participants, an online interview through video-conference with synchronous communication was conducted [17]. As per the number of questions proposed, each interview lasted for approximately 45 minutes. All interviews were recorded using a Dictaphone and later transcribed to Microsoft Word, and then sent to each coach for their approval through a member-checking technique [11–13]. Every meeting with the different coaches followed the guidelines proposed by [17] for procedures before, during, and after an interview. Interviews were conducted for two months in the off-season period.

Table 2. Applied individual semi-structured interview questions

1.	How do you define SSGs?
2.	Do you use SSGs in your daily routine? How often?
3.	In your opinion, what are the benefits of using SSGs?
4.	Is there any specific time of the year/calendar where you more often use SSGs?
5.	Do you use SSGs to develop any specific moment or principle of the game?
6.	How do you use SSGs to develop specific fitness components?
7.	What considerations do you take when planning SSGs for training sessions?
8.	In what part of the session do you usually include SSGs?
9.	Do you believe it is possible to build up a game model using SSGs?
10.	What constraints do you usually manipulate to develop your topics? Can you provide any examples?
11.	How do you manipulate SSGs in accordance with the microcycle day?
12.	How do you manage the use of SSGs, MSGs and LSGs within you microcycle?
13.	Number of players and size of playing area are the most common constraints manipulated by coaches. How do you control these specific variables to achieve your intended goals?
14.	Do you use coach encouragement during SSGs practice, or are you quiet analysing the task? How does your adopted behaviour influence your players' performance?
15.	Do you believe the inclusion of small goals or the use of GK during SSGs influence your players' performance? In which way?
16.	Is there any specific constraint you are likely, or you preferably use, when planning and delivering SSGs?
17.	What kind of rules do you adopt in your SSGs tasks to achieve certain goals?
18.	Do you look to develop decision making within your planned SSGs? If so, what type of constraints do you use to achieve your intended behaviours?
19.	How do you look to develop creativity of players using SSGs?
20.	Are you likely to plan and deliver SSGs tasks in accordance with the next opponent?
21.	Do you take the lead of planning and delivering SSGs in your sessions? Or do you delegate this to your staff?
22.	How do you measure the effectiveness of the use of SSGs on players' performance?
23.	How can you live analyse SSGs in a training session? And how do you usually review them after session?
24.	How do you think players react to the use of SSGs?
25.	Are SSGs an important part on players individual development?
26.	Is there any age group or level of specialisation where you consider the use of SSGs more relevant or beneficial for players and teams?
27.	What advise can you give to coaches when thinking of using SSGs in their training sessions?

SSGs – Small-Sided Games; MSGs – Medium-Sided Games; LSGs – Large-Sided Games; GK – Goalkeeper

Data Analysis

A Reflexive Thematic Analysis (RTA; [14] was conducted to identify patterns across the qualitative dataset and describe and interpret latent meanings [16]. A deductive-inductive approach was used to develop new meanings from data as well as to apply a theory-driven framework guided by ecological lenses. The analysis was produced through the intersection of the theoretical assumptions, disciplinary knowledge, research skills and experience, and the content of data themselves [16]. The analysis involved diverse fluid steps: data familiarization; coding (i.e., development of codes and topics); theme development; theme refinement; naming; and writing the final report [14].

First, the research team read and re-read the transcripts (i.e., four pages per coach and 20 single-spaced pages in total) with the aim of understanding data and developing initial codes. Throughout the analysis, researchers read the transcripts again to revisit meaning and contextual information. This process was pivotal in informing the latent semantical components of the analysis. Codes were developed into topics which represented more complex understandings about the data, but still superficial, unrefined, and unpolished (i.e., semantical component of the analysis).

Then, topics were developed into themes and subthemes were provided for rich and in-depth representations of the dataset (i.e., latent component of the analysis). Subsequently, themes were refined to best align with the participants' perceptions and the purpose of the study. The final stages of the analysis included writing the results section to provide a coherent storyline. The themes that resulted from this process were: 1) the relevance of SSGs, 2) SSGs variations, 3) SSGs in the planning and periodisation processes, 4) the diverse roles and meanings of SSGs within a high-performance team, 5) decision making and creativity implicit into SSGs, and 6) highlighting tactical development in SSGs (Table 3). As per guidelines provided by [18] which have implications across fields and aligned with the current ontological and epistemological positioning, the quality of the analysis was increased through a co-constructed process of data analysis that actively involved the participants (i.e., through diverse discussions). Further, the first author who led the analysis engaged in discussions with the co-authors that, through their diverse expertise and experiences, provided alternative insights and explanations throughout the analysis. More than reaching consensus, this was a process of open discussions and critique to create a complex and complete storyline.

Table 3. Thematic Analysis categories and interview statements

Categories	Interview statements
The relevance of SSGs	<p>SSGs recreate game situations with a smaller number of players in reduced areas. It is important to improve fitness with ball as it allows to develop specific soccer components in intensity (Coach 1).</p> <p>SSGs are a reduction of the formal game, with lower number of players, in a small playing area, with high contact and higher repetitions. SSGs recreates a lot of match demands and with a lot of competition and freedom, promoting motivation to the players and the team (Coach 2).</p> <p>I always thought the training process in an ecological approach, so it is of utmost importance to bring the match demands to our training session. The training process can be divided, but not disintegrated. And that is why SSGs can be a powerful tool used by coaches to improve team and players' performance (Coach 3).</p> <p>SSGs are realistic training tasks, that aim to look like the 11v11 game. They are important to use, especially with younger ages, as coaches don't have enough number of players to train the 11v11 (Coach 4).</p> <p>It allows to provide a big technical component under pressure, with a competitive scenario, in 1v1 and 2v2 situations, being aggressive and using different sectors of the pitch against each other (e.g., attackers vs defenders). It also allows to develop physical components alongside the soccer side. And the social and psychological aspects of the game, so important at this stage: emotion, frustration, overcoming difficulties, manipulation of game scenarios (e.g., wrong referee decision) (Coach 5).</p>
SSGs variations	<p>We will be looking at the space we need and even support players or number of touches. It is important to have a set of rules and I think it is important to let the players know the reason of the SSGs (Coach 1).</p> <p>Playing areas and number of players are the main considerations we take when planning SSGs. Large playing area with lower number will be used to develop anaerobic endurance, while a small playing area with higher number to stimulate the aerobic system. The use of finishing scenarios, such as GKs, mini goals or end zones are also constraints we adopt to develop certain parts of the game (Coach 2).</p> <p>Number (including unbalanced scenarios), playing area, number of touches, finishing type (GK, mini goals, finishing zones). For example, we tend to increase the playing area to develop acceleration, deacceleration and dribbling. But we also tend to increase the number of players, as also as numerical superiority, to develop the ability to keep ball possession and passing circulation (Coach 3).</p> <p>We use extra players, overloads, specific position where certain players need to receive, certain zones to miss out or play through, players locked in, rules for scoring and specific players (e.g., if you score you keep the ball to encourage players possession). We always have direction or finishing situations in SSGs, but not always needing of a GK. Target or mini goals provide realism and an outcome to the task. We also tend to incorporate set-pieces, such as throw-ins (Coach 5).</p>
SSGs in the planning and periodisation processes	<p>From the second week of the pre-season, we tend to introduce SSGs, to improve fitness components and prepare players to competition. During season, in a regular week, we use 100% SSGs on the day -4. In a week with a game in the middle, we tend to use SSGs more often for players without match time to offset the intensity of the match. We work from SSGs, to MSG and to LSG, particularly on day -4 and -3. In these days, we normally include SSGs at the middle of the training session, after a specific warm up and ball drills. We don't like to use it at the end as it increases the risk of injury due to players' fatigue (Coach 1).</p>

SSGs in the planning and periodisation processes	<p>During pre-season we tend to work from the 11v11 to the use of SSGs, so we can increase intensity. From a microcycle perspective, on day -4 we use small playing areas with lower number of players, to increase transitions, and on day -3 we have higher playing areas and small number of players. In international breaks or calendar stoppages, we will use them a lot as well to keep the players ready for competition (Coach 2).</p> <p>SSGs are usually played at the end of the training session, for maximal actions, but lower repetitions. When looking for a more strategic and tactical approach, we tend to use before the last global component. In a microcycle with a match per week, it is always used on the -4 day, alongside with power. When there are more matches a week, we use SSGs specially for the players that did not play. The incidence decreases over the season. We use more SSGs during preseason, and we decrease its use as the seasons is coming to an end (Coach 3).</p> <p>We may use them more at the end of the calendar to have players engaged as they feel tired by then. However, for instance and during pre-season, we can also get more in from the SSGs in between friendlies. Before, coaches used to have SSGs only at the end, and now it become much more embed in training due to their ecology. At the end of the session is always constructive to use them as they are positive, providing a good social side and players want to come back later. But also, at the beginning will allow players to be engaged to the rest of the session. Even in a match day or day before, allowing the players to be ready to compete (Coach 4).</p> <p>We mostly use at the end, to also work with GKs and develop team principles under pressure, and mental and physical fatigue (Coach 5).</p>
The diverse roles and meanings of SSGs within a high-performance team	<p>If the SSG is about physical and enjoyment, I let my assistants to work more on them. If it is having a strong tactical component, it will be led by me from the first moment (Coach 1).</p> <p>When delivering, I like to be away from that to have a better picture and not have confrontation with players. I don't want to confront a player that had a bad decision in certain moment of the SSG. In that situation, players are not likely to think properly (Coach 2).</p> <p>It is important to control external and internal loads, by using global position systems or heart rate, so we are aware of the exercise intensity. Normally, I tend to be more away during SSGs. But my coaching staff behaves like me, so they need to strengthen the task with encouragement and feedback, which can be positive or negative, depending on the needs and player's individualities (Coach 3).</p> <p>Sometimes, I like to see them without encouragement, specially to see the tactical outcome and observe what players understood from the planned task. But sometimes, if we need a more physical outcome, we speak to them in between sets to give them specifically feedback (Coach 4).</p>
Decision making and creativity implicit into SSGs	<p>We need to make the players developing certain actions, as much as possible, to promote a habit thinking, to make a constant decision and the knowledge of how to act. In SSGs, the decision will be natural due the number of repetitions. With reduced space and time, players need to be quicker and think fast, sometimes without even thinking. (Coach 1).</p> <p>We need to allow freedom for the players, to involve a lot of 1v1 and constraint defenders to stay in certain areas to promote those situations. We like players to be free during the tasks, not structured, not overcoaching them, understand what the players want, and let them have mistaken (Coach 2).</p> <p>If we want to develop decision making, we tend to increase the playing area to work without pressing. When our players understood that specific game idea, we then can decrease the playing area to work under pressure, and so on to develop the cognitive components. If we reduce the number of touches on the ball, players won't be able to develop this creativity as they will be forced to use more of passing rather than dribbling (Coach 3).</p> <p>Decision making is difficult to coach and develop, because you can't touch it, you can't lively say decision making is improving, and I think SSGs is a vital tool to make quicker decisions in small playing areas. By using SSGs we can increase the degree of freedom and we encourage players to show their individual brilliance (Coach 4).</p> <p>For example, the constant flow of balls coming in will help the process of decision making. Sometimes we have bounce games, with one team in the outside at 1 touch to develop specifically technical aspects, so they need to learn how to use their body to have success. We look to match up the players. We need to make sure players have success, so sometimes we need to combine players if a defender is stronger, as such 2v1, or a 1v1 with a lower-level defender. Keep it competitive, not restricting the number of touches, but look at tempo and not restrictive movements, so we tend to look at the quick touch, according to opponent and surrounding area (Coach 5).</p>

Highlighting tactical development in SSGs	We like to use SSGs to develop positional play, to work on body angles and movements off the opposition. Particularly from a defensive perspective, it allows to create a guided discovery where players are looking to understand the space available or when to press (Coach 1).
	We tend to use game areas for certain players to allow the creation of positional game and relationship between sectors, as also as certain aspects of the game model, such as progressive progression (Coach 2).
	We can use a SSGs in a specific part of the pitch; in the wing channel, we can manipulate the game to force the players to build up the game from the back and progress through the halfway line. As an example, when working on progressive progression, we can work on a 5v3 in the channel and then progress to a full width 10v7 in $\frac{3}{4}$ pitch. (Coach 3).
	We look to develop overloads, 3v2 and 2v1, manipulating the areas with attacking combinations in underlapping and overlapping running, including 1 or 2 touches to allow quick offensive transitions. So, we try to use SSGs to develop the team aspects, but also able to work towards the needs of the movement, for the moment, in accordance with opponent, teammate, ball and goal. As well, touches restriction to develop team combinations and relationship between players. Look at the game, look at the stats and its analysis, and breakdown to a SSG. For example, finishing with 1 touch, and if players take more, they have straight pressure. And this is what we see in the game (Coach 5).

SSGs – Small-Sided Games; MSGs – Medium-Sided Games; LSGs – Large-Sided Games; GK – Goalkeeper; GPS – Global Position System; HR – Heart Rate

Results and Discussion

The objective of this study was to understand the use of SSGs by soccer coaches in the high-performance context. Data was collected through semi-structure interviews from coaches in the Professional Development Phase or at Senior Elite Level. A total of six themes were developed from the Reflexive Thematic Analysis of the twenty-seven questions presented to the five different coaches: 1) the relevance of SSGs, 2) SSGs variations, 3) SSGs in the planning and periodisation processes, 4) the diverse roles and meanings of SSGs within a high-performance team, 5) decision making and creativity implicit into SSGs, and 6) highlighting tactical development in SSGs. Data is presented through quotes from coaches and followed up by references (in brackets) to indicate similarities with existing literature. As expected, coaches tend to use SSGs as part of their periodised week, with a higher incidence on Matchday (MD) -4 and -3. Coaches also referred the predominant use of SSGs to develop fitness levels, and to work on positional play, constraining specific playing positions on their zones of action on the pitch. All coaches agreed that SSGs motivate players to perform, due to the integration of all soccer components at the same time, being usually the players' favourite part of the session.

The relevance of SSGs

Coaches considered SSGs as training tasks played with lower number of players performed in a reduced area, with the aim to replicate the match demands, and allowing more repetitions with a certain amount of freedom. Coach 1 reinforced the relevance of using SSGs across high-performance contexts "to improve fitness with the ball as it allows to develop specific soccer components in intensity" with in an "interval intermittent training regime" (added by Coach 3), while Coach 4 considered it important to use "different sectors of the pitch against each other". Coach 5 also referred that "agility, coordination, reaction and ability to read the game are very important when using SSGs, rather than only isolated practises". Those comments align with previous research that identified the benefits of using SSGs to improve physical parameters [18]. Therefore, rather than providing isolated physical stimuli to players in a decontextualised environment, coaches can manipulate SSGs to replicate match-like demands, and concomitantly develop all soccer components at the same time, in exact zones of the pitch with specific playing positions [19,20].

Remarkably, Coach 3 believed the training process should be considered from an ecological approach: divided, but not disintegrated [8,21]. This coach mentioned: "And that is why SSGs can be a powerful tool to be used by coaches to improve team and players' performance... as they are more real". It was well accepted by every coach that these tasks promote "motivation to the players and the team" (Coach 2), and if players could choose, they would want SSGs in every session (Coach 1). These two last coaches also recalled their time as soccer players and remembered the SSGs as their favourite part of the session and were always looking forward for the weekly session on these tasks. Finally, Coach 3 mentioned "players love SSGs, they love competition... when we are training at high

intensity, having competition with ball will always be a differential factor of extra motivation... we also want to incite this winning mentality, to develop a winning culture in the club”.

The insights gathered from the coaches' perspectives underscore the multifaceted benefits of incorporating SSGs into soccer training sessions. Coaches unanimously recognised SSGs as valuable tools for replicating match demands, fostering player motivation, and promoting holistic player development. Moreover, the ecological approach advocated by Coach 3 highlights the importance of integrating SSGs seamlessly into training regimens, ensuring that the training process remains cohesive and contextually relevant. The coaches' testimonials also emphasise the intrinsic appeal of SSGs to players, with many recalling their own positive experiences and highlighting the motivational impact of the competitive match. Importantly, the emphasis on fostering a winning mentality and developing a culture of success underscores the broader implications of SSGs beyond physical and technical development. Overall, the collective insights underscore the pivotal role of SSGs in enhancing team performance, player engagement, and cultivating a culture of excellence within soccer clubs.

SSGs variations

There was consensus amongst the coaches that playing area and number of players are the main constraints to consider when planning SSGs, in line with previous studies [6,7]. Coach 2 referred that “a large playing area with lower number of players will be used to develop anaerobic endurance, while a small playing area with higher number of players to stimulate the aerobic system”, and Coach 3 mentioned that he “tends to increase the playing area to develop dribbling ... and increase the number of players, and the numerical superiority, to develop the ability to keep ball possession and passing circulation”. These coaching perceptions come in line with studies from [3,4], that referred the use of large playing areas and numerical superiority affords the development of tactical individual actions in ball possession, without the constraint of pressing.

In regards other task constraints manipulation, the “number of touches, finishing type (e.g., GK, mini goals, finishing zones)” (Coach 3) and “extra player, overloads, specific position, ... rules for scoring” (Coach 4) were used to manipulate SSGs for planned behaviours according with the intended game model for the team, but also to incorporate set-piece development (Coach 5). Particularly at the academy level, Coaches 4 and 5 considered the number of available players for each session to be important for U19s and U23s as this often fluctuated to serve the needs of the first team. Planning needed to be daily adjusted, and the use of SSGs seemed to be an important strategy for mixing different age groups. SSGs were viewed as a pedagogical resource for planning and periodisation that automatically generated learning through a guided discovery paired with feedback and appropriate support [1]. However, aligned with past research, players' understandings about the usefulness of these tasks seemed to be critical for meaningful learning [22], as referred by Coach 1: “it is important to let the players know the reason of the SSGs”, so they are aware of the outcomes expected.

Coaches' perspectives underscored the significance of carefully manipulating constraints, such as playing area and number of players, when planning SSGs in soccer training sessions. Their insights align with previous research, emphasising the role of these constraints in shaping tactical and technical development. Furthermore, the coaches highlighted the importance of adapting SSGs to suit the developmental needs of different age groups within academy settings, necessitating flexible planning and daily adjustments. The pedagogical value of SSGs as a tool for guided discovery and learning was also underscored, particularly when paired with clear communication and feedback to players. However, the coaches emphasised the crucial role of players' understanding and buy-in, highlighting the need for transparent communication regarding the objectives of SSGs to maximise their effectiveness in promoting meaningful learning experiences. Overall, their insights offer valuable guidance for coaches seeking to optimise the use of SSGs in soccer training, emphasising the importance of strategic constraint manipulation and effective communication with players.

SSGs in the planning and periodisation processes

During the macrocycle, every coach acknowledged the importance of using SSGs from pre-season through the end of the season. To illustrate, Coach 1 tended to introduce SSGs from the second week of pre-season, while Coach 2 started pre-season “to work from 11v11 to the use of SSGs”. This coach aims to start working on the main principles of play, at the same time as players return to training with low intensity stimulus, to gradually develop sub-principles of play under fatigue, by using SSGs to increase intensity of the task and promote specific demands for their own individualities.

Coach 4 also emphasised the role of using SSGs “more at the end of the season to keep players engaged as they feel tired by then”. However, Coach 3 mentioned the use “of SSG decreases over the season, as towards the end of

the competitive calendar their training aims were more strategic". Coach 4 works at the Professional Development Phase and is aware of a natural lower match intensity compared to senior level [19]. However, young players can be called to the first team and would therefore benefit from SSGs played at a higher intensity to reduce the risks of suffering from overuse injuries [20].

