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Areas of physical education and specialist roles sensitive to contemporary social demands

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Abstract

Contemporary social transformation requires schools to be innovative in order to meet new educational demands. The main objective of the research was to collect the opinion of physical education specialists, primary and secondary school teachers, in relation to an updated proposal for areas of educational intervention and consequent roles to be assumed. The sample consisted of 209 physical education specialists as part of a descriptive mixed design study. A quantitative Likert-scale questionnaire was used to evaluate the 5 areas and 5 roles proposed. Pearson's correlations for the scores of both scales in relation to the total scores of the questionnaire were positive and strong ($r_{questionnaire\text{-}area}$ = .884, p < .001 and $r_{questionnaire\text{-}roles}$ = .858, p < .001), and the overall reliability of the items was good (α = 0.756). In addition, 30.6% of the sample (64 participants) voluntarily completed a qualitative narrative opinion questionnaire. In all areas and roles, the maximum score was chosen most frequently, with Physical Activity and Health (77.99%) and Teaching (86.6%) standing out respectively. No statistical significance was obtained in relation to gender or years of teaching experience, but the areas were sensitive to educational stage. Accordingly, the narrative responses revealed positive perceptions of the proposed areas and roles. Despite the emergence of new contemporary responsibilities in the discipline, specialists continue to focus on physical education that promotes physical activity and health from the perspective of teaching responsibility.

Keywords: corporeality, motor literacy, physical activity and health, physical activity and learning, sport and society.

Introduction

The epistemological definition of physical education has been a subject of specialist debate regarding subjective understanding of its content and how best to deliver it (Depaepe et al., 2013). The subject has focused more on methodology than on clearly defined content, often not specifying what is to be learned, but rather implying it through vaguely defined objectives (Nyberg & Larsson, 2014). From a holistic perspective, if the learner does not connect meaningfully with the content, their learning is diminished (Dyson, 2014). Following Cañabate et al. (2018), today's schools should base learning on motor skills, cognition, empathy and emotional security. Through interdisciplinary projects incorporating dance and the arts, physical education would enhance creativity. On the other hand, if subject matter is reduced to motor behaviour alone, without touching on the essential disciplines that ensure a comprehensive understanding of human movement (physiology, pedagogy, history, sociology...), specialists will not advance a cultural reflection that gives meaning to practices (Backman & Barker, 2020).

The *International Charter of Physical Education, Physical Activity and Sport* (UNESCO, 2015a) introduced gender equality, non-discrimination and social inclusion, as well as the sustainability of sport. In parallel, *Quality Physical Education* (UNESCO, 2015b) emphasised that physical education should promote lifelong participation and that teaching should be entrusted to qualified staff. Quality physical education that ensures literacy and civic engagement, academic achievement, social inclusion which overcomes stereotypes, and the development of organic health, is underpinned by an emphasis on ethical values.

The study *Making Physical Education Dynamic and Inclusive for 2030* (OECD, 2019), which analysed physical education curricula in 18 countries, highlighted 4 areas of intervention: games and sports (individual and team), outdoor recreation and leisure activities, motor skills, dance and rhythmic expression and health and wellbeing content.

The recent *European Sports Charter* (European Council, 2021) stressed that human beings have the inalienable right to access sport in a healthy environment, both inside and outside schools. Physical education and sport are essential for personal development, as they guarantee rights to health, education, culture and participation in community life. Epistemologically, physical education should be aimed at sports practice, motor literacy and physical fitness, with the objective of acquiring basic motor skills and adequate performance in accordance with one's own abilities.

In the United States, the National Association for Sport and Physical Education (NASPE) launched the *Comprehensive School Physical Activity Programs (CSPAP)* in 2008 to promote physical activity starting in elementary school. The program, revised in 2013 by the Society of Health and Physical Educators (SHAPE America), encouraged quality physical education and the promotion of school physical activity in order to reinforce the academic objectives of the subject. Particularly aimed at public health, the program recommended 60 minutes of moderate-vigorous physical activity per day for children and adolescents (Elliott et al., 2022), although the effectiveness of its implementation demonstrated moderately optimistic results. Mattson et al. (2020) demonstrated the positive effects of a CSPAP promoting physical activity at school after 36 weeks.