From a microcycle perspective, all coaches agreed the predominant use of SSGs on MD -4 and MD -3. For example, Coach 2 mentioned "on MD-4, we use small playing areas with lower number of players to increase transitions, and on MD-3 we have greater playing areas and small number of players", while Coach 3 said "a SSG is always used on MD-4, alongside with power". Interestingly, Coach 1 and 3 mentioned the exclusive use of SSGs for starting or substitute players through the microcycle, and Coach 2 tended to include the use of more regular SSGs in international stoppages "to keep players ready for the competition". Coaches seem to promote specific workload for players by using SSGs, periodising the physical capacities alongside the manipulation of constraints to achieve intended outcomes [7].

From a session planning perspective, Coach 4 mentioned "coaches used to have SSGs only at the end, and now it become much more embedded in training". There were some considerable contrary opinions amongst the coaches on the timing of the SSGs. Coach 1 included "SSGs at the middle of the training session... as at the end it increases the risk of injury due to players fatigue", which is opposite to Coach 3 who mentioned that "SSGs are usually played at the end of the training session for maximal actions, but lower repetitions" and Coach 5 planned SSGs "mostly at the end, to also work with GKs and develop team principles under pressure with mental and physical fatigue".

Coaches provided valuable insights into the strategic use of SSGs across the macrocycle and microcycle of soccer training. Their approaches varied, with some coaches favouring the early introduction of SSGs during pre-season to gradually increase intensity and develop specific demands, while others emphasised their use towards the end of the season to maintain player engagement and strategic training aims. Interestingly, there was consensus among coaches regarding the predominant use of SSGs on specific days within the microcycle, with MD -4 and MD -3 being highlighted as key periods for SSG implementation. Moreover, coaches recognised the importance of tailoring SSGs to suit the developmental needs of players at different levels, from academy to senior teams, and adapting session planning to optimise workload and minimise injury risks. Despite some discrepancies in opinion regarding the timing of SSGs within training sessions, the coaches' perspectives collectively underscored the versatility and effectiveness of SSGs as a pedagogical tool for promoting tactical, technical, and physical development in soccer players throughout the training season.

The diverse roles and meanings of SSGs within a high-performance team

All interviewed coaches tasked their assistants on leading the SSGs to further strengthen the link between the physical component and enjoyment of SSGs. Coach 2 refrains from any tactical involvement, because he does "not want to confront a player that had a bad decision in the SSG", as players may spontaneously react due to task involvement/excitement. As well, Coach 4 preferred most of the time "to see players' performance in SSGs without encouragement, specially to observe the tactical outcome and what players understood from the planned task". However, this coach mentioned they would step in the task with encouragement if players "need a more physical outcome" or any specific feedback necessary to achieve success in the task. This would only occur in between sets and not in the middle of the task. Coach 1 observes the communication amongst players and believes that "if they keep talking to each other, they are looking to find new solutions for the problem". These coaches' ideas align with principles of promoting guided discovery [5]. On the other hand, [23] mentioned there is some impact of active coaching on the physical performance on players. Interviewed coaches choose to not actively coach, but that might compromise on the physical component of the SSG.

All coaches also referred to the importance of monitoring intensity "to control external and internal loads by using global position systems or heart rate" (Coach 3). Therefore, coaches worked in collaboration with Sports Science and Performance Analysis departments and planned specific constraints to achieve intended goals, monitored the SSG live (e.g., emphasise recovery between sets and encouragement to achieve the SSG target), and analysed and interpreted outcomes. Despite this, all coaches stressed they used their "own judgment to understand and adapt SSG tasks" (Coach 2) as "the immediate analysis on the moment will always be coach perception" (Coach 3). Interestingly, Coach 3 also mentioned they "want to have the players' perception of exercise, so we keep asking them during session and during the different tasks" to adapt any momentary constraint and to keep a record for future practises.

Coaches' perspectives shed light on the multifaceted role of coaches in guiding SSGs within soccer training sessions. While all coaches delegated the leadership of SSGs to their assistants, they maintained a keen focus on monitoring player communication and task engagement, recognising the potential for spontaneous player reactions

and the importance of promoting guided discovery. However, the coaches' reluctance to actively coach during SSGs, aimed at preserving the enjoyment and tactical exploration of players, raised concerns about potentially compromising the physical component of these tasks. Nonetheless, coaches emphasised the importance of monitoring intensity and collaborating with sports science and performance analysis departments to ensure the effective implementation of SSGs. Their reliance on personal judgment and player feedback highlights the dynamic and adaptive nature of SSG planning and underscores the ongoing need for coaches to balance tactical objectives with physical development in SSG-based training sessions.

Decision making and creativity implicit into SSGs

The benefits of SSGs are illustrated by several coaches: "the decision will be natural due the number of repetitions" (Coach 1), and "using SSGs we can increase the degree of freedom and we encourage players to show their individual brilliance" (Coach 2). It was acknowledged that small playing areas in SSGs are a feasible manipulation for coaches: "a vital tool to make quicker decisions in small playing areas" (Coach 4), "with reduced space and time, players need to be quicker and think fast, sometimes without even thinking, ... on an instinctive way and in reaction" (Coach 1), and "the repetition of certain aspects will allow players to make better decisions in the game" (Coach 2). As an example, Coach 3 "tend to increase the playing area to work without pressing, ... then decrease the playing area to work under pressure, and so on to develop the cognitive components". Coach 5 also mentioned the importance of having placed balls around the playing area, so players will keep high tempo in the match and potentially fail, so "they will learn from there and not repeat the movements".

Coach 1 defined SSGs as "very closed to understanding the game and to make right decisions" which they found important for the promotion of creativity. Coach 2 considered the "need to allow freedom for the players, to involve a lot of 1v1, ... not structured, not overcoaching them, ... let them have mistaken". This coach considered SSGs as like street football, where players return to the basics of soccer and they "are exploring and enjoying themselves", while Coach 3 believed "SSGs allow to develop creativity by itself, it is almost as the players were playing in the streets as before and need to find solutions for their problems".

Another worthwhile strategy used by Coach 5 is to match up the players by combining stronger individuals in numerical inferiority to increase the difficulty of the task for some individuals, but making sure the success can be achieved. Number of touches on the ball was also discussed, and it was considered a restriction that would influence creativity. For instance, Coach 3 mentioned "if we reduce the number of touches on the ball, players will not be able to develop this creativity as they will be forced to use more of passing rather than dribbling", and Coach 5 would like to "keep it competitive, not restricting the number of touches, but look at tempo and not restrictive movements, so we tend to look at the quick touch, according to opponent and surrounding area" This last coach finished stating, "too many restrictions make them get lost... it is important to force some behaviours, in a balanced way".

Coaches' perspectives underscored the diverse benefits of SSGs in soccer training, ranging from the promotion of decision-making and cognitive components to the fostering of creativity and individual brilliance. The consensus among coaches emphasised the importance of manipulating playing areas and task constraints to create environments that challenge players and encourage spontaneous, instinctive reactions [2]. Coaches highlighted the role of SSGs in replicating the conditions of street football, where players are free to explore and enjoy the game without excessive structure or overcoaching [24]. Moreover, strategies such as matching up players and manipulating the number of touches on the ball were discussed as means to enhance creativity and maintain a competitive yet balanced environment. Ultimately, coaches recognised the delicate balance between imposing constraints to shape behaviours and allowing freedom for players to express themselves, emphasising the need for thoughtful planning and moderation in SSG design.

Highlighting tactical development for SSGs

From a tactical perspective, coaches tended to use SSGs to develop positional play: "to work on body angles and movements off the opposition" (Coach 1). They aimed to develop "relationship between sectors, as also as certain aspects of the game model, such as progressive progression" (Coach 2). In this regard, Coach 3 mentioned the "use of specific parts of the pitch" to "manipulate the game to force players" in match-specific scenarios (e.g., full-back vs winger). This last coach mentioned "the principles of play should be developed in the different sectors... before we can work in its totality... so, by using SSGs to work on specific moments it allows then to transfer this acquired knowledge to full team's game model".

And "particularly from a defensive perspective, it allows to create a guided discovery where players are looking to understand the space available or when to press, ... increasing players' motivation to recover possession" (Coach

1), and “to develop pressing triggers and area awareness” (Coach 4). So, coaches “use SSGs to develop the team aspects, but also able to work towards the needs of the movement, for the moment, in accordance with opponent, teammate, ball and goal” (Coach 5). It was also mentioned that SSGs are planned according with the own team needs, and not considering opponent’s analysis. As per Coach 5, “look at the game, look at the stats and its analysis, and breakdown to an SSG”.

Coaches emphasised the tactical significance of SSGs as a means to develop specific aspects of positional play and game model principles [9]. Their use of SSGs aimed to facilitate a guided discovery process, wherein players could understand spatial relationships, pressing triggers, and defensive responsibilities within the context of match-specific scenarios [24]. Coaches strategically manipulated playing areas and task constraints to replicate game-like situations and promote engagement and motivation among players. Importantly, SSGs were tailored to address the specific needs of the team, focusing on areas of improvement identified through game analysis and statistical data. By integrating SSGs into their training sessions, coaches sought to instil a deeper understanding of tactical concepts and foster a cohesive team dynamic that could be translated onto the pitch during competitive matches.

Limitations and Future Research Directions

Despite the several insights presented in this research in the professional soccer environment, it is necessary to acknowledge some limitations. Firstly, each coach only completed the interview once, which can be seen as an individual source of data [17]. The interview process could have happened a second time so participants might present more/different information as well as added insights. Further, interviews could have been paired with observations or other data collection methods for a more comprehensive understanding about the use of SSGs. As well, it was missing the inclusion of some questions in the interview that could develop knowledge in regard to: 1) playing positions during SSGs, as some players with tactical freedom can influence demands of the task; 2) coaching position during SSGs, as if the coach is more focused in a specific group, this can influence outcome of the task; 3) how coaching staff adjust intensity for players that did not achieved intended internal and external workloads; and 4) what type of feedback is provided by coaches during SSGs, as by the end of the task, players are likely to be fatigued.

Based on the results of this study, several areas for future research in the domain of SSGs have been emphasised by coaches but remain underexplored in scientific literature. Firstly, the cognitive and psychological impacts of SSGs, particularly on players’ decision-making processes and creativity under various constraints, warrant further investigation. Coaches highlighted the importance of fostering cognitive development through SSGs, yet empirical data on the optimal conditions and game modifications that best support these outcomes are limited. Secondly, the long-term effects of SSGs on player development across different age groups and skill levels need to be examined. While coaches frequently use SSGs to develop technical and tactical skills, the longitudinal benefits, and potential drawbacks of these games over a player’s career are not well documented. Thirdly, the integration of advanced monitoring technologies, such as GPS and heart rate monitors, within SSGs requires additional exploration. Coaches noted the utility of these technologies in managing training loads and ensuring optimal intensity during sessions; however, more research is needed to establish standardised protocols and determine their effective utilisation. Lastly, the social and emotional dimensions of SSGs, such as their role in building team cohesion, handling competitive scenarios, and managing emotional responses, should be investigated. Future studies should delve into how SSGs can be designed to maximize these social and emotional benefits, providing insights into their contribution to the holistic development of players. Addressing these gaps can lead to a more comprehensive understanding of SSGs’ multifaceted roles in soccer training, informing coaching practices and enhancing player development.

Conclusion

This study provides valuable insights into the perspectives and practices of professional soccer coaches regarding the use SSGs in training sessions. The thematic analysis of interviews revealed several key findings. Firstly, coaches emphasised the importance of SSGs in replicating match demands, fostering technical and tactical development, and promoting player motivation and engagement. Secondly, variations in SSGs, including adjustments in playing area, number of players, and constraints, were identified as essential for targeting specific fitness and skill components. Thirdly, coaches outlined their strategic incorporation of SSGs within the planning and periodisation processes, highlighting their utilisation for different training objectives across the pre-season, regular season, and international breaks. Fourthly, diverse roles and meanings of SSGs within high-performance teams were elucidated, including their contributions to physical fitness, tactical understanding, decision-making, and team cohesion. Lastly, coaches

underscored the need for future research to explore areas such as the cognitive and psychological impacts of SSGs, the long-term effects on player development, the integration of advanced monitoring technologies, and the social and emotional dimensions of SSG participation.

By synthesising these findings, this study contributes to the growing body of knowledge on SSGs in soccer coaching, providing practical implications for coaches and guiding future research endeavours in this field. Those current insights have multiple implications for coaching education programs and practitioners who may need to be prompted to reflect on how SSGs could be framed within a nonlinear pedagogy that prevents the use of SSGs in a prescriptive and rigid manner. We invite researchers across contexts to further explore this line of inquiry and position qualitative methods as a valid resource to examine how previous research and existent theoretical lenses are indeed permeating coaching practises (e.g., planning, periodisation, programming, instruction).

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THE EFFECTS OF SITUATIONAL VARIABLES ON EXPECTED GOALS: A CASE STUDY IN INTERNATIONAL FOOTBALL

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Authors' contribution:

- A. Study design/planning
- B. Data collection/entry
- C. Data analysis/statistics
- D. Data interpretation
- E. Preparation of manuscript
- F. Literature analysis/search
- G. Funds collection

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Abstract:

Background: In the ever-evolving field of football analytics, understanding the factors influencing expected goals is crucial for gaining deeper insights into team performance. The aim of this study was to examine the effects of match conditions on the expected goals (xG) from defensive and offensive points of view in international elite football matches of the Greek national team.

Methods: Twenty-four (24) Greek national team matches during the period between 23 March 2019 and 14 November 2021 were analyzed for the study. In these selected matches the Greek national team took 369 shots and conceded 174 shots, out of which scored 26 goals, and conceded 23 goals to their opponents.

Results: Our findings suggest that situational variables such as time may influence expected goals (xG). More specifically, the Greek national team obtained higher expected goals for (xGf) during the second half of their matches compared to the first half. Zonal analysis of shots and goals revealed that central areas recorded more shots on goal in the analysis of both Greece and their opponents, but Greece favoured shooting from inside the penalty box more often than their opponents.

Conclusion: The findings emphasize the need for match analysts and coaches to consider the impact of situational variables during assessments of data analytics, especially in future xG research.

Introduction

Football is a relatively low-scoring sport and therefore unpredictable at match level, with singular and rare events such as a goal being scored having a much greater impact than in other team ball sports like basketball [1]. Therefore, it is common in football for the best-performing teams to sometimes lose a game, because although they may dominate in most measures of performance, their opponent may win the match by converting a single opportunity into a goal. This risk makes it difficult for coaches to make decisions during football matches, but in recent years, football analytics has attempted to improve decision-making and reduce the risk by providing data-driven analysis.

One of the most widespread and insightful metrics within football analytics is expected goals (xG), first introduced by Sam Green [2]. xG is a statistical model used to estimate the likelihood of a shot resulting in a goal. It is based on a range of contextual information at the time the shot was taken that can affect its outcome, such as the position of

the shot, the angle of the shot, the type of pass that led to the shot, and the presence of defenders. This metric can be used as a measure of the offensive performance of a team or an individual player, and in its simplest form, this method involves calculating a team's chances of scoring and conceding goals.

As discussed above, the topic of xG is relatively new to the football community, but a vast number of studies have been undertaken to date. Lucey and colleagues [3] were the first to estimate goal probabilities using event and positional data in their model, using 10,000 shots of the English Premier League. Rathke [4] examined factors associated with predicting xG during English Premier League and Bundesliga matches, however, without taking the positions of defenders and goalkeepers into consideration. The results showed that the variables of distance and angle together significantly impacted xG and that xG can support forecasting future performance. Brechot and Flepp [5] proposed to use the xG models for performance evaluation instead of match outcomes, which may easily be influenced by randomness in short-term results. They introduced a chart built upon the concept of the xG by plotting the teams' ranking in the league table against their rankings based on xG. Bransen and Davis [6] investigated the differences between xG models trained on men and women's football event data. Results showed that although the xG models performed the same across the two environments, there were differences in feature importance between men's and women's games, as well as several in-game situations with xG differences, with women shooting from different positions than men and having a higher shot-to-goal conversion rate.

Despite the fact that the expected goals metric is a very active area of research and has been used in research and commercial settings, the model has come under fire [7-9]. This is due to (a) the number of factors that need to be included in calculating xG, (b) the lack of defensive positioning of players in relation to game-specific actions, and (c) not taking into account renowned clubs/players' performance during games. Although criticism is not without reason, the xG model is still seen as a valuable tool in predicting which players and teams will score and the likelihood of conceding goals [4].

Previous studies have identified that teams' performance can be influenced by situational variables such as match location, time, match outcome, team quality, and/or competition stage [10-12]. Yet, a vastly underexplored topic in the context of xG is how these models are affected by the situational variables during football matches. Thus, the aim of the present study was to examine the effects of match conditions on the expected goals (xG), from a defensive and offensive point of view, in international elite football matches.

Material and Methods

Sample

The sample consisted of $n=24$ Greek national team matches during the period between 23 March 2019 to 14 November 2021 in three different competitions, namely Euro 2020 Qualifiers (10 matches), Nations League 2021 (6 matches), and World Cup 2022 Qualifiers (8 matches). During these selected matches, the Greek national team took 369 and conceded 174 shots, out of which scored 26 and conceded 23 goals. Penalties were included in the study and assigned an xG value of 0.766 [13], which is the average conversion rate in the Bundesliga history. Free kicks and own goals were excluded.

The Regression Model

In order to calculate the expected goals for (xGf) and against (xGa) for the Greek national team, a logistic regression model was used that was first introduced by Shaw [14]:

$$xG = \beta_0 + \beta_1 \times \text{distance} + \beta_2 \times \text{angle} + \beta_3 \times \text{pressure} + \beta_4 \times \text{number of defenders}.$$

The regression model included four independent variables:

- **Distance:** the direct distance between the ball and the center of the goalpost measured automatically from Hudl Studio (Hudl, NE, USA), after calibrating the pitch size. The accuracy of this technique was determined by comparing the length between the penalty spot and the goal line to the actual dimension (11m), as proposed by Schulze and colleagues [15]. Accuracy was within previously estimated acceptable ranges for positional data [16], with an average absolute error of $0.8 \pm 0.3\%$. The reliability of the above technique was tested by re-calculating 43 randomly selected shots (approximately 10% of the total) manually. By using the visible references of the goal, the penalty box, and the penalty spot, the perpendicular distance between the ball and the goal line (x) and the horizontal line between the ball and the center of the goal line (y) were calculated, as shown in Figure 1. Moreover, using the Pythagorean theorem, the direct distance between the ball and the center of the goal line was calculated:

$$z = \sqrt{x^2 + y^2}$$

The agreement between the automatic and manual measurements was tested with Cohen's kappa. The yielded kappa value of 0.85 reflects a strong agreement between the two measurements and thus acceptable reliability of the technique used in the present study.

- **Angle:** the angle formed by the two lines drawn from the two vertical posts was calculated (Figure 1), where 7.32m is the length of the goal. The result was converted into degrees as follows:

$$\tan\Theta = \frac{7,32 * x}{x^2 + y^2 - \left(\frac{7,32}{2}\right)^2}$$

- **Pressure:** the defensive pressure exerted on the shot-taker, rated on a scale ranging from 0 to 5 [14].
- **Number of defenders:** the number of defensive players (including the goalkeeper) in a direct line from the shot position to the goal. In the example presented in Figure 1, the shot-taker confronted two defending players.

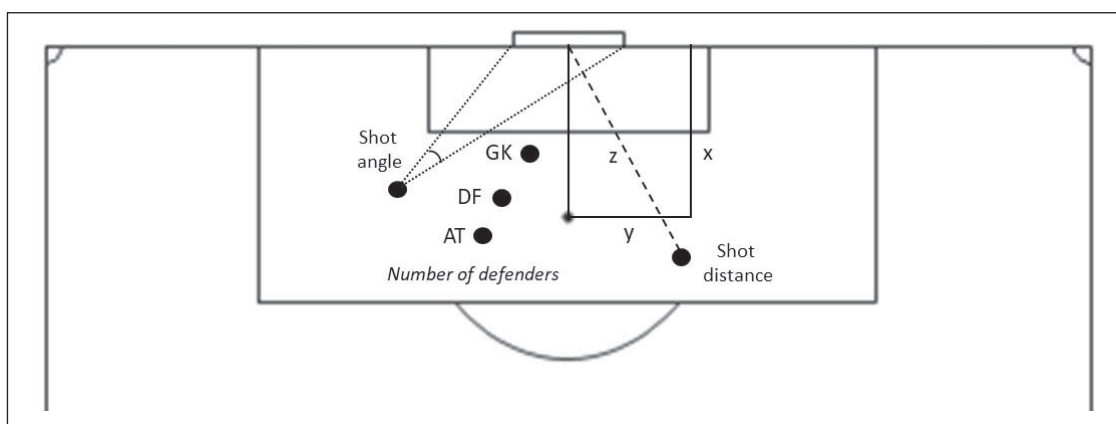


Figure 1. Definition and example of calculating shot distance, shot angle and number of defenders (AT: attacker, DF: defender, GK: goalkeeper)

Procedures

All shots for and against the Greek national team were observed in videos downloaded from Wyscout (Hudl, USA). An Excel (Microsoft, USA) spreadsheet was created to record the variables included in the model and the situational variables for each shot taken. The situational variables included:

1. **Match location:** the variable was recorded as “home” or “away”, depending on whether the Greek national team was playing on its own ground or the opponent's [17].
2. **Time 45:** the variable was recorded as “1st half” or “2nd half”, depending on the half that the sampled team's shot was taken [18].
3. **Time 15:** the playing time was divided into six periods of 15 minutes, i.e. “1-15”, “16-30”, “30-45+”, “46-60”, “61-75”, “76-90+”; the variable recorded the period when the sampled team took the shot [18].
4. **Opponent quality:** the variable recorded the difference in the FIFA ranking between the competing teams [19]. Teams were separated into 2 groups based on the Greek national team's ranking (#45), published before the start of the Euro 2020 Qualifiers (released on 7 February 2019). Teams ranked higher than the Greek national team were categorized as “Group A”; teams ranked lower than the Greek national team were categorized as “Group B” [20].

Statistical Analysis

The statistical analysis was performed in SPSS Statistics for Windows, version 26.0 (SPSS Inc., IBM, USA), and the statistical significance was set at 5%. Prior to the analysis, the assumption of normality was verified using the Shapiro-Wilk test, while the assumption of homogeneity for xGf and xGa was verified using the Levene test. Paired t-test was used for the comparison of the groups referring to match location (Home, Away), opponent quality (Group A, Group B), and time 45 (1st Half, 2nd Half).

The mean number of expected goals for and against per match was compared among the six 15-minute periods using a series of non-parametric Kruskal-Wallis H tests, with p-values lower than 0.05 indicating significant time-

period effects. Whenever a significant time-period effect was found, individual pairs of variables (xGf and xGa) were compared between the two time-period groups using a series of Bonferroni-adjusted Mann-Whitney U tests, with p-values of under 0.004 (0.05/15) indicating significant differences. Effect sizes (Cohen's *d*) for between-period differences were determined, with values of 0.20, 0.50, and 0.80 representing small, moderate, and large differences, respectively [21].

Results

The results for xGf and xGa are presented in Table 1. A paired sample t-test was conducted to compare xGf between 1st Half and 2nd Half. There was a significant difference between the 2nd Half (mean=1.00, s.d.=0.82) and 1st Half (mean = 0.69, s.d.=0.46). These results suggest that time does have an effect on xGf and specifically that the Greek national team obtained higher xGf during the second half of their matches compared to the first half. The remaining situational variables concerning xGf did not reveal any statistically significant differences in match location and opponent quality. However, it should be mentioned that there was a trend to obtain higher scores when playing at home and when playing against weaker teams from Group B.

The results for xGa revealed a significant difference in the scores when playing against teams from Group A (mean=1.60, sd=0.70) compared to Group B (mean=0.81, s.d.=0.59). Furthermore, there was a significant difference between the xGa in the 2nd Half (mean=0.64, s.d.=0.58) compared to the 1st Half (mean=0.39, s.d.=0.37). These results suggest that time and opponent quality do have an effect on xGa, i.e. the Greek national team suffered higher scores of xGa during the second half of their matches and when playing against a stronger opponent. No statistically significant differences were observed regarding match location.

Table 1. Statistics for expected goals for (xGf) and expected goals against (xGa)

	xGf (M±SD)	t-statistic	p-value	xGa (M±SD)	t-statistic	p-value
Home	1.97 ± 1.01	1.116	.288	1.12 ± 0.85	.557	.589
Away	1.43 ± 1.15			0.95 ± 0.59		
Group A	1.44 ± 0.95	-.290	.779	1.60 ± 0.70	3.358	.010*
Group B	1.56 ± 1.17			0.81 ± 0.59		
1st half	0.69 ± 0.46	-2.144	.041*	0.39 ± 0.37	-1.997	.047*
2nd half	1.00 ± 0.82			0.64 ± 0.58		

Note: M = Mean; SD = Standard deviation; * The mean difference is significant at the 0.05 level

The xGf and xGa for the 15-minute periods are presented in Figure 2. The Kruskal-Wallis H test showed a statistically significant difference in xGf between the six 15-minute periods ($H(5) = 11.447, p = 0.043$) but no significant differences were documented for xGa ($H(5) = 6.317, p = 0.277$). The post hoc Mann-Whitney U test revealed that xGf scores were significantly lower in the first 15-minute period ($Md = 0.0650, n = 18$) compared to the fourth 15-minute period ($Md = 0.3050, n = 18$), with $U = 79.000, z = -2.647, p = 0.002$, and a moderate effect size $d = 0.62$.

During the 24 matches studied, the Greek national team took 369 shots and scored 26 goals, while conceded 23

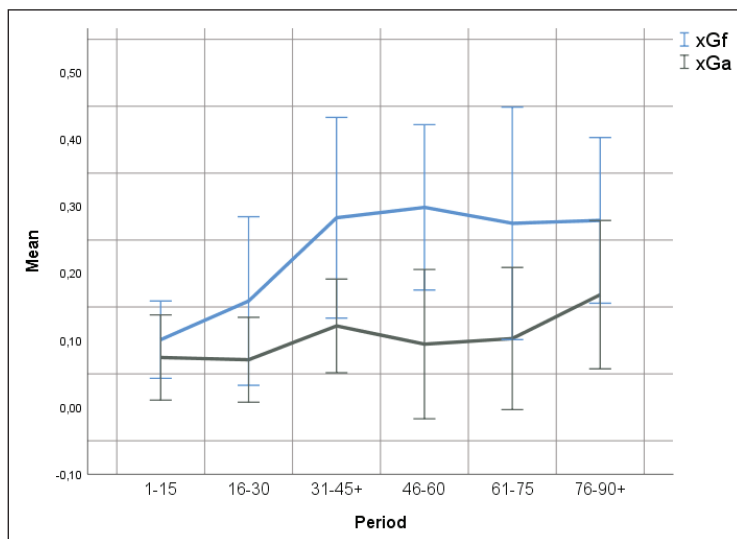


Figure 2. Expected goals for (xGf) and against (xGa) vs. 15-minute periods

goals from 174 shots. Concerning the taken shots as presented in Figure 3, the zone analysis revealed that the majority of shots were taken from the central zone located in front of the penalty box (33.3%). Moreover, the two zones inside the box, close to the penalty spot, were largely used. Overall, the central zones were used more frequently by the Greek national team compared to lateral zones, in terms of shooting and goal-scoring.

From a defensive point of view (Figure 4), the opponents used the two zones outside the penalty box more often and more specifically the central zone located just in front of the penalty box (42.5%). As mentioned above for the attacking shots, the central zones were used more frequently in relation to lateral zones from the opponent teams, both concerning shooting and goal-scoring.

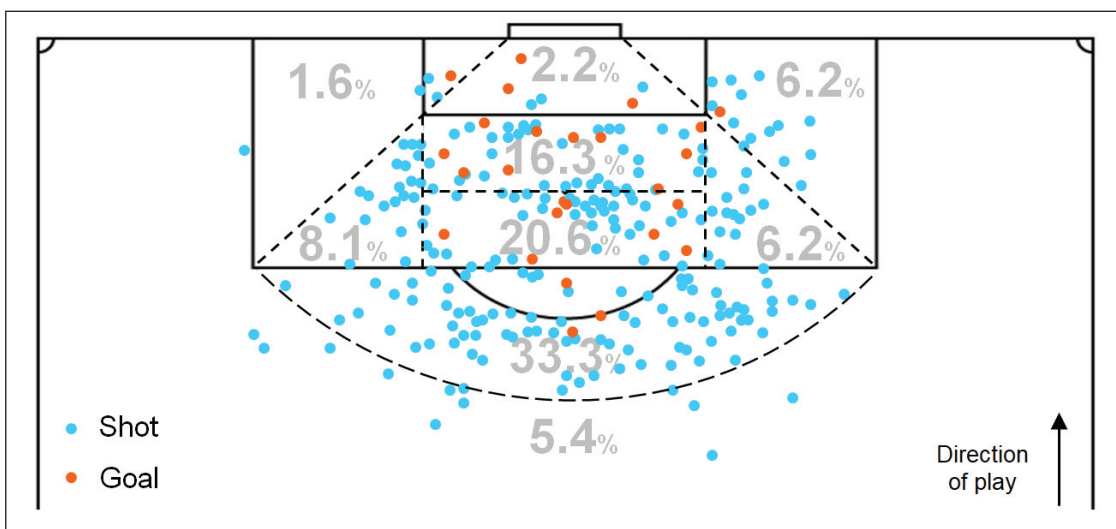


Figure 3. Scatterplot of shots and goal locations taken from the Greek national team

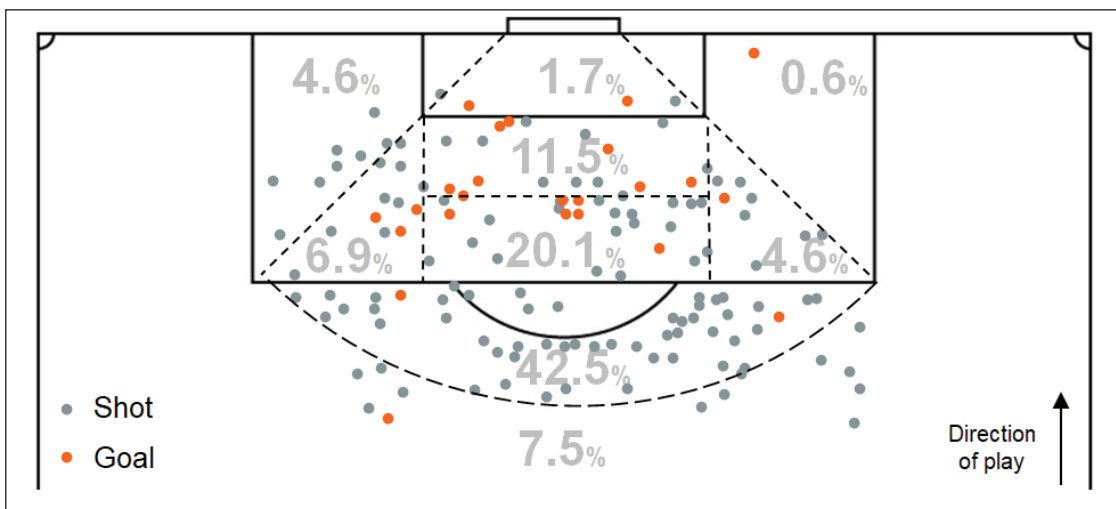


Figure 4. Scatterplot of shots and goal locations conceded by the Greek national team

Discussion

The aim of the present study was to examine the effects of match conditions on the expected goals from a defensive and offensive point of view in international elite football matches of the Greek national football team.

Results suggest that time does have an effect on xGf and more specifically that the Greek national team obtained higher xGf during the second half of their matches compared to the first half. As mentioned above, to the best of our knowledge, no studies have examined xG based on situational variables during football matches. However, a large number of studies attempted to identify goal-scoring patterns through the temporal analysis of scoring occurrences

and presented that a greater number of goals were scored in the second half of matches [18,22,23]. Moreover, Alberti and his colleagues [22] examined the English Premier League, the French Football League 1, the Italian Serie A, and the Spanish Football League and suggested that goal-scoring patterns are not related to particular seasons or country-related styles of play.

Moreover, the analysis revealed significant differences in xGa scores when playing against teams from Group A (mean=1.60, sd=0.70) compared to Group B (mean=0.81, s.d.=0.59). This indicates that the quality of the opponent had a notable impact on the defensive performance of the Greek national team. Furthermore, there was a statistically significant difference between xGa scores in the second half compared to the first half of matches. These results suggest that the Greek national team experienced higher scores of xGa during the second half of their matches. This finding suggests the possibility of fatigue, changes in defensive strategy, match context, or opponents' change in their attacking strategy as the match progresses. Importantly, the study found no statistically significant differences in xGa scores based on match location. This suggests that factors such as home advantage or environmental and atmospheric conditions did not have a significant impact on defensive performance in terms of xGa.

Concerning the analysis of time over a 15-minute period, a relationship between xGf and xGa and time of chance creation in the 24 matches analyzed for the study appeared, yet only xGf was found to be statistically significantly different when analyzed between the six 15-minute time periods. The findings of several studies support the contention that the majority of goals are scored late in each half, probably on account of fatigue, both physical [24,25] and mental [26], which accumulates as a match proceeds, leading to a greater number of technical failures [27]. Another reason could be the adoption of riskier attacking strategies in an attempt to change the current score [23,28]. It seems that the final fifteen minutes of the second half frequently represent a critical period in a match. Coaches should take this trend into account by reinforcing their team's defense, especially if the team does not enjoy a score advantage, or by making attacking substitutions or alterations to their teams' formation if they are looking to win games from a losing or drawing score position. The Kruskal-Wallis H test showed that there was a statistically significant difference in xGf for the Greek national team between the six 15-minute periods but no significant differences were found for xGa. The post hoc Mann-Whitney U test revealed that xGf scores were significantly lower in the first 15-minute period compared to the fourth 15-minute period, with a moderate effect size. Given the sample size for the study, it is advisable to continue this research across multiple teams for xGf and xGa, with a larger sample of matches in future study designs.

The remaining situational variables concerning xGf did not reveal any statistically significant differences in match location and opponent quality. However, it should be mentioned that there was a trend to obtain higher scores when playing at home and when playing against weaker teams from Group B.

With regards to the zone analysis for shots (for and against) and goals, the majority of shots on goal by Greece were taken from the central zone in front of the penalty box, accounting for 33.3% of the shots in total. The two zones inside the box, close to the penalty spot, between 6-18 yards away from the goal, were also heavily utilized. Overall, the Greek national team preferred the central zones for shooting and scoring goals, showing a higher frequency compared to the lateral zones. From a defensive standpoint (xGa), the opponents tended to use the two zones beyond the penalty spot more often (12-18 yards away), particularly the central zone just in front of the penalty box, which accounted for 42.5% of their shots. Similar to the attacking shots (xGf), the opponents also favored the central zones over the lateral zones for both shooting and scoring goals. Based on the number of shots taken (369) and conceded (174) across the 24 matches, it can be suggested that Greece adopted a proactive style of play that afforded them more than double the number of chances for (xGf) when compared to (xGa). However, we must observe that they only scored from ~7% (26/369) of their chances created, in comparison to ~13% (23/174) of shots from opponents resulting in goals. The discrepancy between the total number of chances for/against and goals scored could be because of the individual quality of the players taking the shot on goal, as well as the quality of goalkeepers involved in each match.

Limitations of study

There were many shortcomings in this study that should be noted. First, the analysis focused on 24 matches played by the Greek national team during a specific period. Expanding the dataset to include more matches across different competitions and involving other national teams as well as investigating xG patterns across various club teams with different playing styles and tactical approaches could strengthen the generalizability of the findings. Additionally, the study relied on publicly available data, which may have limitations in capturing the nuances of specific match events. Access to more comprehensive performance data could allow a more detailed analysis of the relationship between situational variables and xG. By acknowledging these limitations, we recognize the need for further research

to build upon this initial investigation. Future studies addressing these limitations can provide a more comprehensive understanding of how various match conditions interact with xG across different teams and playing styles in elite international football.

Conclusion

This study investigated the influence of match conditions on expected goals (xG) in international elite football, focusing on matches played by the Greek national team. The results revealed a clear trend: the Greek team generated a significantly higher xG value during the second half compared to the first, highlighting the importance of maintaining or improving attacking strategies later in the game. Additionally, the final 15 minutes of the second half emerged as a critical period for xG, suggesting potential fatigue or tactical adjustments impacting both teams. While the study did not find significant effects of match location on xG, there was a tendency for higher scores against weaker opponents, aligning with previous research. Both the Greek team and their opponents primarily targeted central areas for shots and goals, underlining the importance of controlling the central midfield and penalty area. The study emphasizes the need for future research to incorporate a wider range of situational variables and teams to offer even more comprehensive insights for coaches and analysts working in international elite football.

Practical implications

The above results could be practically incorporated into training to aid players' understanding and their needs, in particular how the offensive player takes a shot and how the defensive player should be positioned to defend this shot. The trend towards increased xG in the final quarter of the second half suggests a potential window for tactical adjustments to maximize scoring opportunities. Coaches could consider introducing attacking substitutions or employing more aggressive tactics during this period to capitalize on this trend. The preference for central areas in both attacking and defending highlights the importance of controlling the central midfield and penalty area. Training exercises and tactical strategies can focus on maintaining possession and winning challenges in these crucial zones.

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Institutional Review Board Statement: All procedures were carried out in accordance with the 1964 Declaration of Helsinki and its subsequent amendments. Consent to perform testing was provided by the Bioethics Committee of the School of Physical Education and Sport Science, National and Kapodistrian University of Athens (1143/13-11-2019).

Data availability statement: The data presented in this study are available on request from the corresponding author.

Informed consent statement: The present study did not involve humans.

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A SYSTEMIC REVIEW OF SMART TECHNOLOGY SPORT BRAS FOR EXAMINING CARDIOVASCULAR FUNCTION

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Authors' contribution:

- A. Study design/planning
- B. Data collection/entry
- C. Data analysis/statistics
- D. Data interpretation
- E. Preparation of manuscript
- F. Literature analysis/search
- G. Funds collection

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Keywords: Wearable Technology, Exercise physiology, Systematic Review, Sport Science

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Abstract:

Background: Unremitting advancements in wearable technology provides female consumers a plethora of fabricated garments that claim to monitoring biological function. This systematic review examined current literature pertaining to smart technology sport bras fabricated to assess cardiovascular function.

Methods: The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was utilized, and the review was registered in the International prospective register of systemic reviews (PROSPERO) within the National Institute for Health and Care Research (NIHR). A total of 949 articles were screened after using key search terms using the Covidence systematic review software. Articles were sourced from PubMed, SPORTDiscus, or Medline via OVID databases.

Results: A total of 19 articles were examined for eligibility and was reduced to a total of three articles to be included in the review. The results from this systematic review highlight the paucity of commercially available sport bras capable of accurately examining cardiovascular function during rest and exercise, while concomitantly providing the necessary support and comfort requirements for females. Of the commercially available sport bras, the Berlei sport bras was identified as the most accurate for recording cardiovascular stress during resting, walking, and running conditions. The three studies included in this review demonstrate strong potential for washable and flexible e-textile sensors with sufficient accuracy in pressure ranges that can be used in sport bras to monitor biological functioning.

Conclusions: Future research should prioritize enhancing participant diversity in the examination of smart sport bras to ensure comprehensive inclusion of all body types.