Successive changes in the Spanish state's competency-based education system since 2006 have shaped curricula in terms of the applicability of knowledge and its transversality. In the 2007-2022 period, physical education was organised in very stable content blocks, such as physical fitness and health, corporal expression, sports and outdoor recreational physical activities. However, although the latest curriculum revision (Department of Education, 2022) maintains a strong focus on active and healthy lifestyles, it reduces the emphasis on sport and corporal expression to accommodate for more current content on emotional management and the sustainability of practice spaces.

The above literature review provides a framework for defining the proposal areas. "Motor literacy" has been understood as the acquisition of motor skills allowing people to interact successfully in their natural and social environment (Edwards et al., 2017), while physical education aims to reclaim a corporeality outside of dualistic traditions (González & Sepúlveda, 2021). Neuroscience has emphasised that physical activity is a privileged framework for learning, highlighting the cognitive demands implicit in motor activity (Pesce et al., 2016). Sport values education through multiple gestural and tactical situations does not occur in simple practice, but in pedagogical impact, which gives it meaning (Philpot et al., 2021). Finally, the abundant evidence of the health benefits of regular physical activity in adolescence (Julian et al., 2022) necessarily establishes the school as the optimal setting for its promotion (Bentsen et al., 2022).

Along these lines, competence-based curriculum decrees have emphasised the importance of physical activity guidance and promotion in schools. At state level, the previous Royal Decree 1105/2014 (art. 6, *transversal elements of the curriculum*) emphasised that physical activity and a balanced diet had to become habits for pupils. Schools needed to promote the daily practice of sport and physical exercise during the school day, following the

recommendations of the relevant bodies. Unfortunately, it was specified that the design of the measures to be applied should be the responsibility of teachers with the appropriate specialisation, without explicit reference to a Physical Education specialist. Recently, in Catalonia, Decree 175/2022, on basic education (Annex 1, *Key competences and exit competences profile*), highlights the challenge of developing healthy lifestyle habits based on an understanding of the functioning of the body.

In order to define a physical education sensitive to contemporary social demands, the main objective of this article was to ask specialists their opinions in relation to a proposal for areas of educational intervention in line with the reference documents consulted, whilst also emphasising their role in their implementation. Secondary objectives were to find out whether this assessment would be significantly different according to gender, years of teaching experience and educational stage.

Methodology

The study used a descriptive cross-sectional mixed methods research design, which integrates a primarily quantitative approach with a complementary qualitative approach (Creswell & Plano, 2017). This has been found to be fully adequate in physical activity and sport science research (Castañer et al., 2013).

Participants

The non-probabilistic purposive sample consisted of 209 Physical Education specialists in Catalonia. The outreach for participation was carried out by the College of Physical Activity and Sport Professionals of Catalonia (COPLEFC), which centralised and organised the requests for presentations to the groups that showed interest (universities, associations, congresses and schools). All participants answered the quantitative part of the survey, and only 64 participants (30.6%) answered the qualitative part. In relation to gender, there were 129 male participants (62.2%) and 79 female participants (37.8%). Regarding years of teaching experience, the majority of the participants had more than 12 years of experience (59.1%). In terms of professional stage, 124 participants were primary school teachers (59.3%) and 85 were secondary school teachers (40.7%).

The required ethical principles were ensured by explaining the study to all participants in advance, obtaining their informed consent and guaranteeing the protection of their personal identity. COPLEFC itself promoted the research through a university scientific collaboration project.

Procedure

15 face-to-face presentations were scheduled in different parts of Catalonia, only 11 of which took place due to the compulsory COVID-19 lockdown. From then on, data collection was carried out virtually. The face-to-face data collection followed a 45-minute presentation explaining the project, the promoting institution and, in particular, encouraging specialist participation to validate the proposal. This was done using links to the questionnaires on mobile phone or laptops. Following the lockdown, the questionnaires were made available online, accompanied by a video explaining the project, and a videoconference open to all interested parties was organised.

Resources

Two *ad hoc* questionnaires were designed. A quantitative one, based on a Likert scale, and a qualitative one that asked for personal reasoning in relation to the items assessed. In order to finalise the two questionnaires and guarantee the validity of the content, successive modifications were made to improve the original questionnaire based on the information gathered in the pilot test carried out at the Pedagogical Resources Centre in Badalona with the participation of 50 Physical Education specialists, and on the basis of the opinion of 3 experts (2 Physical Education Pedagogy university teachers and an inspector from the Department of Education with the same speciality).