Introduction

The comfort and support provided by undergarments worn by female athletes can play a significant role in their performance during sport [1]. For example, the literature examining weight bearing exercise, such as running, and its effect on breast discomfort in females, highlights ratings of exercise-induced pain that are significantly lower in females who use robust undergarments, compared to those using garments with minimal support [2]. Breast tissue discomfort arising from poor support can lead to injury if left untreated [1]. For this reason, increasing endeavors to support female athletes with proper fitting sport bras are at the forefront of sporting organizations to augment human performance [3].

The chest strap heart rate monitor is the most widely utilized consumer wearable device for examining cardiovascular function during rest and exercise [4,5]. Advancements in wearable technology that can examine biological function have significantly increased over the past decade. The manufacturing of these devices has also grown considerably to keep up with consumer demand, resulting in a joint European Initiative (Towards Intelligent Health and Well-Being: Network of Physical Activity Assessment – INTERLIVE) which provides consensus statements on best practice and recommendations for evaluating device validity and reliability [6]. The perpetual lack of equity and inclusion when examining the validity and reliability of these products in females has been emphasized [6]. Many sport bras are fabricated with a thick elastic band that is situated directly underneath the breast tissue during use. Thick elastic bands reduce breast tissue displacement by providing compression against the rib cage to secure both the sport bra and tissue. This band can range between 2.5cm to 5cm in width, which can cover from the xiphoid process to the upper abdominal wall. Although this band is deemed necessary for the efficacy of sport bras, in terms of the support they provide, it also provides challenges when using wearable technology, such as heart rate monitors. The location of these elastic bands inhibits the usage of chest strap heart rate monitors by females. In addition, the validity of cardiovascular monitors is significantly influenced by their proximity to the sternum/xiphoid process [7] and whether they cover breast tissue itself [8].

A sport bra with integrated heart rate technology has yet to be deemed both reliable and valid during high intensity exercise, while also providing adequate support and comfort. Designing athletic apparel with integrated technology needs to account for a wide range of criteria, including physical comfort and breathability for the user, and appropriate support and protection for the technology; the materials used must be sufficiently rigid and flat [9]. An inevitable connection between cardiac autonomic activity and subjective comfort of sport bras in studies of female athletes exists, as clothing pressure has shown to significantly reduce cardiac vagal activity [10]. This reduction in vagal modulation coincides with alterations in metabolic function during exercises [11], and suggests the significant impact a sport bra can have of psychophysiological function.

Consequently, the material used in fabricating sport bras must remain comfortable during periods of high-intensity exercise and actively control the pressure around the chest to prevent interference with heart rate measurements. Breathable textile electrodes have been developed using a pad-dry-cure method that display washing cycle resistance and improves electrical conductivity in resting, walking, and running testing conditions [12]. Conductivity is generally a large issue for devices in operating the way users are expecting, such as simply measuring heart and breathing rates accurately. Furthermore, conductivity was a primary consideration for past work in female collegiate athletes showing that health screening procedures using questionnaires and physical examinations typically display a low sensitivity to detecting cardiac abnormalities that are associated with sudden cardiac death and cardiac arrhythmias [13].

This systematic review examined current literature pertaining to fabricating sport bras designed to assess cardiovascular function during rest and exercise, and to highlight their advantages and limitations to assist in future design efforts.

Materials and Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was used as the protocol for the design of the review [14]. The PRISMA guidelines include a 27-item checklist considered to improve reporting transparency, limiting the risk of publication and selection bias. This review was registered with the National Institute for Health and Care Research (NIHR) using Prospero (CRD42023391426) under the title “A Systematic Review of Commercially Available Sport bras with Integrated Heart Rate Monitors.” The PRISMA flowchart is provided in Figure 1.

Inclusion Criteria

Studies were selected for the review if they met the following criteria: 1. Female individuals; 2. written in the English language; 3. original articles; 4. provided detailed information about sport bras design and capability of determining

cardiovascular health or sport bras fabricated with textiles to examine cardiovascular health; and 5. were sourced from either PubMed, SPORTDiscus, or Medline via OVID databases.

Exclusion Criteria

Studies were excluded if articles included the following: 1. sport bras designed solely for comfort and/or design, and not related to cardiovascular assessment; 2. written in any language other than English; and 3. summary-based articles.

Information Sources

An electronic search was conducted in November of 2023 that included all publication years (including and after December 2018). To minimize selection bias and to perform a comprehensive search, three databases were used including SPORTDiscus (1800–present), PubMed (1800–present), and Medline via OVID (1946–present).

Search String

Key search terms that were produced from reviewing previous literature and using several synonyms of the different forms of cardiovascular assessment were grouped and searched within the article title and abstract, and keywords using the search conjunction 'OR'. Combinations of the following terms were used as search terms: 'heart rate', 'sport bras', 'monitor', 'cardiovascular'.

Search Limits

To provide a more accurate search, the following limits were selected: 1. English language, 2. humans, and 3. journal article, all publications including and after the year 2018.

Study Selection

The titles and abstracts of the papers resulting from the search were independently assessed for relevance by two authors. Full text articles were retrieved if the titles or abstracts contained any combinations of the key search terms and if the publications met the inclusion criteria while not satisfying the exclusion criteria. If there was uncertainty or disagreements between the authors, it was resolved through a discussion between the two authors. A third author was consulted if the first two authors could not reach an agreement. The rationale for excluding articles was documented.

Data Collection Process

This review was conducted using Covidence, a computer software program designed for supporting systematic reviews germane to health research [15]. Two authors were responsible for collecting and importing data into the computer software program for screening and extraction. Disagreements were discussed between the two authors. A third author was consulted if the first two authors could not reach agreement.

Data Items

The following data were searched for from the articles that were included in the review: study methodology (study design and duration); the participant characteristics (age, height, mass); error between criterion method and prototype sport bra for measuring cardiac function; association between criterion method and prototype sport bra for measuring cardiac function. The pad-dry-cure method used by Shathi et al. was used to measure the deposition of poly (3,4-ethylenedioxythiophene) polystyrene sulphonate (PEDOT:PSS) which was acquired on reduced graphene oxide (rGO) coated substrate using layer by layer (LbL) technique and ECG signals [12].

Risk of Bias of Individual Studies

A modified Downs and Black scoring system [16] was used to assess the quality of the included articles in terms of the risk of bias between studies. All questions from the modified Downs and Black checklist were included and scored (as either 0 – not present in the article, 1 – present in the article, or UTD – unable to determine) relative to each eligible article. The question number from the original scoring system was maintained to provide clarity to the reader. Two reviewers decided upon the included questions prior to scoring the articles. The results of the modified Downs and Black scoring system are provided in Table 1.

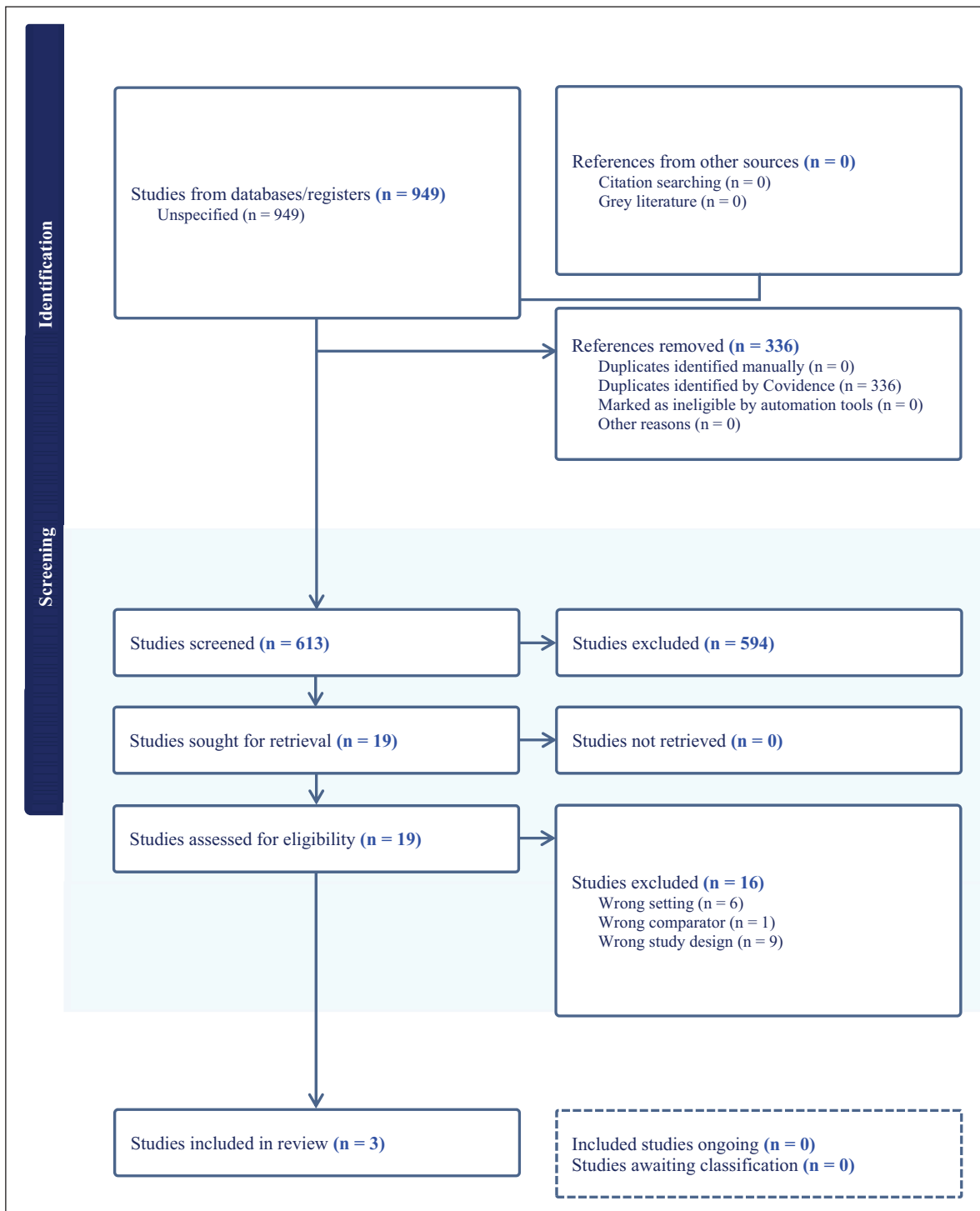


Figure 1. PRISMA diagram

Results

Table 1. Risk of bias of individual studies

	Navalta et al. (2020) [17]	Shathi et al. (2020) [12]	Schauss et al. (2022) [18]
Q1 Hypothesis/aim/objective clearly described	1	1	1
Q2 Main outcomes in Introduction or Methods	1	0	1
Q3 Patient characteristics clearly described	1	0	0
Q4 Interventions of interest clearly described	0	0	0
Q5 Principal confounders clearly described	1	0	0
Q6 Main findings clearly described	1	1	1
Q7 Estimates of random variability provided for main outcomes	1	1	1
Q8 All adverse events of intervention reported	0	0	0
Q9 Characteristics of patients lost to follow-up described	0	0	0
Q10 Probability values reported for main outcomes	0	0	1
EXTERNAL VALIDITY			
Q11 Subjects asked to participate were representative of source population	1	UTD	UTD
Q12 Subjects prepared to participate were representative of source population	UTD	UTD	UTD
Q13 Location and delivery of study treatment was representative of source population	UTD	UTD	UTD
INTERNAL VALIDITY – BIAS & CONFOUNDING			
Q16 Any data dredging clearly described	1	1	1
Q17 Analyses adjust for differing lengths of follow-up	0	0	0
Q18 Appropriate statistical tests performed	1	1	1
Q19 Compliance with interventions was reliable	1	1	1
Q20 Outcome measures were reliable and valid	1	1	1
Q21 All participants recruited from the same source population	UTD	UTD	UTD
Q22 All participants recruited over the same time period	UTD	UTD	UTD
Q23 Participants randomized to treatment(s)	0	0	1
Q25 Adequate adjustment for confounding	0	0	0
Q26 Losses to follow-up taken into account	UTD	UTD	UTD
POWER			
Q27 Sufficient power to detect treatment effect at significance	1	1	1
TOTAL	12	8	11

*UTD = Unable to Determine

Table 2. Study characteristics

Study	Sample	Sport Bra(s) Examine	Textile	Study Design	Study Protocol
Navalta et al. (2020) [17]	24 Healthy females Participant characteristics (mean ± SD). Age = 22.2 ± 5.8 y Height = 174.6 ± 9.9 cm Weight = 71.2 ± 14.4 kg	Adidas Smart Sport Bra Berlei Sport Bra Sensoria Sport Bra	Addidas (86% nylon, 14% spandex, fabric heart sensors) Berlie (47% polyamide, 37% polyester, 16% elastin, flexible plastic sensors) Sensoria (74% polyamide 18% polyester, 8% elastin, flexible plastic sensors)	A test re-test study was utilized to examine the validity & reliability of each sport bra to record heart rate.	Participants engaged in two 14-minute treadmill exercise sessions. A Polar H7 chest strap heart rate monitor was used as the criterion method. Each session included a 1-minute standing period on the treadmill, followed by a 3-minute self-paced warm-up walk. This was succeeded by a self-paced run and walk, each lasting 5 minutes. Participants set their own pace, choosing a treadmill speed they felt they could sustain throughout the 5-minute bout. To ensure reliability, each bout was performed twice with participants wearing the same sports bra for both rounds. The speed for all trials was consistent with that of the initial bout. Between bouts, participants rested, sitting down until their heart rate was within 10 bpm of their initial resting value before proceeded to perform the second bout. Each sport bra was examined separately.
Shathi et al. (2020) [12]	1 Female Participant Characteristics (N/A)	Self fabricated sport bra.	A graphene-based highly, conductive, flexible, washable, and breathable textile electrode were developed using the pad-dry-cure method and fabricated into the sport bra. The reduced GO coated textile electrodes (rGO) were coated with conductive polymers to develop highly flexible, washable, and breathable textile electrodes for health monitoring.	Design evaluation study of a prototype sport bra with fabricated electrodes. Study examined its efficacy for recording cardiac cycles.	Three graphene-based electrodes where fabricated into the sport bras at locations (LA, RA and V ₃). A three-lead ECG was connected to each graphene-based textile electrode to examine components of a complete cardiac cycle. Medical electrodes were used as the criterion method for comparing signal quality. Continued ECG monitoring was performed during rest, walking, and running.

Schauss et al. (2022) [18]	<p>4 Females</p> <p>Participant Characteristics (mean ± SD).</p> <p>Age = N/A</p> <p>Height = 170.2 ± 4.25 cm</p> <p>Weight = 59.5 ± 2.1 kg</p>	<p>ARGONAUT sport bra.</p> <p>The electrode was fabricated using A TC2 digital Jacquard loom (Tronorud Engineering, Norway) and AdaCAD software.</p>	<p>Design evaluation study of a prototype sport bra. Study examined its efficacy for recording cardiac cycles.</p>	<p>A three-lead ECG was connected to each electrode to examine components of a complete cardiac cycle.</p> <p>Two electrodes were woven into the front of the sport bra for direct contact against the upper chest. A third electrode was woven into the front left of the support band of the sport bra.</p> <p>Participants performed four motions (sitting, arm flexion & extension, arm abduction & adduction, and walking).</p> <p>Each motion was completed for one-minute. A 30-second segment of data was extracted for ECG analysis.</p> <p>Medical electrodes were used as the criterion method for comparing signal quality.</p>
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Table 3. Study outcomes

Study	Condition	Error Reported	Association Reported	Signal to Noise Ratio	
Navalta et al. (2020) [17]	Addidas Smart Sport Bra	MAPE (%)	ICC (95% CI)	N/A	
		I. Rest	4.45		0.79 (0.77 : 0.81) p < 0.001
		II. Warm-Up	9.32		0.60 (0.57 : 0.62) p < 0.001
		III. Run	13.57		0.53 (0.51 : 0.55) p < 0.001
		IV. Walk	9.56		0.57 (0.55 : 0.59) p < 0.001
	V. All	10.56	0.66 (0.65 : 0.67) p < 0.001		
	Berlei Sport Bra	MAPE (%)			
		I. Rest	0.93	0.99 (0.99 : 0.99) p < 0.001	
		II. Warm-up	0.78	0.99 (0.99 : 0.99) p < 0.001	
		III. Run	0.58	0.99 (0.99 : 0.99) p < 0.001	
		IV. Walk	0.61	0.99 (0.99 : 0.99) p < 0.001	
	VI. All	0.66	0.99 (0.99 : 0.99) p < 0.001		
	Sensoria Sport Bra	MAPE (%)			
		I. Rest	2.26	0.97 (0.96 : 0.97) p < 0.001	
		II. Warm-up	5.32	0.70 (0.68 : 0.71) p < 0.001	
III. Run		4.00	0.63 (0.61 : 0.65) p < 0.001		
IV. Walk		1.91	0.96 (0.96 : 0.96) p < 0.001		
V. All	3.40	0.84 (0.84 : 0.84) p < 0.001			
Shathi et al. (2020) [12]	I. Rest	ECG wave forms displayed similar quality to medical grade electrodes.	N/A	Graphene-based electrode = 21.6 dB	
	II. Walking				
	III. Running				
				SNR was not affected by sweat.	

Schauss et al. (2022) [18]	I. Sitting	ECG wave forms displayed similar quality to medical grade electrodes.	N/A	P-wave = 0.022 dB
				Q,R,S waves = 0
				T-wave = 0.356 dB
	II. Flexion/Extension			P-wave = 0.056 dB
		Q-wave = 0.024 dB		R,S waves = 0
				T-wave = N/A
	III. Abduction/Adduction			P-wave = 0.022 dB
				Q-wave = 0.06 dB
				R,S waves = 0
				T-wave = N/A
	IV. Walking			P-wave = 0.022 dB
				Q-wave = 0.06 dB
				R,S waves = 0
				T-wave = N/A

MAPE (%) = Mean absolute percentage error. ICC = Interclass correlation coefficient. SNR = Signal to noise ratio

Discussion

The purpose of the systematic review was to examine current literature pertaining to fabricating sport bras designed to assess cardiovascular function during rest and exercise, and to highlight their advantages and limitations to assist in future design efforts. Based on the included studies, each utilizing different textiles and sensors, we suggest that there is a lack of available sport bras that provide comfort and support, and accurate measurements of cardiovascular functioning.

Current advancements in textile development have led to using fabricated electrodes capable of recording biological functioning during daily living. Incorporating woven structures, such as dry electrodes within fabric, is now desired for its structure stability, increased surface contact area, and because they offer a variety of design options [19]. Schauss et al. designed a novel sport bra using a sateen woven electrode made of steel yarn that was integrated in the weft direction [20], with each sensor being fabricated using A TC2 Digital Jacquard loom (Tronrud Engineering, Norway) and AdaCAD software [21]. This study found that compression garments closest to the skin must have a high neckline to allow for sensor attachment below the clavicle. When examining the accuracy of the bra for recording cardiovascular function during different movements like shoulder flexion/extension and shoulder abduction/adduction, they observed comparable recordings in R peaks within the ECG waveforms compared to traditional adhesive electrodes. However both P and T waveforms were easily affected by motion artifact noise (poor electrical connection between the electrode and ECG) in the system and deemed less effective than traditional ECG [21]. Due to the constraints posed by the size of the garment, data collection was limited to a single participant. Consequently, this study failed to consider the possible effects that factors which vary considerably between people, such as breast size and body composition, have on comfort [22] and heart rate measure determination using this type of wearable technology. Additionally, the limited sample size made it impossible to examine the between-participant reliability of the garment in terms of its ability to record cardiac autonomic activity. Pulling a sport bra over the head, as is typically performed for many existing designs on the market, may place too much strain on the technology within a wired design. This could negatively impact the signal quality. This suggests that vigorous or high-intensity exercise where increased vertical breast tissue displacement occurs may place excessive strain on the material of the garment, thereby effecting the accuracy of sensors for recording cardiac autonomic activity [23]. Therefore, two closure mechanisms were tested, a front zipper mechanism and three snaps at the back of the bra. The front zipper was shown to interfere with the sensors and decrease signal quality, while the mechanism with three snaps at the back of the bra showed clear signalling and identification of peaks in the ECG signals. Although this mechanism was more difficult to put on the body and remove from the body, this garment iteration was used instead of the zipper mechanism. Moreover, the durability of the fabrics used in sport bras requires further study, including how they hold up during frequent washing. Future advancements in sport bra design should prioritize inclusion for females of various weights, sizes, and physical capacities. Including females in the process of designing, developing, testing, and assessment of sport bras, will ensure that these important issues are considered. Additionally, further research addressing gender disparities in the design of wearable technologies and textiles is crucial to enhance accessibility to accurate cardiovascular data, particularly for individuals engaged in sports and strenuous physical activities.

Emerging pad-dry-cure methods have become increasingly popular for developing textile electrodes to use in sport bra designs. Graphene-based textiles with enhanced breathability offer advanced opportunities for fabricating sport bras. Furthermore, these textile electrodes are capable of withstanding repeated washing, a significant advancement over metal electrodes which often provide low binding ability in addition to skin irritation [24]. Shathi et al. designed a novel sport bra utilizing a 3,4 – ethelenedioxythiophene polystyrene sulfonate (PEDOT:PSS) and graphene oxide (GO) solution to examine cardiac autonomic activity during rest, walking, and running. They reported that the electrical conductivity (measured in ohms) of the graphene-coated textile electrodes was improved from $3.5\text{M}\Omega$ to $400 \pm 5.0 \text{ k}\Omega$ for 12 padding passes, which means the dyeing process was repeated 12 times until a significant coating of graphene oxide and the required electrical conductivity was achieved. Furthermore, these graphene-coated textile electrodes using the pad-dry-cure method demonstrated improved structural stability during washing cycles and maintained conductivity during increased sudomotor responses where participants had elevated sweating. With respect to the accuracy of the graphene-coated electrodes for recording cardiac autonomic activity, the textile-based ECG electrodes from the sports bra was comparable by image of the signal to the ECGs of healthy individuals using medical electrodes. The authors warned that further analysis is required given that there were inconsistencies in the individual cardiac waveforms documented. Additionally, the authors did not provide any insights into determining the parameters for sizing and usage of sport bras in female sports. For prototypes to be accessible on the market, sizing for all females must be considered.

When examining the validity and reliability of commercially available smart bras that are fabricated with textiles for examining cardiovascular stress, there remains limited evidence for their efficacy. Navalta et al. examined three commercially available smart bras (Adidas Smart bra, the Sensoria fitness biometric bra, and the Berlei sport bras) in 24 healthy females. The validity and intra-reliability of each bra was examined during rest, walking, and running conditions. The Adidas Smart sport bras demonstrated reliable measurements only under resting conditions with an intra-class correlation coefficient (ICC) of 0.79 and a mean absolute percentage error (MAPE) of 4.5%. The Berlei sport bras demonstrated high reliability across all conditions, with an impressive ICC of 0.99, and high validity with a MAPE of 0.66%. In contrast, the Sensoria biometric bra was deemed valid only under resting and walking conditions, with a high ICC of 0.96 and a MAPE of 1.9%. The authors concluded that the Berlei sport bras was the most reliable and accurate across all conditions, making it a suitable option for consumers. However, an important limitation of this study is that the menstrual cycle of participants was not taken into account in terms of its impact on breast position and size [25]. The effect that menstrual cycle phase might have on the validity and reliability of the measurements reported by Navalta et al. remains unknown.

Future studies should consider incorporating technology such as heart rate monitors into the sport bras being tested, and for assessing females with a range of body and breast sizes. A lack of consideration for different body sizes seems to be the overarching limitation in the few studies that have been completed related to this work to date. Accommodating for different chest sizes to achieve properly fitting sport bras is one of the most important factors for many females shopping for sport bras on the market.

Sport bras provide large compression forces on the thoracic cavity that have shown to significantly influence cardiac autonomic activity in young, healthy females [10]. This observation is consistent with previous literature, and suggests that female undergarments may adversely impact cardiovascular health [26]. It is recommended that the clothing pressure of point H (the lateral side of the bust line), a focal point for demonstrating the overall pressure on the chest area [10], should range between 2.01 kPa and 4.74 kPa. These findings are important clinically because reductions in heart rate variability have been associated with predictors of all-cause mortality [27]. However, different body types must be considered when fabricating sport bras for women. Yan et al., notes that the 35 women who participated were similar in shape which conformed to 160/84A size which translates to the term “small” in US women’s clothing. In addition, only three bust sizes (66cm, 64cm, and 62cm) were represented. These measurements approximately translate to a 26A, 28AA, and 26AA respectively in terms of breast size. Globally, the average female breast size has increased over the past 25 years. In the USA alone, the current average breast size is 34DD, a large increase from a 34B since 1998 [28]. This dimension translates to a chest measurement of approximately 74-76cm. It is important that a range of bust sizes and chest sizes for different women are considered in research and the sport bra design process. Most recently, the practical significance of clothing pressure affecting cardiorespiratory function in female athletes, was established by Kipp et al. who demonstrated that respiratory function can be compromised by the pressure exerted by the under band of a sport bra. This study identified a reduction of two percent in oxygen consumption due to the pressure exerted on the thoracic cavity. It was estimated that this pressure would translate into a three-minute difference in marathon time [29]. Pressure exerted against the thoracic cavity has also been highlighted as the most common complaints for women wearing sport bras [30].

Conclusion

The results of this systematic review highlight the paucity of commercially available sport bras that are capable of accurately examining cardiovascular function during rest and exercise, while concomitantly providing the necessary support and comfort required by females. The three studies included in this review demonstrate strong potential for washable and flexible e-textile sensors and accuracy in pressure ranges that can be used in sport bras to monitor biological functions within the human body. Future research should prioritize the assessment of a more diverse range of designs of smart sport bras to ensure that all body types are included. Sizing and function of these bras should also consider changes in breast size and behaviour that may occur during each phase of the menstrual cycle.

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THE ROLE OF THE COACH DEVELOPER IN THE DEVELOPMENT OF SPORTS COACHES' COMPETENCIES

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Authors' contribution:

- A. Study design/planning
- B. Data collection/entry
- C. Data analysis/statistics
- D. Data interpretation
- E. Preparation of manuscript
- F. Literature analysis/search
- G. Funds collection

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Abstract:

Background: The paper focuses on the continuous professional development of sports coaches, and the role of informal education and coach developers. Special attention is devoted here to the coach training and development system in Poland. The paper aims to indicate the need for strong support for both informal coach education and the important role of coach developers in professional coach development in Poland and worldwide.

Methods: An analysis of secondary data on the system of sport training and continued professional development in Poland was applied. Primary research data on Polish Olympic and Paralympic national team coaches (13 sports), their qualifications, competencies, and views on their continued professional development were also used. The study covered 103 coaches in Olympic or Paralympic sports. The national team coaches surveyed also conducted a self-assessment of their professional development needs, opportunities, and challenges. The method of balance of competencies based on data documenting the stock of knowledge, experience, and social competencies acquired in the learning process of the surveyed coaches was applied.

Results: It was found that after completing their formal education, the coaches declared participation in various types of continuous professional development courses and training, while the most valued forms of continued professional development included informal learning, and sharing experiences and good practices with other coaches.

Conclusions: The data supports the need to educate more sport coach developers and introduce them to the professional coach development system to guide coaches and facilitate their knowledge and competence acquisition. Particular in the area of Paralympic sports development.

Introduction

The current level of professionalisation in the sports sector requires that a significant amount of focus and attention be given to the education and development of training staff, among whom coaches play a key role. The sporting performance of individual athletes and/or teams, as well as the clubs' financial standing, depend on coaches' qualifications and competences. The improvement of sporting performance and athletic development are, according to coaches, the main measures of coaching success [1]. Operating in this result-oriented sports environment and cooperating with the numerous actors in this field of social reality requires high-level qualifications and competences; their development is the

primary goal of the coaching education and professional training system. Frameworks for defining qualifications began to be developed to help understand the international context of coach work and education [2-5]. The application of methodology in developing educational programs, along with increased interest in professionalizing coach education, laid the groundwork for the formation of coach developers [6-10]. Based on the results obtained, it was found that after completing formal education, the surveyed coaches declare participation in various types of workshops, courses and training. The study showed that coaches most prefer to exchange experiences with other coaches. This is particularly significant for the development of Paralympic coaches [11]. Therefore, a more precise understanding of the role of coach developers, the possibilities of facilitating the learning process in non-formal and informal education settings by professionally prepared educators in the sports sector, is essential for the effectiveness of building coach education systems.

In this paper, we intend to highlight new trends in the continuous professional development of sports coaches (especially in competitive and professional sports) in Poland and around the world, and the role of experts such as coach developers [12] in the process. We also present conclusions from the study of competencies and qualifications of coaches of Polish national teams in Olympic and Paralympic sports in the light of the coaches' continuous professional development. As an introduction to the deliberation on coach developers' significance and functions, the evolution of the sports coaches' education system in Poland and its changes will be briefly presented, especially after the profession was deregulated in 2013.

Material and Methods

An analysis of secondary data on the system of sport training and continued professional development in Poland was applied. Primary research data on Polish Olympic and Paralympic national team coaches (13 sport disciplines), their qualifications, competencies, and views on their continued professional development were also used. The study covered 103 coaches in Olympic or Paralympic sports. The surveyed national team coaches also conducted a self-assessment of their professional development needs, opportunities and challenges. The method of balance of competencies based on data documenting the stock of knowledge, experience and social competencies acquired in the learning process of the surveyed coaches was applied.

To verify the significance of differences between the examined groups, parametric t-Student and non-parametric U Mann-Whitney tests were used. Additionally, the relationship between the variables under investigation was analyzed using Pearson's correlation coefficient. Responses to open-ended questions were subjected to categorization and subsequently coded. Descriptive statistics were computed for the variables, including data range, mean, and standard deviation for normally distributed results, as well as median, quartiles, and coefficient of variation.

Education of sports coaches in Poland

Poland has a long tradition of educating sports coaches and instructors, dating back to the interwar period [13]. It was between WWI and WWII that the first coaching schools and courses for sports instructors were established in Poland. After World War II, the development of coaching education also continued under the socialist formula of complete state control over sports, and the profession of sports coach was recognised in Polish law as early as 1953. "The omnipotence of the socialist state manifested in its entirety in the sphere of physical culture and competitive sport", and concerned the prevailing ideology and policy, state ownership of sports facilities and equipment, and the central financing of sport under state and sectoral patronage [14].

The development of sports coaches' training is a process that is constantly changing in response to the increasing demands and expectations in the world of sports. With this process, educational programmes and training institutions¹ were developed to ensure a high level of coaching preparation. Coaching teams were trained mainly by state-funded national and non-commercial sports associations, covered by the aforementioned sectoral (military, police, mining, metallurgy, etc.) patronage of league competition between clubs.

The formally regulated coaching education system in Poland focused on providing coaches with solid theoretical knowledge [15-17]. This included the knowledge of the physiological fundamentals of human body functioning, exercise physiology, training theory, and other theoretical foundations of sports science. Due to the concept of physical culture sciences which were developed in Poland and many other socialist countries (encompassing not only the narrower

¹ Academies of Physical Education are one example of Polish higher education institutions that train coaches and which offer sports coaching degree programmes. The Polish Olympic Committee also played an important role in the development and training of coaches, as did the Central Sports Centre. Each sport in Poland had its own sports federation, which was responsible for the training of coaches in its specific discipline. The federations organised coaching courses and practical training for future coaches. The Coaching Academy was established at the Sports Institute.

scope of sports science, but also e.g. physical education, and socio-pedagogical aspects of the work of sports coaches and instructors, physical recreation, and physical education teachers) in the education of physical culture specialists from several physical education academies in the country, attention was paid to adequate pedagogical, moral, and social preparation in addition to the formation of the so-called hard competences [18-20].

Despite the fact that Poland entered free-market capitalism after 1989, the general framework and principles of the coaches' training system remained largely unchanged for many years (until the deregulation of the profession in 2013). The training system was still centralised and there was a highly regulated certification system for sports coaches and instructors. The Sports Act of 25 June 2010 [21] defined professional titles of a certified sports coach and instructor for the sports, governed by Polish sports associations. Certification levels were also defined as Class 2 Coach, Class I Coach, and Master Coach (Article 41).

The minimum time and content of specialised courses were set out in the Ordinance of the Sport and Tourism Minister on the detailed conditions for obtaining professional qualifications in sports of 18 February 2011, as referred to in the Sports Act. The Class 2 coaching course lasted 400 hours, with 300 hours devoted to sport-specific classes (including 30 hours of internship), and the remaining 100 hours were devoted to core and specialist subjects, particularly sports theory and methodology, physiology, biochemistry, biomechanics, nutrition, pedagogy, psychology, management and marketing, and first aid. Panfil et al. [22] point out that although stable, this long-established tightly regulated system of coach education was not without its flaws and was characterised by the fact that the educational content was largely unified for all learners and paid little attention to specific aspects unique to each sport; many of the differences between e.g. gymnastics, rowing, judo, tennis or basketball were ignored; the differentiation of knowledge and skills acquired by coaches in their advancement to the next certification level was mainly of quantitative nature; certification courses did not take into account the different approaches required when working with adults compared to working with children and youth, or high-performance athletes. The authors also pointed out that teaching was mainly focused on the biological aspects of training, while the social aspects of the coach's work were somewhat neglected (regardless of the recommendations for strong pedagogical, moral, and social preparation mentioned earlier). Regarding teaching methods, coaches were mainly educated through directive methods such as instructing, teaching, and training. Methods such as tutoring, coaching, and mentoring, as well as the function of the coach developer, which is the focal point in this paper, were not discussed as relevant teaching tools.

This imperfect but reasonably safe and stable system of educating sports coaches and instructors (the system of awarding qualifications in the sports sector) was deregulated in 2013 [23]. Following the deregulation of the profession of sports coach and instructor in Poland, Polish sports associations gained independence in defining coaching grades and requirements for those who aspired to a sport coach. In sports governed by Polish sports associations, a person applying for a coach and/or instructor certificate must now be at least 18 years old, have graduated from a secondary school, and have the knowledge, experience, and skills necessary to work as a sports coach or instructor and not have been convicted of an intentional offense [23]. The amendment also cancelled the obligation to obtain permission from the Ministry of Sport and Tourism to organize specialised courses for coaches and instructors. This means that in Poland, any private entity can now organise such educational undertakings, and train sports coaches and instructors according to their own, preferably low-cost, standards. The deregulation of the professions of sports coaches and instructors has opened up the profession further and led to an increase in the number of certified sports coaches and instructors in Poland. In 2021, 33923 sports coaches were registered across the country [24]². This is more than three times the number of people working as coaching staff than in 2012, when the sports coaching profession was still formally regulated. The quality of their specialist training certainly varies, and a certificate of training as a sports coach or instructor is not a guarantee of good professional preparation. Polish sports associations themselves pay attention to the quality of the training system, especially for sports coaches. They train coaches according to the requirements of European and world sports organisations and run strict certification systems allowing coaches to work in professional sports leagues. Sports associations exercise a very high degree of autonomy in this respect and can create autonomous (although usually linked to the certification requirements of European sports federations) certification or licensing systems, and determine the competences necessary to work as a sports coach in a given sport.

The changes resulting from the deregulation of the professions of sports coach and instructor in Poland, pose threats to maintaining educational quality, and, at the same time, provide opportunities to improve the training and foster professional development processes in sports coaching. They have also certainly highlighted the necessity to check and validate the qualifications and actual competences of candidates for the profession of a sports coach.

² The number of people in possession of an active sports coaching licence.

New perspectives for sports coach education

Following the deregulation of the professions of sports coach and instructor in Poland in 2013, it was necessary to structure qualifications in the sports sector based on new criteria defining who can become a coach or instructor. There are differences in the requirements for training and coaching qualifications both between countries and between different sports organisations, and training providers offer a variety of programs for the development of sports coaches. Coaches can acquire competences through formal education, as well as through non-formal and informal learning. The situation in the European Union countries with regard to systems for the recognition and validation of non-formal and informal learning also varies. There is a growing popularity of educated people to effectively and efficiently support different forms of learning for sports coaches.

Research among sports coaches on how they acquire the knowledge that informs their professional practice shows that they learn their craft best through formal, informal, and non-formal learning [25-28]. Formal learning includes structured training methods, such as courses organised by higher schools, universities, or school programmes leading to a certificate of completion [29]. As the name suggests, this type of learning is generally highly structured in terms of objectives, curriculum, and attendance requirements and is usually designed to enable the achievement of formally recognized, prescribed, and predetermined outcomes designed to meet competency-based requirements [28]. Formal learning is characterized as occurring within an institutionalized, tiered, and hierarchically organized educational system. This involves the implementation of formal curricula, where admission prerequisites for universities are established, attendance is mandatory, and completion is validated by a certificate following a summative examination. Educational activities falling within this definition encompass certification programs for sports coaches developed by national bodies for sports management, and higher education courses in sports and coaching sciences. Historically, most coach education initiatives have entailed formal instruction in classroom settings [30].

In the realm of learning, the concept of informal education unfolds without a singular, all-encompassing definition. Instead, in the present understanding, it unfolds beyond the confines of formal educational systems. It takes on a predominantly unstructured nature, devoid of the pursuit of formal qualifications, and often emerges as a product of random everyday encounters. Informal learning is organized through various channels: the written word, internet, television, public lectures from experts, relevant programs and documentaries and personal interactions, shared stories, a wealth of knowledge is transferred from one generation to the next. Learning by doing, a cornerstone of informal education, allows individuals to acquire skills, problem-solving abilities, and practical insights that might elude formal instructional settings.

In this narrative of informal learning, the boundaries blur, and education becomes a tapestry woven from the threads of diverse experiences, personal connections, and the ever-evolving journey of exploration [31,32]. Learning takes place in a wide variety of socio-environmental contexts, most of which take place outside of specialised formal learning institutions. Okoń [33] refers to this as incidental learning.

Non-formal learning methods typically apply short-term educational approaches such as workshops, lectures, or symposia [34], leading to obtaining new competences confirmed formally by a certificate of participation. These include various types of sports coaching conferences, seminars, workshops, and clinics.

Duarte and Culver [35] conducted a number of interviews with sailing coaches and recorded their complex stories on how they acquired knowledge and skills, which focused particularly on the role of training through non-formal educational channels. A study of the qualifications and professional competences of 103 sports coaches of Polish national teams in Olympic and Paralympic sports representing 13 sports and 28 training managers of Polish sports associations [36]³ showed that sports coaches gained the most benefit from exchanging experience with other coaches, and joint training with sports science theoreticians and practitioners. The surveyed sports coaches of the Polish national team in thirteen Olympic and Paralympic sports were unanimous about what forms of education they considered the most beneficial for their professional development. They declared these to be 'non-formal training and self-learning' as well as 'participation in multi-day training courses for sports coaches' (Table 1). Coaches at the highest levels of their careers in Poland were most willing to use forms of education that involved the exchange of experience and interaction with other coaches. This form of education is most effective when supported by a competent coach developer equipped with solid facilitation skills [12, p.22].

³ Doctoral thesis by Piotr Marek (2021) "Professional competences and qualifications of coaches of Polish national teams in Olympic and Paralympic sports", University of Physical Education in Warsaw. The studied group of national team coaches covered 13 sports: equestrianism, canoeing, cycling, athletics, archery, swimming, weightlifting, shooting, fencing, tennis, table tennis, rowing, and sailing. The study applied, among other things, the competence balance method based on data documenting the knowledge, experience, and social competences learned by the sports coaches studied. The coaches also self-assessed their competences and professional development needs.