Quantitative Questionnaire. This consisted of three distinct parts. The first part collected personal information: gender, professional stage and years of teaching experience. The second part assessed the areas of educational intervention in physical education, and it consisted of five items: motor literacy, corporeality, physical activity and learning, sport and society and, finally, physical activity and health. The third part assessed the role of Physical Education specialists, a category which also consisted of five different items: organising and teaching, promoting a vision of the school from the perspective of the body, promoting and advising on multidisciplinary actions, promoting physical activity in school and, finally, ensuring the proper guidance of physical activities.

A Likert scale with a range of five options, ranging from 1 "Strongly disagree" to 5 "Strongly agree", was used to record the responses. Cronbach's α statistic was applied to measure the reliability or internal consistency of all items. Taking values of .70 as "acceptable" and values of .80 as "good" (Navarro & Foxcroft, 2019), the reliability of the questionnaire as a whole, taking into account all 10 items, was considered good ($\alpha = .756$).

Qualitative Questionnaire. In order to support the participants' critical reasoning, the qualitative part of the assessment followed the quantitative questionnaire, so that they were already familiar with the items. It consisted of two open-ended questions asking for an overall written assessment of the five areas of educational intervention and specialist roles, by means of the following text: *"Please give an overall assessment of the approach to the areas of intervention (or the specialist roles). Please set out your main ideas, highlight the most relevant areas and make any suggestions for improvement that you think are relevant."*

Statistical Analysis

Quantitative analysis was carried out using the freely available statistical program Jamovi, version 2.2.5. Although the Likert scale minimises differences between the response options so that a quantitative analysis can be applied, this article will treat the items as categorical variables, calculating the statistics as frequency tables. Concepts such as "motor literacy", "corporeality" and "holistic content" are essentially qualitative in nature.

The 10 items were subjected to univariate multi-category analysis. The χ^2 Chi-square_Goodness Of Fit Test was used to verify whether the observed frequency corresponded to the expected frequency. This test requires the assumption of sufficiently high expected frequencies, higher than 5, or 80% of expected frequencies higher than 5. As the lowest Likert ratings did not reach the minimum frequency, the variables had to be recategorised into three definitive items that fulfilled the statistical assumption of the test: the observed frequencies of values 1 and 2 were added to value 3 for each item. From this recategorisation, identical expected frequencies were sought for each of the three items (.333), and a 95% confidence interval.

Moreover, each of the 10 items was also subjected to a bivariate analysis in relation to gender, years of teaching experience and the professional stage of the participants. In this case, the Bivariate_Chi Squared Test of Association was used and the variable "years of teaching experience" had to be recategorised. From the five categories presented in the questionnaire (0-3, 4-6, 7-9, 10-12 and 12+ years of experience), the statistical analysis was synthesised into 3 categories: 0-6, 7-12 and 12+. A 95% confidence interval was sought. Where there was statistical significance, the effect size or strength of association was calculated using Cramer's V statistic, ranging from 0 (none) to 1 (perfect).

Finally, Pearson's correlation coefficients were applied between the total scores of the quantitative questionnaire and the specific scores of both scales (areas of intervention and specialist roles).

The qualitative analysis of the content of the written responses was carried out using a double deductive-inductive approach. On the one hand, answers to the open-ended question on areas of educational intervention were analysed using the five items as previously established categories. On the other hand, answers to the open-ended question on specialist roles were analysed using an inductive approach in which the categories were derived from the textual data analysed.

Results

Statistical Results

When applying the χ^2 Chi-square_Goodness Of Fit Test to both the variables "areas of educational intervention" and "specialist roles", statistically significant differences were found in the assessments of all items (Table 1).

Table 1
χ^2 Chi-square_Goodness Of Fit Test

Areas of Intervention	χ^2 (2)	*p*
Motor Literacy	73.9	.001*
Corporeality	42.7	.001*
Physical Activity and Learning	77.1	.001*
Sport and Society	76.3	.001*
Physical Activity and Health	194	.001*
Specialist Role	**χ^2 (2)**	***p***
Teaching	268	.001*
School and Corporeality	24.2	.001*
Holistic Actions	30.0	.001*
Promoting Physical Activity	183	.001*
Physical Activity Guidance	96.9	.001*

Note: * Significant differences $p < .01$

For all intervention area items, the maximum score on the Likert scale (5) was the most frequent choice, and scores were above 50% in all cases: Physical Activity and Health (77.99%), Physical Activity and Learning (60.3%), Motor Literacy (58.9%), Sport and Society (57.42%) and Corporeality (51.2%). Similarly, in all the specialist role items, the maximum score on the Likert scale (5) was the most frequent choice, ordered as follows: Teaching (86.6%), Promoting Physical Activity in Schools (76.56%), Proper Guidance of Physical Activities (63.16%) and, lastly, the only two items that did not reach 50%, School and Corporeality and Holistic Actions, both chosen with the same frequency (45.5%).