Table 1. The most beneficial forms of coach education according to the surveyed coaches of national teams [36]

No	Coaches' opinion	Olympic sport		Paralympic sport		Test t-Student	
		Mean	SD	Mean	SD	t	p
1.	non-formal exchange of practice with other coaches	2.0	1.2	2.3	1.4	-1.053	0.296
2.	participation in multi-day training for sports coaches	3.0	1.7	3.1	1.3	-0.105	0.917
3.	participation in scientific conferences	4.6	1.8	4.4	1.7	0.548	0.585
4.	formal study programmes in sport sciences confirmed by a diploma	5.6	1.9	5.6	1.8	-0.125	0.901
5.	formal courses improving sports coaching qualification	5.0	1.5	5.5	1.6	-1.301	0.197
6.	self-learning	4.1	2.0	2.5	1.8	3.384	0.001
7.	online courses (e-learning platforms)	6.6	2.0	6.8	1.5	-0.615	0.540
8.	delivering training/training other coaches/teaching others	5.1	2.6	5.7	2.1	-1.061	0.292

* (the lower the average value, the higher the ranking)

Strengthening the non-formal exchange of practices between sports coaches (for both Olympic and Paralympic sports) was identified by the coaches included in the study as key to developing their professional skills. Information-sharing platforms, meetings, and workshops that allow coaches to share their experiences can be an effective tool for continuous professional development.

The role of a coach developer in the continuous professional development of sports coaches

Non-formal education includes education and training delivered through programmes that do not lead to a full qualification but can be validated, accumulated, and transferred in the course of obtaining a qualification [37]. Dewey [38] pointed out that we do not learn from experience but from reflecting on that experience. One model for such reflective learning is that proposed by Kolb [39], referred to as 'The Experiential Learning Cycle'. Kolb's model involves treating and understanding learning as a process of accumulating experiences that lead to changes in behaviour. Experiential learning during training involves offering participants an experience, having them reflect on it, analyse it, and apply what they have learned. Kolb's experiential learning cycle includes elements such as concrete experience (analysing one's own work experience), reflective observation (working with a trainer-moderator), abstract conceptualisation and generalisation (summarising in connection with theory and feedback from the trainer-moderator), and active experimenting and testing the acquired knowledge in practice. The Kolb model is particularly relevant in the areas where learning occurs through experience. The education of sports coaches is the area where practices derived from adult learning models should be particularly applicable. The introduction of such innovative teaching methods into the education and professional development of sports coaches should be left to coach developers. The term coach developer encompasses a variety of roles played by those involved in the process of developing sports coaches. These roles differ from those of lecturers, academic teachers, or even coaches using conventional teaching methods (lectures, workshops). Coach developers are trained to develop, support, and encourage other sports coaches to continually learn and improve their knowledge and skills to provide a positive and effective sporting experience for all sports participants. A coach developer is an individual who has undergone training and taken an examination confirming their readiness to work as a learning facilitator, presenter, mentor, and assessor of the competences of sports coach candidates. A coach developer is also capable of supporting the development of experienced trainers and experts, evaluating them, and encouraging them to take responsibility for their continuous development. He or she should exemplify best practices, and apply reflective thinking skills expressed through well-thought-out techniques that enable sports coaches to 'immerse' themselves in their thoughts and analyze their coaching practice. Coach developers consciously use the Kolb's cycle of experiential learning. They can (and this is their main role) help sports coaches to become self-improving coaches by teaching them how to learn, and reflect upon what they are doing [3].

Relevant to the work of a coach developer are competence standards, which define how coaches should perform their work or their designated professional roles so that their skills can be assessed as objectively as possible. Given the diversity of sports, countries, and socio-economic circumstances in which sports coaches work, it is particularly

difficult to compare the levels of professional training of different coaches. It is difficult to create a single guideline for all countries, and it is virtually impossible to encourage them to use the same terminology and standards for qualifications. Therefore, a framework for defining qualifications is now being developed in order to help understand the international context of the conditions of sports coaches' work and education [2-5,27]. It is becoming increasingly important to ensure that developers of coaching education programmes provide the knowledge to develop high-quality sports coaching curricula and to use professional competence, experience, and pedagogical and andragogical approaches during the education process.

Results

The sports sector needs coach developers who are confident in their professional, interpersonal, and intrapersonal knowledge and possess the ability to facilitate sports coach learning [40]. This means that a person gaining knowledge from a coach developer will use the newly acquired information and combine it with skills and knowledge that they already acquired in order to cause a lasting change in his/her daily work mode as a consequence. The main role of a coach developer is to see to the development of his or her key competences as relevant for a given sport. He or she helps to define educational material for improving coach development systems.

The contemporary interest in developing research ideas related to the work of coach developers is evident in a growing number of publications and initiatives such as the ICCE-NipponSport Science University Coach Developer Academy, which provided an internationally recognised training programme for coach developers for six years [40]. Between 2014 and 2020, the Japanese government supported the coach development initiative by establishing the Coach Developer Academy. It brought together individuals who, after formal verification of the required documents (including, but not limited to, validated qualifications in a given sport, evidence of developing educational programmes for sports coaches, and documented educational activities conducted for other sports coaches), were invited to participate in a coach developer training programme⁴ designed according to the International Coach Developer Framework [12]. Two people from Poland qualified for this programme for 2016-2018, becoming the first ICCE-certified coach developers in Poland according to the international standard and validation methods. This resulted in the implementation of newly learnt methods into educational programmes developed by the Institute of Sport at the Polish National Research Institute with the support of subsequent coach developers who confirmed the qualification standards based on the International Coach Developer Framework guidelines [12]. Based on the educational materials of the International Council for Coaching Excellence, a training programme for representatives of Polish sports associations was developed to build a cadre of Polish education specialists in the sports sector.

The way coaches who train other coaches can model an approach to educating their colleagues, and base it on identified competencies relevant for coaches and goals set by the organisation, can become a future direction for research and development of coach development that serves to professionalise coaching staff. This way of learning connects coach development around the world and is becoming increasingly popular. It is about focusing on experiential learning using adult learning principles of the LEARNS model [41]. The expansion of this acronym reveals a way of coach development based on the principles applied in the delivery and planning of coach development and education. It is recommended that the education programme places the one who wants to learn at the centre (L – learner centred). It is a learner-centred strategy in which learners are placed in a well-thought-out and selected environment (E – environment), are involved in the learning process (A – actively involved), and have the opportunity to apply their knowledge and skills in a workshop setting. This also includes reflection (R – reflect) before, during, and after the training. The model involves extracting or providing new knowledge (N – new) to demanding sports coaches so that they feel more valued and involved in their development. Training programmes should also embrace what may go beyond the existing coaching experience (S – stretch) [41].

Discussion

Understanding generational change in a dynamic world means changing the forms of learning, especially for adults. Learning by doing, talking, and interacting with other people is becoming increasingly important, and the typical forms of academic lectures are becoming less accepted. Much of the knowledge acquired by sports coaches is acquired

⁴ The educational programme was of a mixed nature. It consisted of online self-education prior to arriving at the compulsory residential training at Japan's Nippon Sport Science University. In order to obtain an ICCE Coach Developer certificate, it was necessary to document educational practice with other coaches, consistently fill in reflection notes according to the ICCE template and guidelines. The course lasted 24 months and culminated in a certificate of competence as a coach developer according to the ICCE qualification standard.

through 'observational practice', followed by experiential learning and mentoring. Research findings confirm that sports coaches mainly learn on the job [42-44]. The process of changing behaviour and applied coaching practice in learning is particularly difficult if it is not supported and comprehensive. Coach developers have access to a number of strategies to support coach reflection and development and are able to use their skills. Effective sports coaches transform experience into knowledge through the reflection process [45]. In order to promote learning opportunities, it is therefore important to ensure that the learner-coach is more likely to be exposed to more advanced methods than shadowing and observing. The coach developer can be the one who provides optimal encouragement and learning opportunities.

The use of competent staff to act as coach developers among sports coaches will facilitate the definition and evaluation of their skills in the real context of their work. The possibility of having people with such competences in sports organisations to support coach development is a test that sports organisations will face. They (coach developers) make a concerted effort to encourage sports coaches responsibility for their own learning and professional development. This often takes the form of using mentoring techniques, which are particularly important in coach development [46].

Modern sports pose increasingly complex challenges to coaches. The pursuit of sports performance must be supported by the strengthening of capacity and, at the same time, the improvement effectiveness of physical culture staff. Duffy et al. [47, p.95] argue that "sport coaching should define its future identity as a blended professional area, operating within the wider field of sport and physical activity" [47:95]. Developing an awareness and understanding of how coaches can learn will certainly facilitate working with them most effectively. This can influence the ways in which they continue to develop and improve the learning processes for sports coaches to promote effective work with others [48, p. 209]. The need for coaches and sports scientists to work directly together in order to effectively communicate and disseminate the knowledge gained through research is emphasized. A coach needs to be able to communicate openly with sports scientists in order to understand and apply research findings efficiently.

Research contributions and limitations

The results of this study can serve as a guideline for Polish Sports Associations, sports clubs employing coaches, and educators in the sports sector in Poland. The development of education experts for the sports sector can be a response to the effective utilization of educational programs, based on informal and non-formal education. Coach developers can maximize the effectiveness of learning and avoid problems related to adult lifelong learning reluctance. Diagnosing the preferred learning methods of Olympic and Paralympic coaches surveyed can be used to develop more effective training and professional development methods for coaches in Poland. The conclusions from this work may lead to the development of a specific coach education program based on qualified coach developers, utilizing the diagnosed learning outcomes for this profession. The presented research may serve as an incentive for designing teams supporting coach development in sports organizations.

Limitations of Study

This study has limitations, such as the lack of defined skill sets that should be utilized by educators. There is a noticeable lack of standardization and consistency in educational programs between sports associations in Poland, between Olympic and Paralympic sports organizations, which can lead to uneven levels of coach preparedness. Relying solely on formal education and the absence of educators employed by sports organizations in Poland may affect the effectiveness of training and, consequently, and thus the involvement in them of the coach themselves. Therefore, we hope that the creation of a culture of lifelong learning and a thorough assessment of sports organizations' abilities to undertake such interventions becomes increasingly important. It is essential to ensure that individuals developing educational programs for coaches have knowledge of how to create high-quality coaching curricula, utilizing their prior professional experiences and established pedagogical approaches. We need sports sector educators with extensive capabilities to facilitate coach learning, who are confident in their professional knowledge.

Conclusions

Sports organizations, striving for the athletic development of their athletes, are looking for competent and capable candidates to perform assigned tasks. The development of coaches' competence should be based on the results of an open, honest, and substantive discussion of what actually improves the effectiveness of training methods. Sports organizations should ensure that their coaches have opportunities to interact with professional colleagues

and international experts as well as are familiar with established practices. Due to the benefits of informal and non-formal training courses and facilitated meetings, coach developers can effectively assist in developing their mentees' competencies. Courses and trainings should ultimately lead to new ideas and encouragement for deeper reflection on their coaching practice. However, specialized supervision and support by experts, such as coach developers, is needed for the effective development of coaches' professional competence through non-formal training and sharing best practices. Nonetheless, developing sports coaching as a profession is a complex and challenging prospect which requires solutions to be selected carefully.

Practical Implications

The experience of the Japanese Coach Developer Academy and the development of a training framework for coach developers by the International Council for Coaching Excellence [12] resulted in the implementation, also in Poland, of newly learned methods into educational programmes developed by the Coaching Academy at the Sports Institute within the National Research Institute (PiB) in Warsaw, and the development of a special training programme for representatives of Polish sports associations aimed at building specialist teams according to the methodology proposed in the Coach Developers Qualification Framework [12]. Since 2017, six courses for coach developers have been organized within the framework of the Coaching Academy of the Sports Institute within the National Research Institute (PiB). Nearly 150 people have completed the course to date. Armed with new skills, the graduates work for the benefit of the sports sector in Poland, and apply the competencies defined in the aforementioned qualification framework to contribute to the development of sports coaches with respect to their expectations and needs in this field.

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Institutional Review Board Statement: The experimental protocol and study design were approved by the local Institutional Research Ethics Committee and conducted in compliance with the Helsinki Declaration and approved by Scientific Board of the Academy of Physical Education, Warsaw, Poland (No. 50/2021/2022).

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THE PHENOMENON OF SPORT DROPOUT: INTERNAL STAKEHOLDER PERCEPTIONS

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- A. Study design/planning
- B. Data collection/entry
- C. Data analysis/statistics
- D. Data interpretation
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Abstract:

Background: At a young age, the phenomenon of abandoning sports practice is frequent. This can be attributed to various causes that, however, are not investigated in the literature. The aim of this study is to understand the perceptions of the main internal stakeholders (coaches and technical managers) with regard to the possible causes for early drop-out from football.

Methods: The sample that took part in this study consisted of 15 coaches and 12 technical managers of football schools in the province of Naples. The study made use of the following methods: analysis of scientific literature, formulation and administration of a questionnaire, and data analysis using mathematical and statistical methods. To analyze the data, the chi-square test (X²) was applied.

Results: The results showed that 86.7% of the coaches and 66.6% of the technical managers have social education as their primary goal, with a significant relationship in the perception of the two categories at $p=2.80692E-25$. Furthermore, it was found that, according to 66.7% of the coaches and 50% of the technical managers, early leaving causes insecurity in children, with a significant relationship in the perception of the two categories at $p=0.002$.

Conclusion: The study showed that, among the many possible causes of dropout, the attitude of the main internal stakeholders of football schools also has a considerable effect. This study investigated the perceptions of the main internal stakeholders of football schools, an element that other studies have neglected, focusing on other causes to address the phenomenon.

Introduction

Participation in organized youth sports is already started from an early age in Western countries. The practice of sporting activities in childhood is valued for the positive contribution it can make to the training and personal experience of children and young people. In Italy, the motor and sports sciences have been present in the academy since 2000, following the reform of the Higher Institutes of Physical Education, and are, at present, placed in the pedagogical and medical fields, as both academic disciplines are included in social and humanistic sciences and life sciences [1]. The importance of effectively supporting the development of the capacity for sensorimotor integration seems to be one of the most important objectives that every school system, and not only, should pursue. In addition to sport, the relationship between body, movement, and learning enables the acquisition of spatial, temporal, sequential, linguistic, expressive, and musical skills [2]. The motivations that drive children to participate in sports are heterogeneous, such as having fun, improving skills, making friends, or getting fit [3]. In addition, it must be admitted that sporting activities

can promote inclusion, based on the integration of people regardless of their health status. In fact, the use of physical and sporting activity is also widely used to obtain benefits in the mental aspect [4]. In other studies, it has been shown that motivation to participate can also depend on other factors such as age, gender, perceived ability, type, and level of sports skills, or influence from family, peers, and coaches [5]. It is no coincidence that a footballer's technical and tactical improvement cannot be separated from the position and attitude of his teammates and the position and behavior of opponents [6]. One of the main components that determine the quality of performance is certainly the motivation to play sports because young people love sports, mainly as an opportunity to socialize and have fun [7]. Despite these positive aspects, it is possible to note, recently, a gradual decrease in the practice of sports at an early age [8]. This phenomenon is called sports dropout, which is as intense as the premature abandonment of a sporting career, even before an athlete has been able to fully demonstrate his or her potential or before having reached peak performance. The onset of this phenomenon, which is the problem discussed in this study, is caused by both personal and situational factors, such as the difficulty of reconciling school and sport, disagreement with the coach, lack of enjoyment, the presence of injuries, poor perception of competence, the influence of other people (parents or teammates), and poor opportunities for success. A further aspect that can be considered as a causative factor of sports dropout at a young age is burnout, i.e., a psychological condition associated with feelings of physical and emotional exhaustion, reduced sense of personal fulfillment, and devaluation of sport and the sporting environment. It is, therefore, a psychological condition that makes the sporting experience difficult to sustain. In this study, particular attention is paid to analyzing the dropout phenomenon in the context of football schools. According to data reported by the FIGC (Italian Football Federation), this phenomenon is reported in 33% of football schools. The drop-out rate from sporting activity, within football schools, is much higher in the Campania region of Italy than in other regions. In fact, according to ISTAT data, in 2021, 50% of children aged 3 years and over in Campania did not practice sports or physical activity, and, in 2022, the percentage was 53.4% [9]. Considering the guidelines issued by the WHO 'Global Recommendations on Physical Activity for Health', in which it is recommended that children and adolescents engage in at least an average of 60 minutes per day of moderate to vigorous intensity physical activity, mostly aerobic, throughout the week, the percentages of children who do not engage in sport or physical activity are critical, to say the least [10]. Many football clubs face the phenomenon of young athletes dropping out early because it not only represents a loss of potential talent but can also have negative repercussions on the psychological well-being of the youngsters involved and on the economy of the football clubs themselves [11]. However, the causes of this early drop-out are often multifactorial and poorly understood. Despite the extensive literature on football, there is a lack of in-depth analysis on the phenomenon of dropout and, in particular, on the perceptions of the main stakeholders within the football sector. In particular, there are no studies that explore how coaches, managers, players, and other internal actors interpret and evaluate the dynamics and challenges within the sector in reference to sports abandonment [12]. Understanding these perceptions is fundamental to developing targeted strategies that can improve management practices, athlete well-being, and the overall effectiveness of football organizations, thus reducing the phenomenon of dropout [13]. This gap in the scientific literature highlights the need for research focused on these aspects to fill the knowledge gap and offer new perspectives on the development of professional and amateur football. The objective of this study is to understand and analyze the perceptions of key stakeholders within the football sector regarding the causes contributing to early football dropout. This study aims to identify and assess the key factors, both individual and organizational, that influence the decision to drop out of football, providing a solid basis for the development of effective preventive strategies.

Material and Methods

Study design

In order to understand the perceptions of the coaches and technical managers of the football schools in the province of Naples, Italy, with respect to all the causes that lead to the early abandonment of football, an ad hoc questionnaire was created via Google Forms and subsequently administered via e-mail and social media. The questionnaire administered to the stakeholders mentioned above consisted of 18 items, all of which were closed-ended. It was divided into three different thematic sections. The first section, containing five items, concerned gender, education, and the role played in the football school. Specifically, the questions in this section were aimed at understanding whether the role each of them played within the football school was consistent with their qualifications. The second section, consisting of 9 items, focused on the stakeholders' perception of the role each of them played. This section aimed to investigate the coaches' and technical managers' knowledge of their profession and the influence it exerts on their pu-

pils. The third and final section of the questionnaire, consisting of four items, was specifically dedicated to the central topic of the study, dropout in football. More specifically, it examined what kind of perceptions these stakeholders have regarding this issue, what consequences this phenomenon may have on children's growth, and how its occurrence could be prevented. This section also aimed to find out whether coaches and technical managers might feel in any way responsible for young children dropping out of the sport in question. A detailed description of the questionnaire administered is shown in Table 1.

Table 1. Questionnaire for coaches and technical managers of football schools in the province of Naples

Internal Stakeholders Questionnaire					
Items	Answer 1	Answer 2	Answer 3	Answer 4	Answer 5
1. Age	23-27 years old	28-32 years old	> 32 years old		
2. Gender	Male	Female			
3. Title of study	Bachelor's Degree	Master's Degree	Other qualifications		
4. Where were you trained as a coach?	UEFA C licence	UEFA D licence	UEFA B licence	UEFA A licence	
5. What role do you play within the football school?	Coach	Manager			
6. What are the characteristics a coach should have?	Teaching discipline	Be patient and understanding	Motivating commitment	Alliance with the family system	Helping to tolerate frustration
7. What value do you attribute to coach education?	Training obligation	A tool for approaching to current social needs	Knowledge of technical and tactical skills		
8. What is the main function of your evaluative action?	Selecting trainees	Knowing the capabilities of the learners	Creating individualised paths	Preventing those without quality from continuing in business	
9. Which of the following is your training principle?	Insist on intensive loading in training	Gradual approach from simple to complex	Neither of the two		
10. During your training, is the goal set?	Entertainment	Technical-individual performance	Bodily self-knowledge and development of skills		
11. What is the primary goal of a coach of a children's team?	Educating for sociality	Teach how to read the game situation	Promoting the development of technology		
12. Are the proposed trainings fun and challenging?	Always	Most of the time	Sometimes	Almost never	Never
13. In front of a child with excellent football qualities, how do you position yourself?	The subject assumes a role central in training	The subject is always assessed from a team perspective			
14. How much aspect is given to the emotional management of success and failure?	A lot	Little	Remarkable		
15. In your opinion, early abandonment what repercussions on the child's growth?	Insecurity	Refusal of sporting activity	Anxiety		

16. At the conclusion of the football year, what is most valuable?	Talent output	Technical and tactical performance of the team	Achieving a homogeneous level of preparation	Constancy in the number of members
17. Do you feel guilty about the abandonment by children?	Yes	No	Quite	
18. How to prevent the phenomenon of drop-outs?	Maintaining a constant focus on individual athletes	Constant motivation	Creating a coach-parent relationship of trust	

All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki. According to Regulation (EU) 536/2014 and Directive 2001/20/EC, research involving minimal risks to participants may be exempt from formal ethical review, as it does not involve invasive or experimental interventions. Additionally, under Legislative Decree No. 211 of 24 June 2003, research that does not pose significant risks and is solely aimed at improving educational practices might be exempt from Institutional Review Board (IRB) or Ethics Committee review and approval.

Study participants

The sample in this study consisted of 15 coaches and 12 technical managers of football schools in the province of Naples. The entire sample consisted only of male participants, with an average age between 23 and 32 years. A convenience sampling method was used and every participant was informed in detail about the research protocol and gave their written consent.

Statistical Analysis

The data collected using the questionnaire were analyzed using SPSS software. The chi-square (X²) test was applied to assess the differences in perceptions between the two stakeholder groups. The statistical significance threshold was set at p<0.05.

Results

As described above, the questionnaire is divided into three sections. The first section is depicted in Table 2.

Table 2. Results first section of the questionnaire

Results, first, 5 Items					
Items	Answer 1	Answer 2	Answer 3	Answer 4	Chi-squared
1. Age	23-27 years old	28-32 years old	> 32 years old		p= 0.0002
Coach Frequency	13	1	1		
Percentage Coach	86.6%	6.7%	6.7%		
Frequency Technical manager	2	0	10		
Percentage Technical manager	16.6%	0	83.4%		
2. Gender	Male	Female			p=6.89518E-12
Coach Frequency	11	4			
Percentage Coach	73.3%	26.7%			
Frequency Technical manager	12	0			
Percentage Technical manager	100%	0			
3. Title of study	Bachelor's Degree	Master's Degree	Other qualifications		p=0.005
Frequency (coach)	10	4	1		
Percentage (coach)	66.6%	26.7%	6.7%		

Frequency (technical manager)	1	4	7		
Percentage (technical manager)	8.4%	33.3%	58.3%		
4. Where were you trained as a coach?	UEFA C licence	UEFA D licence	UEFA B licence	UEFA A licence	p=7.85012E-05
Frequency (coach)	11	2	1	1	
Percentage (coach)	73.3%	13.3%	6.7%	6.7%	
Frequency (technical manager)	2	5	4	1	
Percentage (technical manager)	16.6%	41.7%	33.3%	8.4%	
5. What role do you play within the football school?	Coach	Manager			p=0.0002
Frequency (coach)	15	0			
Percentage (coach)	100%	0			
Frequency (technical manager)	0	12			
Percentage (technical manager)	0	100%			

The results contained in Table 2 show, in question 1, that 86.6% of the coaches were in the age range of 23-27 years, 6.7% were in the age range of 28-32 years and the remaining 6.7% were older than 32 years. With regard to technical managers, 83.4% were older than 32 years and the remaining 16.6% were in the age range of 23-27 years. The chi-square analysis showed a significance between the group of coaches and the group of technical managers at $p=0.0002$. On question 2 concerning gender, in the category of coaches, 73.3% were male, and the remaining 26.7% were female. Of the group of technical managers, 100% were male. The chi-square analysis showed a significance between the groups of coaches and technical managers at $p=6.89518E-12$. Following question 3 on educational qualifications, 66.6% of coaches had a bachelor's degree, 26.7% a master's degree and the remaining 6.7% had other qualifications. In question 3, technical managers were 8.4% with a bachelor's degree, 33.3% with a master's degree, and 58.3% with other qualifications. The chi-square analysis revealed a significance between the groups of coaches and technical managers at $p=0.005$. For question 4 'Where does your coaching education fit in?', it appears that for the category of coaches, 73.3% held a UEFA C licence, 13.3% held a UEFA D licence, 6.7% held a UEFA B licence and the remaining 6.7% held a UEFA A licence. For the technical manager category, 16.6% held a UEFA C licence, 41.7% a UEFA D licence, 33.3% a UEFA B licence and the remaining 8.4% a UEFA A licence. The chi-square analysis revealed a significance between the group of coaches and the group of technical managers at $p=7.85012E-05$. With question 5 'What role do you play within the football school?' there is identification of the sample, with 15 units making up the category of coaches and 12 units for the category of technical managers. Chi-square analysis revealed a significance between the group of coaches and the group of technical managers at $p=0.0002$. The second section of the questionnaire is presented in Table 3.

Table 3. Results of the second section of the questionnaire

Items	Results, second, 9 Items					Chi-squared
	Answer 1	Answer 2	Answer 3	Answer 4	Answer 5	
6. What are the characteristics a coach should have?	Teaching discipline	Being patient and understanding	Motivating commitment	Alliance with the family system	Helping to tolerate frustration	p=7.55261E-10
Frequency (coach)	4	2	8	1	0	
Percentage (coach)	26.7%	13.3%	53.3%	6.7%	0	
Frequency (technical manager)	5	5	2	0	0	
Percentage (technical manager)	41.7%	41.7%	16.6%	0	0	
7. What value do you attribute to coach education?	Training obligation	A tool for approaching to current social needs	Knowledge of technical and tactical skills			p=0.1

Frequency (coach)	6	3	6			
Percentage (coach)	40%	20%	40%			
Frequency (technical manager)	4	4	4			
Percentage (technical manager)	33.3%	33.3%	33.4%			
8. What is the main function of your evaluative action?	Selecting trainees	Knowing the capabilities of the learners	Creating individualised paths	Preventing those without quality from continuing in business		p=3.74218E-32
Frequency (coach)	0	11	1	3		
Percentage (coach)	0	73.3%	6.7%	20%		
Frequency (technical manager)	0	9	0	3		
Percentage (technical manager)	0	75%	0	25%		
9. Which of the following is your training principle?	Insist on intensive loading in training	Gradual approach from simple to complex	Neither			p=2.0752E-130
Frequency (coach)	0	14	1			
Percentage (coach)	0	93.3%	6.7%			
Frequency (technical manager)	1	11	0			
Percentage (technical manager)	8.4%	91.6%	0			
10. During your training, is the goal set?	Entertainment	Technical-individual performance	Bodily self-knowledge and development of skills			p=0.3
Frequency (coach)	10	0	5			
Percentage (coach)	66.6%	0	44.4%			
Frequency (technical manager)	6	0	6			
Percentage (technical manager)	50%	0	50%			
11. What is the primary goal of a coach of a children's team?	Educating for sociality	Teach how to read the game situation	Promoting the development of technology			p=2.80692E-25
Frequency (coach)	13	0	2			
Percentage (coach)	86.7%	0	13.3%			
Frequency (technical manager)	8	1	3			
Percentage (technical manager)	66.6%	8.4%	25%			
12. Are the proposed trainings fun and challenging?	Always	Most of the time	Sometimes	Hardly ever	Never	p=0.08
Frequency (coach)	5	10	0	0	0	
Percentage (coach)	44.4%	66.6%	0	0	0	

Frequency (technical manager)	4	8	0	0	0
Percentage (technical manager)	44.4%	66.6%	0	0	0
13. In front of a child with excellent football qualities, how do you position yourself?	The subject assumes a role central in training	The subject is always assessed in a team perspective			p=1
Frequency (coach)	0	15			
Percentage (coach)	0	100%			
Frequency (technical manager)	0	12			
Percentage (technical manager)	0	100%			
14. How much aspect is given to the emotional management of success and failure?	A lot	Little	Remarkable		p=0.08
Frequency (coach)	8	5	2		
Percentage (coach)	53.3%	33.4%	13.3%		
Frequency (technical manager)	6	3	3		
Percentage (technical manager)	50%	25%	25%		

The results show that in question 6 'What are the characteristics a coach should have?' 53.3% of the coaches answered 'motivate commitment', 26.7% answered 'teach discipline', 13.3% answered 'be patient and understanding', and 5% answered 'alliance with the family system'. To the same question, 41.7% of the managers answered 'be patient and understanding', another 41.7% answered 'teach discipline', and 16.7% answered 'motivate commitment'. The chi-square analysis revealed a significance between the group of coaches and the group of technical managers at $p=7.55261E-10$. To question 7 'What value do you attribute to coach education?', 40% of the coaches answered 'training obligation', another 40% answered 'knowledge of technical and tactical skills', and 20% answered 'tool for approaching current social needs'. When asked the same question, the managers were equally divided, with 33.3% each answering 'training obligation', 'knowledge of technical and tactical skills', and 'tool for approaching current social needs'. Based on the chi-square analysis, no significance was found between the group of coaches and the group of technical managers at $p=0.1$. Subsequently, to question 8 'What is the main function of your evaluative action?', for the category of coaches, 73.3% answered 'Knowing the abilities of the learners', 6.7% 'Creating individualised pathways', the remaining 20% answered 'Preventing those who lack quality from continuing in the activity', and none answered 'Selecting learners'. For the category of technical managers, 75% answered 'Know the abilities of the trainees', and the remaining 25% answered 'Avoid that those who do not have qualities continue the activity'. The chi-square analysis revealed a significance between the group of coaches and the group of technical managers at $p=3.74218E-32$. In question 9, 'Which of the following is your training principle?', for the category of coaches, 93.3% responded with 'Gradual approach from simple to complex', the remaining 6.7% answered 'Neither', and none responded with 'Insist on intensive loading in training'. For the category of technical managers, 8.4% answered 'Insist on intensive loading in training', and 91.6% answered 'Gradual approach from simple to complex'. The chi-square analysis showed a significance between the group of coaches and the group of technical managers, at $p=2.0752E-130$. For question 10 'During your training, is the goal set?', 66.6% of coaches answered 'Fun', 44.4% answered 'Body self-knowledge and skill development' and none answered 'Technical-individual performance'. In the category of technical managers, 50% answered 'Fun', the remaining 50% answered 'Body self-knowledge and skill development', and none answered 'Technical-individual performance'. The chi-square analysis showed no significance between the group of coaches and the group of technical managers at $p=0.3$. In question 11 'What is the primary goal of a coach of a children's team?' for the category of coaches, 86.7% answered 'Educating social

skills', and the remaining 13.3% answered 'Promoting the development of technique'. For the category of technical managers, 66.6% answered 'Educate on sociability', 8.4% answered 'Teach how to read the game situation', and the remaining 25% answered 'Promote the development of technique'. The chi-square analysis revealed a significance between the group of coaches and the group of technical managers at $p=2.80692E-25$. Continuing with question 12 'Are the proposed trainings fun and challenging?', 44.4% of coaches answered 'Always' and the remaining 66.6% answered 'Most of the time'. This was also the case for the category of technical managers. Based on the chi-square analysis, no significance was found between the group of coaches and the group of technical managers at $p=0.08$. To question 13 'In front of a child with excellent football qualities, how do you position yourself?', for both the category of coaches and technical managers, 100% of the sample answered 'The subject is always assessed from a team perspective'. The chi-square analysis showed no significance between the groups of coaches and technical managers at $p=1$. On question 14 'How much aspect is given to the emotional management of success and failure?' for the category of coaches, 53.3% answered 'A lot', 33.4% answered 'A little', and the remaining 13.3% answered 'Considerable'. For the category of technical managers, 50% answered 'A lot', 25% 'A little' and the remaining 25% 'Considerable'. The chi-square analysis showed no significance between the group of coaches and the group of technical managers at $p=0.08$. The third section of the questionnaire is shown in Table 4.

Table 4. Results of the third section of the questionnaire

Items	Result, third, 4 Items				Chi-squared
	Answer 1	Answer 2	Answer 3	Answer 4	
15. In your opinion, early abandonment what repercussions on the child's growth?	Insecurity	Refusal of sport- ing activity	Anxiety		$p=0.002$
Frequency (coach)	10	5	0		
Percentage (coach)	66.6%	44.4%	0		
Frequency (technical manager)	6	3	3		
Percentage (technical manager)	50%	25%	25%		
16. At the conclusion of the football year, what is most valuable?	Talent output	Technical and tactical training of the team	Achieving a level homogeneous level of preparation	Constancy in the number of members	$p=7.64485E-18$
Frequency (coach)	0	2	12	1	
Percentage (coach)	0	13.3%	80%	6.7%	
Frequency (technical manager)	0	4	6	2	
Percentage (technical manager)	0	33.4%	50%	16.6%	
17. Do you feel guilty about the abandonment by children?	Yes	No	Quite		$p=2.07096E-06$
Frequency (coach)	1	11	3		
Percentage (coach)	6.7%	73.3%	20%		
Frequency (technical manager)	1	4	7		
Percentage (technical manager)	8.4%	33.3%	58.3%		
18. How to prevent the phenomenon of drop-outs?	Maintaining a constant focus on individual athletes	Constant motivation	Creating a coach-parent relationship of trust		$p=7.13126E-05$

Frequency (coach)	2	4	9
Percentage (coach)	13.3%	26.7%	60%
Frequency (technical manager)	1	4	7
Percentage (technical manager)	8.4%	33.3%	58.3%

To question 15 'In your opinion, what repercussions does early leaving have on the child's growth?' 66.7% of the coaches answered 'insecurity', and 33.3% answered 'refusal of sporting activity'. To the same question, 50% of the technical managers answered 'insecurity', and the remainder was divided equally between 'refusal of sporting activity' 25% and 'anxiety' 25%. The chi-square analysis revealed a significance between the group of coaches and the group of technical managers at $p=0.002$. To question 16 'At the conclusion of the football year, what is most valuable?' for the category of coaches, no one answered 'Exit of talents', 13.3% answered 'Technical and tactical formation of the team', 80% answered 'Reaching a homogenous level of preparation' and the remaining 6.7% answered 'Constancy of the number of members'. For the category of technical managers and the same question, no one answered 'Exit of talents', 33.4% answered 'Technical and tactical training of the team', 50% answered 'Reaching a homogenous level of preparation' and the remaining 16.6% answered 'Constancy of the number of members'. The chi-square analysis revealed a significance between the group of coaches and the group of technical managers at $p=7.64485E-18$. A different perception between coaches and managers can be seen in question 17 'Do you feel guilty about children dropping out?', with 73.3% of the coaches answering 'No', 6.7% answering 'Yes' and the remaining 20% answering 'quite a lot'. While 58.3% of the technical managers answered 'Quite', 33.3% answered 'No', and the remaining 8.4% answered 'Yes'. The chi-square analysis revealed a significance between the group of coaches and the group of technical managers at $p=2.07096E-06$. Finally, to question 18 'How do you prevent the drop-out phenomenon?', 60% of the coaches responded with 'Create a coach-parent relationship of trust', 26.7% with 'Constant motivation' and the remaining 13.3% with 'Keep the focus on individual athletes constant'. For the category of technical managers, 58.3% responded with 'Create a coach-parent relationship of trust', 33.3% with 'Constant motivation' and the remaining 8.4% with 'Maintain constant focus on individual athletes'. The chi-square analysis revealed a significance between the group of coaches and the group of technical managers, at $p=7.13126E-05$.

Discussion

The results of the present study provide a detailed analysis of the perceptions of coaches and technical managers regarding the causes of early drop-out in youth football, identifying significant differences in their opinions and characteristics. These results are consistent with previous research, which highlighted how various individual and organizational factors can influence the drop-out phenomenon in youth sports [14]. The analysis revealed significant demographic differences between coaches and technical managers. Most coaches were in the age group of 23 to 27 years, whereas technical managers tended to be older than 32 years. This age difference might influence their perspectives and approaches to coaching, as suggested by some studies indicating that experience and age can play a crucial role in coaching strategies and understanding athletes' needs [15]. The gender distribution was also significantly different between the two groups, with a greater female presence among coaches than among technical managers. The existing literature highlights how gender differences can influence coaching dynamics and athletes' expectations, leading to different approaches in team management [16]. Coach education plays a key role in the quality of sports experience of young athletes [17]. Data show that coaches tend to have a lower level of education than technical managers, with a prevalence of three-year degrees and lower-level UEFA licences (C and D). Literature suggests that more advanced training is often correlated with a greater awareness of the psychological and social dynamics that influence youth sports participation and could contribute to more effective strategies to prevent drop-out [18]. A critical aspect that emerged from the study is the perception of the causes of early drop-out. Both coaches and technical managers recognized the importance of creating a trusting relationship between coach and parent as the main strategy to prevent drop-out, in line with the literature that highlights the essential role of communication and cooperation between the adult figures involved in the young athlete's education [19]. However, there is a significant divergence in the perception of guilt regarding dropout, with technical managers showing a greater tendency to feel responsible. This could reflect a greater awareness of technical managers of the impact of their decisions and organi-

zational dynamics on the experience of young athletes [20]. The differences in training preferences between coaches and technical managers suggest distinct approaches to athlete training [21]. Coaches emphasize the motivational aspect and fun, while technical managers may have a more performance-oriented and discipline-oriented vision. These differences could be explored further to understand how to better balance the competitive and educational aspects to reduce the risk of dropout [22]. Among the main studies, it is possible to mention Esposito et al., who in 2024 demonstrated the reduction of dropouts in football practice, through the strengthening of motivation, acting on the variation of the formation, and on the inclusive and collaborative skills of the team [23]. Another study, by Molinero et al., verified the reasons for abandonment, in a large sample of young Spanish athletes, in relation to their gender, participation in individual or team sports, and the level of competition achieved at the time of abandonment [24].

Limitations of the study

The main limitation of this study is the small sample size. With larger numbers, it would have been possible to obtain more variability in the answers and, consequently, a more complete view of the perceptions regarding the causes of early dropout in youth football. Another limitation is the lack of randomness of the sample. A more random sampling would have reduced possible bias, e.g. other internal stakeholders such as boys and families, who were not considered. In any case, the usefulness of this work lies in attempting to investigate the perceptions of individuals considered to be the main internal stakeholders of football schools and to understand how much their perceptions may influence participation and/or dropout in the sport, an element that other studies have neglected, focusing on other causes.

Conclusions

The contribution that sporting activity makes to people, especially in the developmental age group, is of considerable importance. Considering the numerous benefits it brings at a psychophysical level, it is therefore necessary to take action to remove the obstacles to practicing sports. In this study, it was found that the attitudes of the main internal stakeholders of football schools exert a considerable influence on whether or not children take part in the activity. It is relevant that coaches focus a lot on the emotional and motivational aspects of each individual and less on the technical and tactical aspects, for two reasons: firstly, because the training process is different for athletes and among team sports, and secondly because, in the current context, the coach has become a qualified professional figure, who must possess all-round skills. This consideration is also supported by the Sports Reform of 28 February 2021, through Legislative Decree No. 36, which legally recognized the profession of the sports kinesiologist (commonly coach). This professional is given responsibility for the proper conduct of physical and sporting activities, the protection of well-being, and the promotion of healthy lifestyles. The coach must be able to observe and understand the needs of young players, evaluate their shortcomings and qualities, and subsequently help define the goals necessary to set the training course. At this juncture, managers will also have to play their part, i.e., recruit competent and qualified professionals. To help produce more experienced coaches in terms of participation and performance, many governing bodies have set up coach mentoring systems.