When applying the Bivariable_Chi Squared Test of Association, significant associations were only found between gender and the item School and Corporeality (χ^2 (2) = 8.53; p = .014), and between educational stage and 4 intervention area items: Motor Literacy (χ^2 (2) = 11.1; p = .004), Corporeality (χ^2 (2) = 6.74; p = .034), Sport and Society (χ^2 (2) = 13.1; p = .001), and Physical Activity and Health (χ^2 (2) = 6.97; p = .031). In contrast, the other item in this block, Physical Activity and Learning, was not significant (Table 2). For all statistically significant items, Cramer's V was used to consider the strength of the association, and it was weak in all cases (Gender – Corporeality and School = .202; Educational Stage and Motor Literacy = .231; Educational Stage and Corporeality = .180; Educational Stage and Sport and Society = .251 and Educational Stage and Physical Activity and Health = .183).

Overall, the bivariate analysis demonstrated that there was no statistical significance in relation to gender (except for the item School and Corporeality alone) and years of teaching experience. The items from the areas of educational intervention did reveal sensitivity to the educational stages of the specialists.

Pearson's correlation matrix revealed strong positive ratings between the total scores of the questionnaire and the scores of each scale ($r_{questionnaire\text{-}area}$ = .884, p < .001 and $r_{questionnaire\text{-}roles}$ = .858, p < .001).

Qualitative Analysis

Analysis of the qualitative responses allowed for a more in-depth exploration of the participants' views on the proposal presented. Consistent with the quantitative assessments, the narrative responses revealed positive perceptions of the areas of intervention and roles.

With reference to the areas of intervention, the need for holistic and cross-cutting implementation was highlighted. Participants emphasised the complementarity of the five items ("All 5 areas of PE intervention are equally important and complement each other" - Participant 25), and their application as fundamental learning for the participant ("Above all, I agree on life-sustaining PE" - Participant 22).

The value of coordinated work between different disciplines was highlighted. In this sense, the importance of physical education being supported by other areas of learning was emphasised ("I personally believe that it is important to work on all areas of PE and that they should simultaneously be worked on from other areas in order to reinforce the importance of PE in children of all ages" - Participant 27). However, they highlighted the potential for PE to complement the acquisition of learning in other areas ("I consider PE as an area capable of intervening in different areas of our children's learning, not only in aspects related to motor skills" - Participant 54). The emotional competences of the participant were also emphasised: "I would add the body and emotions" -

Table 2
Bivariate χ^2 Chi Squared Test of Association

	Gender		Years of Teaching Experience		Educational Stage	
Areas of Intervention	χ^2 (2)	P (Cramer's V)	χ^2 (4)	*p*	χ^2 (2)	*p*
Motor Literacy	5.92	.052	0.389	.983	11.1	**.004*** (V=.231)
Corporeality	1.87	.393	3.78	.436	6.74	**.034*** (V=.180)
Physical Activity and Learning	1.94	.378	2.95	.566	2.16	.340
Sport and Society	0.712	.701	3.33	.504	13.1	**.001*** (V=.251)
Physical Activity and Health	2.96	.227	0.647	.958	6.97	**.031*** (V=.183)
Specialist Role	χ^2 (2)	*p*				
Teaching	5.96	.051	3.97	.410	0.526	.769
School and Corporeality	8.53	**.014*** (V=.180)	6.29	.179	4.40	.111
Holistic Actions	2.51	.285	0.198	.995	1.93	.381
Promoting Physical Activity	0.165	.921	2.91	.573	3.65	.161
Physical Activity Guidance	1.64	.441	5.53	.238	0.947	.623

Note: * Significant differences p < .05. Cramer's V is applied to establish the strength of the association.

Participant 46, and "I see the introduction of a new field as interesting. This area would aim to provide students with psychological resources, empowerment, self-knowledge, emotion management, conflict management, social cohesion, etc." - Participant 32.

Some participants highlighted the need for general awareness-raising ("I feel that there is little awareness of the power of learning and therefore we should raise awareness among the general public, but especially among professionals themselves" - Participant 20); and that specific to the school ("The mentality of teaching staff should be changed into one that is more holistic" - Participant 44).

The need for joint critical reflection among all physical education professionals was also identified ("I think it is important to be aware that, as PE professionals, we have a specific literacy, and it is often very biased and limited" - Participant 17); as well as the need to unify criteria within the discipline itself ("Not having some basic common lines of work for each course doesn't help either... An academic body on which to rely. The competences are very general and everyone does what they can. That doesn't happen in other subjects" - Participant 12).

With regard to specialist roles, the qualitative inductive analysis allowed the participants' responses to be grouped into two categories. Firstly, participants gave an overall positive assessment of specialist roles. A tendency to prioritise the task "of organising and delivering teaching" as the main task from which actions related to other tasks could be derived was identified ("Organising and delivering teaching in the area of PE is our priority. The other areas of intervention contribute to the first objective" - Participant 11). However, a perception of the specialist as an active agent in education was defended: physical activity and physical education are not the same. In this sense, the importance of perceiving the specialist as a professional who transforms the local and social reality was highlighted ("To promote the link between the school and the social environment with a transforming, critical and humanist will" - Participant 17).

Secondly, responses aimed at conveying the need to recognise and value the role of physical education specialists were identified. The position currently occupied by a single professional in relation to other professionals is perceived as an impediment to the satisfactory development of competences ("You may want to do a lot, but if no one follows your lead, you are on your own" - Participant 21). In line with this, some answers emphasise the importance of professionals being involved and trained in order to guarantee a quality discipline ("For me it is paramount, it is the need for good professionals who dignify the profession and who embody it with the passion and energy necessary for this paradigm shift" - Participant 10). As can be observed in the responses, the role of the specialist must be defended both by professionals themselves ("Teachers must try to make their work visible and not make it appear as though anyone could do it" - Participant 49) and by the organisation of the school ("We cannot allow the basketball monitors, for example, in our schools to be CSE students with no training whatsoever" - Participant 64).

Discussion

With regard to the main objective of the study, it can be affirmed that physical education specialists rate the 10 proposed items as absolutely correct, all of them of statistical significance and coherently aligned with the demands of the main international organisations (UNESCO, 2015 a and b; OECD, 2019; Council of Europe, 2021).

However, despite attempts to modernise the subject, the focus remains on teaching and physical activity for health. In fact, based on the frequency of the maximum score on the Likert scale, the most highly rated area is Physical activity and Health, 17.69% above the preferred learning framework. The most prominent role continues to be Teaching, 10.1% above Promoting Physical Activity in Schools. One might consider that PE is still not very responsive to demands (Kirk, 2012), with the most innovative areas being less valued.

The overwhelming acceptance of physical activity for health reinforces recognition of the subject, which includes the roles of health promotion and guidance (Romero et al., 2021). Schools increase physical activity at break time, incorporate restorative periods of physical activity for the body and promote active travel from home (Mahar et al., 2006). Although most curricula include health-related competences, studies reveal little evidence of the impact of physical activity covered in the subject on the total exercise of adolescents (Arboix et al., 2022).

The high value placed on physical activity as a privileged framework for learning and its importance in motor literacy stands out. In this sense, positive evidence of physical activity on executive functions and memory has been reported (Álvarez et al., 2017). In parallel, the correct acquisition of movement patterns contributes to body awareness, self-fulfilment, expressiveness and social relationships (Edwards et al., 2017).

Sport is surprisingly undervalued even in qualitative assessments. Sport constantly appears in mass media, but not always reflecting exemplary behaviour (Shields et al., 2018). A sport culture is necessary for practitioners and consumers in order to implement the values that characterise sport in everyday life (Wallhead et al., 2020).

Corporeality represents the great unknown in schools, and scores the lowest, a remarkable fact given the participants were specialists. The dualist school does

not consider motor activity to be intellectual education and keeps it separate from classically cognitive subjects. In contrast, new trends establish the body as the core of emotional intelligence managed through motor practice (Quin et al., 2017). The new PE competency curriculum in Catalonia (Department of Education, 2022) focuses on emotional education linked to corporeality, which revalues an integral definition of human individuality, and this is echoed in the study's own qualitative assessments.