Practical Implication

In practice, to effectively tackle the drop-out phenomenon, it would be crucial to provide continuous and specialized training for coaches, including studies on psychological and motivational aspects in the management of athletes. Another winning strategy could be greater involvement of families, through the organization of regular meetings, since the relationship of trust between coach and parent is recognized as a key factor in preventing sports drop-out. In addition, a more balanced approach between performance and educational orientation is proposed, introducing variable training sessions according to the needs of young people

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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QUALITATIVE EXERCISES BASED ON ENERGY SYSTEMS TO DEVELOP SOME PHYSIOLOGICAL INDICATORS AND PASSING AND SHOOTING SKILLS IN JUNIOR HANDBALL PLAYERS

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Authors' contribution:

- A. Study design/planning
- B. Data collection/entry
- C. Data analysis/statistics
- D. Data interpretation
- E. Preparation of manuscript
- F. Literature analysis/search
- G. Funds collection

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Abstract:

Background: Handball is one of the sports that involves a large number of positional changes and skills; in addition to that, and from a physiological point of view, it relies on supply of energy, both anaerobic and aerobic. The aim of this study was to prepare qualitative exercises based on energy systems to develop some physiological indicators and passing and shooting skills in junior handball players and evaluate the effect of specific exercises based on energy systems on the improvement of physiological indicators and passing and shooting skills in junior handball players.

Methods: The participants were 20 youth athletes from the Kiwan Sports Club during the 2022–2023 season in Iraq. They were randomly divided into two groups with the same number of participants. The experimental group followed the proposed training program, which was based on prepared-specific exercises according to energy systems, and the control group followed the regular training program implemented by the coach. The proposed program lasted eight weeks, with three training sessions per week, each lasting 120 minutes.

Results: The training programs had a significant main effect on the tested physiological indicators and basic handball skills ($p < 0.05$), with a large effect size. The percentage of improvement ranged from 3.04 to 55% for the program prepared by the coach and from 8.24 to 90.48% for the program with specific energy-system-based exercises. The t-values ranged from 2.641 to 4.788, indicating a significant difference between the two training programs ($p < 0.05$), favoring the experimental group.

Conclusions: Both groups showed improvements in physiological indicators and passing and shooting skills in young handball players. A better development in these areas was found in junior handball players from the experimental group.

Introduction

The revolution in science and technology has had an impact on the training sector in recent years. As a result, the training process has evolved to adopt a shape, structure, and organization that aligns with the latest advancements in training techniques and resources. With the goal of attaining and maximizing training specificity based on the type of activity, coaches must select the best and most recent methods that fit the specialized activity to improve physical, occupational, planning, psychological, and mental skills. Handball is one of the most popular sports and holds a good position because it is an interesting game requiring players to master both offensive and defensive skills. Further-

more, the use of modern training methods and organized and codified training based on scientific foundations has led to the advancements in sports performance across various disciplines, while training young athletes in this developmental stage is as crucial as training in any other sport [1]. Furthermore, one of the most crucial principles of sports physiology that is utilized in the sports world is the coach's awareness of how the body's different organs respond and adapt to training loads [2], which is reflected in the identification of the physiological markers of sports training to develop training techniques that minimize stress and help accomplish the desired results. The ability to produce energy in handball depends on two factors: (1) anaerobic capacity, which refers to the muscle's ability to function in the absence of oxygen during high-intensity periods of effort, with the performance duration ranging from 3–1 minutes for the lactic acid regimen and from 70–5 seconds for the ATP–CP system, and (2) aerobic capacity, which means the muscle's efficiency in oxygen consumption. This ability is important for sustained performance throughout the match, which can sometimes take more than an hour. This requires the preparation of training programs for athletes based on modern scientific methods to achieve optimal performance [3]. An active role in training should emphasize the player's ability to control the ball in various positions and directions, which is essential for achieving the best results in handball [4]. The specificity of training sessions is expected to correspond to differences in training loads experienced by players. Naturally, the behaviors observed during the training drills emphasize different locomotor patterns in players, depending on their everyday actions and roles [5]. Due to the variable nature of training sessions, it is important to pay special attention to fluctuations in the load imposed on players [6].

The study by Massuça, Fragoso, and Teles [7] confirmed that morphological characteristics, physical fitness, handball-specific skills, and psychological and physical characteristics are important to being successful in handball [7]. Determining the physical profiles of young handball players enables the assessment of strengths and weaknesses in areas relevant to performance and the design of specific and focused training models to improve performance [8]. The study of Mohamad and Choo [9] revealed that training in coordination, dynamic balance, and agility has positive effects on adolescent handball players [9]. Korkmaz and Polat [10] concluded that measuring the maximal respiratory exchange ratio values of athletes during incremental exercise may provide information about physiological adaptations in response to physical training [10]. According to Ketema [11], university students' physiological characteristics significantly improved after eight weeks of low-intensity interval training [11]. The findings of the study conducted by Shanta and Ajita [12] indicated a significant effect of endurance training on the anaerobic threshold and blood lactate concentration in Bangladeshi female handball players [12]. From a physiological perspective, handball is a sport that relies on both aerobic and anaerobic energy sources. In this sport, players perform quick muscle contractions and high-speed throws over distances of 15 to 30 meters before returning to the game and performing at medium to low intensity. Furthermore, the lack of focus on physiological exercises results in fatigue, which impairs the player's performance. Therefore, the aim of this study was to develop qualitative exercises based on energy systems to enhance some physiological indicators and passing and shooting skills in junior handball players and to evaluate the effects of specific exercises based on energy systems to improve these areas. This research hypothesizes that 'Specific exercises based on energy systems have a positive effect on developing some physiological indicators and passing and shooting skills in junior handball players.

Materials and Methods

Participants

The participants were chosen by the purposive sampling method from the youth athletes in the Kiwan sports during the 2022–2023 season in Iraq. A total of 20 youth athletes were included in the study (age: 17.23 ± 2.60 years, body height: 177.05 ± 2.6 cm, body mass: 65.43 ± 4.26 kg). The participants were randomly divided into two groups with the same number of participants. The experimental group followed the proposed training program based on specific exercises based on energy systems, and the control group followed the regular training program implemented by the coach. All participants were informed about the study's design and protocol prior to its commencement. None of them reported having any previous injuries. Then, they provided written informed consent before undergoing testing. The study protocol was approved by the ethics committee of Al-Kitab University, and all procedures followed the ethical standards of the Declaration of Helsinki for research involving human subjects. There were no significant differences between the groups in terms of some anthropometric measurements, physiological abilities, or handball skills before the training programs were implemented ($p > 0.05$).

Research Design

The research employed an experimental research design using a two-group pretest-posttest approach (Figure 1) with a limited number of participants [13]. The participants were tested at baseline and after exposure to six weeks of training. The participants were instructed not to engage in any other types of physical interventions that could influence the sole effect of the programs. The pre-test was conducted before the start of the training programs, whereas the post-test was performed after the completion of the eight-week programs.

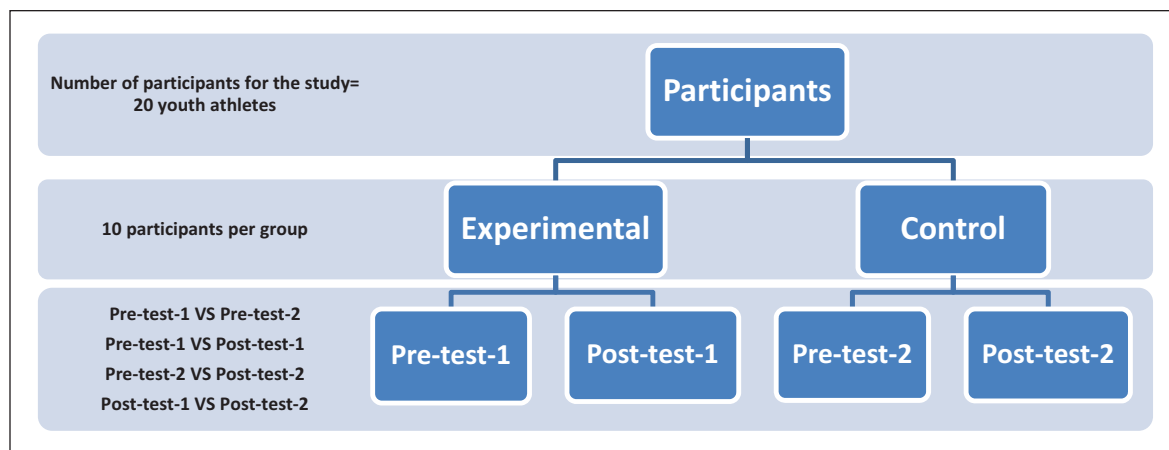


Figure 1. Flow of the experiment.

Tests used in the research

A form was designed to determine the most important physiological indicators and basic handball skills along with their respective tests. This form was presented to a group of experts to gather their opinions on the validity of these indicators. Based on their feedback, the following tests were used in the research: vertical jump test (Sargent test) [14], step test for anaerobic capacity, Harvard test [15], shooting accuracy test performed from the base of the head at target squares (50 × 50), shooting accuracy test performed by jumping high to shoot at target boxes (50 × 50), shooting accuracy test performed from the front drop position at target boxes (50 × 50), hand whip passing from above the head in a circular shape from 4 m away for 30 sec, head-level passing whip handle on an oval drawn on a 30 sec wall [16- 19]. The validity of the tests ranged from 0.87 to 0.96, while their reliability ranged from 0.82 to 0.90.

Qualitative exercises protocol

The authors prepared specific exercises based on energy systems and drawing from scientific reviews and the opinions of some experts in the fields of sports training, physiology, and handball. In developing them, the authors took into account the research sample, the tools used, the method of implementation, and the surrounding conditions, ensuring that the exercises effectively targeted the studied variables. The exercises used in the curriculum focused on developing energy systems and their capabilities through the application of the prepared training program, and the curriculum included the following components:

- The curriculum used during the special preparation period was applied to the experimental group, while the control group followed the curriculum prepared by their coach.
- The curriculum used included 24 training sessions, with three sessions per week, spanning a total duration of 8 weeks.
- The duration of the training unit was 120 minutes, and the course part was in the main section of the training sessions (20–30 minutes), which is the period during which the special exercises were applied.

The authors ensured a gradual progression in the application of the training method used to ensure success, as the increase in the training load must occur at intervals to allow for functional adaptation [20]. The contents of the training were the exercises used in terms of size, intensity, and comfort. The authors relied on some scientific sources as well as personal interviews and the opinions of experts and specialists in the science of sports, physiological training, and handball training. The intensity ranged from maximum to sub-maximal, maintaining a work-to-rest ratio of 1:2. Rest periods were set according to the energy systems to allow for the recovery to be sufficient for starting the next exercise [21].

Statistical Analysis

The statistical processing was performed using the Statistical Package for the Social Sciences (SPSS) for Windows, version 22.0 (IBM Corp., Armonk, NY, USA). The percentages were calculated, and the analysis also included means, standard deviations, the correlation coefficients, the paired sample t-test, and the independent sample t-test. Statistical significance was set at $p < 0.05$. For the purpose of using practical significance tests to complement statistical significance tests, the effect size was calculated [22]. Practical differences were assessed by calculating Cohen's d effect size (ES) [23- 24]. The magnitudes of the t-test results were classified as follows [25]: 0.2–0.5 (small effect), 0.5–0.8 (moderate effect), > 0.8 (large effect).

Results

The mean pre- and post-program results for the tested physiological indicators and basic handball skills for the control and experimental groups are presented in Table 1. A significant main effect of the training programs was found for the study indicators ($p < 0.05$). Large ES values were also found for differences in study indicators between pre- and post-program results (prepared by the coach). ES values ranged from 2.943 to 6.957, as the percentage improvements ranged from 3.04-55%. Large ES values were observed for differences in the study indicators between pre- and post-program results (energy-system-specific exercises), with ES values ranging from 4.685 to 28.66 and the percentage improvements ranging from 8.24 to 90.48%.

Table 1. Study variables (mean \pm standard deviation, T value, effect size and percentage of improvement) in the pre- and post-programs of the experimental and control groups

Group	Tests	Pre-test	Post-test	R (p)	T (p)	Effect size	Magnitude	Improvement (%)
Control								
	Vertical jump test (for Sargent)	55.8 \pm 3.61	60.6 \pm 2.99	0.74(0.014)*	6.22(<0.001)**	3.934	Large	8.60
	Step test of anaerobic capacity	451 \pm 18.25	464.7 \pm 17.44	0.87(0.001)**	4.653(0.001)**	2.943	Large	3.04
	Harvard test	64.8 \pm 2.57	68.4 \pm 1.65	0.68(0.032)*	6(<0.001)**	3.795	Large	5.56
	Shooting from the base of the head on the shooting accuracy squares (50x50)	2.4 \pm 0.70	3.2 \pm 0.63	0.80(0.005)**	6(<0.001)**	3.795	Large	33.33
	Jumping high to shoot on the accuracy boxes (50x50)	2.6 \pm 0.52	3.5 \pm 0.53	0.82(0.004)**	9(<0.001)**	5.692	Large	34.62
	Shooting from the front drop on the Shooting accuracy boxes (50x50)	2 \pm 0.47	3.1 \pm 0.57	0.83(0.003)**	11(<0.001)**	6.957	Large	55
	Hand whip passing from above the Head in a circular shape 4m away for 30 sec	13.3 \pm 1.89	17.2 \pm 2.39	0.70(0.025)*	7.134(<0.001)**	4.512	Large	29.32
	Head-level passing whip handle on an oval drawn on a 30 sec wall	15.2 \pm 2.94	18 \pm 2.67	0.92(<0.001)**	7.799(<0.001)**	4.933	Large	18.42
Experimental								
	Vertical jump test (for Sargent)	56.4 \pm 4.48	64.9 \pm 4.12	0.65(0.043)*	7.408(<0.001)**	4.685	Large	15.07
	Step test of anaerobic capacity	448.9 \pm 16.27	485.9 \pm 17.88	0.72(0.02)*	9.033(<0.001)**	5.713	Large	8.24
	Harvard test	63.3 \pm 2.58	72.8 \pm 2.39	0.95(<0.001)**	35.35(<0.001)**	22.357	Large	15.01
	Shooting from the base of the head on the shooting accuracy squares (50x50)	2.1 \pm 0.57	4 \pm 0.47	0.83(0.003)**	19(<0.001)**	12.017	Large	90.48
	Jumping high to shoot on the accuracy boxes (50x50)	2.7 \pm 0.67	4.5 \pm 0.53	0.78(0.008)**	13.5(<0.001)**	8.538	Large	66.67

Shooting from the front drop on the Shooting accuracy boxes (50×50)	2.5 ± 0.85	4 ± 0.82	0.80(0.005)**	9(<0.001)**	5.692	Large	60.00
Hand whip passing from above the Head in a circular shape 4m away for 30 sec	12.4 ± 1.84	19.8 ± 1.99	0.97(<0.001)**	45.316(<0.001)**	28.660	Large	59.68
Head-level passing whip handle on an oval drawn on a 30 sec wall	16.1 ± 3.28	22.5 ± 3.47	0.95(<0.001)**	18.827(<0.001)**	11.907	Large	39.75

Significant difference between Pre-test Vs Post-test: ** p < 0.01, * p < 0.05

The independent sample t-test was employed to determine whether either of the two training programs had a more robust effect than the other on the participants' study indicators (Table 2). The t-values ranged from 2.641 to 4.788, indicating a significant difference between the two training programs (p < 0.05) in favor of the experimental group. Large ES values were found for differences in the study indicators, ranging from 1.181 to 2.141.

Table 2. Study variables (mean ± standard deviation, T value, and effect size) in the post-program of the control and experimental groups

Tests	Control	Experimental	T (p)	Effect size	Magnitude
Vertical jump test (for Sargent)	60.6 ± 2.99	64.9 ± 4.12	2.671(0.016)*	1.194	Large
Step test of anaerobic capacity	464.7 ± 17.44	485.9 ± 17.88	2.684(0.015)*	1.201	Large
Harvard test	68.4 ± 1.65	72.8 ± 2.39	4.788(<0.001)**	2.141	Large
Shooting from the base of the head on the shooting accuracy squares (50×50)	3.2 ± 0.63	4 ± 0.47	3.207(0.005)**	1.434	Large
Jumping high to shoot on the accuracy boxes (50x50)	3.5 ± 0.53	4.5 ± 0.53	4.243(<0.001)**	1.897	Large
Shooting from the front drop on the Shooting accuracy boxes (50×50)	3.1 ± 0.57	4 ± 0.82	2.862(0.01)**	1.280	Large
Hand whip passing from above the Head in a circular shape 4m away for 30 sec	17.2 ± 2.39	19.8 ± 1.99	2.641(0.017)*	1.181	Large
Head-level passing whip handle on an oval drawn on a 30 sec wall	18 ± 2.67	22.5 ± 3.47	3.25(0.004)**	1.454	Large

Significant difference between two the groups: ** p < 0.01, * p < 0.05

Discussion

It is evident from the analysis of the preceding tables and presentation that there was progress in the control and experimental groups regarding the development of handball players' passing and shooting skills as well as improvement of physiological markers. The players' consistency and regular training, along with the coach's consistent approach, were identified by the authors as key factors contributing to the growth observed in the control group [26]. Expert agree that, regardless of their scientific and practical background, "if the training program is built on a scientific basis in organizing and programming the training process, using appropriate and gradual intensity, noticing individual differences, as well as using optimal repetitions and effective inter-rest periods under the supervision of specialized and under good training conditions in terms of place, time, and tools used, then it will inevitably lead to greater performance" [27].

The authors attribute the significant development in the performance of the experimental group in the tests to the special exercises that the authors used to enhance aerobic capacity: the use of anaerobic exercises has been shown to contribute to improvements in aerobic capacity [28- 30]. Since the applied curriculum contains anaerobic exercises, which led to the development of aerobic capacity, the importance of special exercises was limited by the fact that they work hand in hand with good technique to enhance performance during various sporting events [31]. This provides unambiguous scientific evidence supporting the relationship between workouts and players' engagement in the development of their competitive performance. According to the authors, one of

the most crucial physical attributes required for performing tasks involving the vertical jumps, such as shooting and jumping, is explosive power. The development of explosive power leads to an increase in vertical jump height [32]. In the majority of sports activities that require the vertical jump, explosive power takes precedence among the physical abilities [33].

To the best of our knowledge, this study is the first to examine the effects of specific exercises based on energy systems on the development of physiological indicators and passing and shooting skills in junior handball players.

Limitations of the Study

This study has some limitations. Specifically, long-term physiological effects should be monitored, and the sample size should be increased to obtain more reliable results. Future research should aim to address these limitations.

Conclusions

Both groups showed improvements in physiological indicators and passing and shooting skills in young handball players. Greater improvements in the experimental group in both physiological indices and skill execution were also observed. The time required for skill development was reduced by using qualitative exercises that were designed to mimic motor patterns and muscle functioning.

Practical Implications

Therefore, we recommend the implementation of a qualitative exercise method to evaluate physiological indicators and the skills of young handball players. Periodic tests of special physiological indicators should be conducted at regular intervals when implementing training curricula. Using field-based tests will facilitate performance monitoring by coaches and athletes without resorting to complex and costly laboratory tests.

Conflict of Interest: The authors declare no conflict of interest.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of Al-Kitab University (approval No. 2, 10.01.2023).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Upon request, the data presented in this study are available from the corresponding author.

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