On the other hand, the lack of defined areas is problematic for the more academic specialists. Poorly defined areas of intervention mean that each specialist interprets these areas subjectively and that educational proposals can be highly variable. Academic specialists would like to see improved specification of content, which would facilitate stronger collaborative work, because all participants would employ similar narratives (Decorby et al., 2005).

The fact that teaching is the responsibility of specialist teachers at secondary level, and that at primary level generalist teachers assume responsibility for it, can create dysfunctions in the pedagogical approach. Qualitative approaches highlight the teacher's own responsibility to raise the prestige of the social recognition of the subject, which is usually regarded skeptically in terms of its contribution to social demands (Viscione et al., 2019). A good example is the call to link school and society from a humanistic perspective. In this sense, García et al. (2023) highlighted that the promotion of values is a critical factor in the role of teachers, which encourages coexistence, emotional development and the integral achievement of a healthy lifestyle.

Although the current education system emphasises interdisciplinary projects, holistic content receives the worst rating. In contrast, the qualitative reflections of specialists insist on promoting interdisciplinary activities that mix several fields and create connections between physical education and other subjects, which would reinforce transversality (Solà, 2021).

In relation to the secondary objectives, it is concluded that the areas of educational intervention are neither gender-sensitive nor sensitive to years of teaching experience. On the other hand, they are sensitive to educational stage, representing different expectations among teachers and professors (D'Elia, 2019). This is particularly significant given the new curricula mention a joint basic education that brings together both primary and secondary education (Jones & Green, 2017). Specialist roles are not very sensitive to the variables analysed, and gender differences are only revealed in relation to the item Corporality. In fact, the variable years of teaching experience proved to be insignificant, although 59.1% had more than 12 years of experience.

Conclusions

Following a mixed methods design, the unanimous acceptance of the areas of intervention and the consequent roles to be assumed by physical education specialists has been demonstrated, with Teaching and Physical Activity for Health standing out respectively. Despite the current system of competency-based education, holistic proposals still need to be strengthened, along with the treatment of corporeality and emotional education at school. It has been demonstrated that the areas of intervention are sensitive to educational stage, but no differences have been found in terms of gender or years of teaching experience. This suggests that the areas of intervention should be reconsidered in order to ensure that they are universal to primary and secondary school stages.

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The experience of LGB students in Physical Education: exploring the Spanish context

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Abstract

Despite legal advances and greater respect for LGTBI individuals, their experience in the education system is still problematic, as they suffer discrimination of various kinds. This homophobic school environment is even more intensified in Physical Education, given the peculiarities of this subject, particularly due to its technical focus and affinity for sports content with a high emphasis on hegemonic masculinity. The aim of this study was therefore to collect data on students' recollection of their experiences, with particular attention to harassment in the educational context, participation in the subject of Physical Education, and their preferences in terms of content. To this end, an online questionnaire was used to collect data from 989 people, 47.5% of whom were gay, 21.3% lesbian, 18.6% bisexual and the remaining 12.5% heterosexual. The results showed a higher perception of harassment among LGB students than among heterosexual students (mostly verbal), especially among gay students, who displayed very negative results in almost all the items analysed. Gay students also reported that they were not chosen for activities and did not use the changing rooms at the end of class sessions, compared to their lesbian or heterosexual peers. In view of these results, it can be concluded that it is necessary to address all forms of harassment, as well as to refocus the subject in order to accommodate the obvious diversity of the student body. A critical stance towards teachers' decisions and more teacher training seems relevant today.

Keywords: discrimination, diversity, harassment in the educational context, heteronormativity, homophobia, teacher training.

Introduction

Legal protection for individuals with diverse affective-sexual orientation and gender identity has improved across various fields in Spain in recent decades (Piedra et al., 2014). These legislative advances, among other factors, have led to an increase in the visibility of the LGTBI (lesbian, gay, transgender, bisexual, intersex) community in various socio-cultural contexts, which has in turn attracted interest as a research phenomenon (Córdoba, 2021; Landi et al., 2020).

However, despite legislative advances, discrimination against members of the LGTBI community persists, and this reality is one of the most common reasons for hate crimes in Spain (Spanish Ministry of the Interior, 2021). The main cause of this state of affairs is the heteronormative discourse that is maintained in most social institutions (López Corlett et al., 2021), as well as in sport (Rovira-Font & Vilanova-Soler, 2022). The term "heteronormativity" refers to the privileged position of heterosexual culture in Western societies, naturalising its dominance and rendering individuals of sexual dissent invisible, categorising them as abnormal (Warner, 1991). Thus, heteronormativity is a form of social surveillance that leads to discrimination and subalternity of those who do not conform to heterocentrism, creating barriers, oppression and inequality for non-heterosexual individuals (Madureira & Branco, 2015). Moreover, it conditions gender expectations in such a way that it shapes stereotypical expressions of femininity and masculinity, resulting in different implications for men and women in sport (Lenskyj, 2013; Soler-Prat et al., 2022).

Heteronormativity is deeply embedded in various social institutions, and schools are unfortunately not immune to its influence (Dornelles & Dal'Igna, 2015; Wilkinson & Pearson, 2009). Thus, schools assume that students are heterosexual and forcibly reject those who do not conform to hegemonic gender and sexuality standards (Madureira & Branco, 2015; Prado & Ribeiro, 2016). Multiple publications linking schooling to LGB (lesbian, gay, bisexual) students have shown that they are one of the minority groups that experience the highest levels of violence, harassment and discrimination in educational institutions (Birkett et al., 2009; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2019). Findings from a meta-analysis by Toomey & Russell (2016) on the role of sexual orientation in school victimisation indicate that sexual minorities experience higher levels of victimisation during primary and secondary school compared to their heterosexual peers. This data is in line with the state of affairs in Spain, as shown by Elipe et al. (2018).

Heteronormativity is more prevalent in Physical Education (PE) than in other subjects (Clarke, 2012; Hortigüela-Alcalá et al., 2022; Larsson et al., 2011; Lynch et al., 2022). This is due not only to gender separation in the development of the curriculum (Clarke, 2012), which is especially prevalent in other countries, but also to the reinforcement of male and female stereotypes provided by sport-related PE (Devís-Devís et al., 2005; Sánchez-Hernández et al., 2022). Furthermore, the subject consistently harbours negative attitudes towards the wider LGB group, due to the reproduction of heteronormative values and conservative attitudes that are exclusionary, hostile and sexist (Ayvazo & Sutherland, 2009; Landi et al., 2020; Larsson et al., 2011; Sáenz-Macana & Devís-Devís, 2020). However, within the LGB community, it has been demonstrated that lesbian students' experiences tend to be less negative than those of gay students (Landi et al., 2020; Müller & Böhlke, 2023).

In this sense, the strong influence of sport-based activities in PE promotes hegemonic masculinity and those activities in which adolescent and young men tend to excel (Gill et al., 2010; lisahunter, 2019). Femininity, by contrast, is relegated to the background in PE, where teaching is not oriented towards female adolescents and non-hegemonic students (Berg & Kokkonen, 2022; Forestier & Larsson, 2023).

From this perspective, homophobia stemming from heteronormativity affects not only LGB students, but also all male adolescents who challenge conventional gender stereotypes, by threatening to demean them with the status of "faggots" or "pussies" (De Stéfano, 2017). On the other hand, women who excel in PE classes are considered "tomboyish" and "macho" (Devís-Devís et al., 2005). As a result, LGB and even non-hegemonic heterosexual students have cause to fear harassment or discrimination, which may result in their exclusion and marginalisation in the context of PE (De Stéfano, 2017). In this regard, it is pertinent to note how the use of homophobic comments and insults in PE is recurrent, as well as the use of hurtful and offensive words with sexual connotations (Gill et al., 2010; Piedra et al., 2013). In the case of female students specifically, lesbian students tend to experience these insults more because of their status as women than because of their sexual orientation (Müller & Böhlke, 2023).

The consequences of this homophobic environment are significant for the conduct of PE. Thus, the latest National School Climate Surveys carried out in the United States by the Gay, Lesbian and Straight Education Network (GLSEN) state that the percentage of LGTBI students who avoid PE classes because they feel uncomfortable or unsafe has steadily increased from 31.9% in 2013 to 40.2% in 2019 (Kosciw et al., 2013; Kosciw et al., 2020). In the UK context, data indicate that 14% of LGB students

feel harassed during PE lessons (Bradlow et al., 2017). Specifically in Spain, a statewide study that analysed the reality of LGB students in educational institutions found that homophobic harassment leads 43% of students to consider suicide, more than half (56%) to do so continuously, and 27% to do so on a sustained basis over time (Generelo, 2012). In relation to PE, Piedra et al. (2013) reported homophobic behaviour, data that has recently been corroborated by Hortigüela-Alcalá et al. (2022).

In other words, the school environment which LGB students experience is one of constant teasing, insults and exclusion (De Stéfano, 2017). Homophobic harassment is considered to be prolonged aggression over time, carried out with the intention of harming the victim, by one or more schoolchildren in an imbalanced power relationship, where the victim has difficulty defending him/herself and is, to a certain extent, helpless in the face of those who harass him/her (Olweus, 1998).

In this context, the power and influence of schools in shaping the character and personality of students is considerable. As such, it is essential that the education system and teachers take measures to eliminate the barriers, discrimination and homophobic harassment that LGB students still suffer (Hortigüela-Alcalá et al., 2022; Piedra et al., 2014); and it is a priority for PE to stop reinforcing the heteronormative framework. Despite this state of affairs, the experience of LGB students in the Spanish context has not received the academic attention it deserves. It is therefore important to carry out research that sheds light on the situation, hence the relevance of this study, which aims to collect and interpret the experiences of LGB students in PE, comparing them with their heterosexual peers, and looking especially at types of harassment, frequency, participation and content preference.

Methodology

Participants

A total of 1,659 people, aged 18-74, from different regions of Spain participated in this study. The data were collected during 2019 and 2020 and are part of a larger project designed to assess LGTBI people's experiences in different contexts of their daily lives. Of the total number of participants, 670 were eliminated for: a) not answering the questions of interest; b) identifying as transgender, non-binary, or cisgender with a sexual orientation other than homosexual (gay or lesbian), heterosexual or bisexual. Therefore, the final sample consisted of 989 participants, with a mean age of 33.5 years (SD = 11.1; range: 18-74) (Table 1). For the comparative purposes of this work, all individuals were cisgender and 4 subgroups were established according to sexual orientation: lesbian, gay, bisexual and heterosexual. While there is a fair distribution in relation to the number of male and female participants, there are differences in representation according to sexual orientation. The largest group is gay (47.5%), twice as many as lesbians (21.3%) and bisexuals (18.6%). The heterosexual group was the smallest (12.5%), as the survey was mainly aimed at the LGTBI community.

Materials and Resources. Procedure

To collect data, an online questionnaire was created in LimeSurvey (version 2.73.1+), with different psychosocial questions related to the experiences of LGTBI individuals. For the purposes of this study, data were only collected on recall questions related to harassment experienced in the educational context, as well as to the type of harassment (physical, verbal, gestural, material or cyberbullying), and to various experiences in the subject of PE throughout schooling.

Table 1
Participants in the study (n = 989).

	Female	Male	Total
	n (%)	*n* (%)	*n* (%)
Lesbian	211 (21.3)	-	211 (21.3)
Gay	-	470 (47.5)	470 (47.5)
Bisexual	144 (14.5)	41 (4.2)	185 (18.7)
Heterosexual	76 (7.7)	47 (4.8)	123 (12.5)
Total	431 (43.5)	558 (56.4)	989 (100)

Harassment refers to aggression from others that ranges from nuisance to serious abuse and may be intimidating and/or an affront to personal dignity. In relation to PE experiences, answers were recorded using a Likert scale on the frequency of certain experiences (1- Never to 5- Always); and the degree of agreement with different statements (1- Strongly disagree to 5- Strongly agree). For example, questions were asked about the use of changing rooms, strategies for avoiding or participating in the subject, and about the methodological strategies applied by the teaching staff. There were also questions about the content they found most enjoyable in PE lessons, with a choice between sports, games, corporal expression, outdoor activities, fitness and health or none at all.

As in a previous study (Devís-Devís et al., 2022), the sample was accessed mostly through ~200 Spanish LGTBI activist associations, which are committed to preventing discrimination, promoting visibility and protecting their rights. These associations were sent an email explaining the purpose of the study and containing a link for them to forward to their members and staff.

The questionnaire, which was completely anonymous and voluntary, was also disseminated through posts on social media (e.g. Twitter and Facebook). The materials and procedures were approved by the Ethics Committee of the Catalan Sports Council (023/CEICGC/2021), as part of a joint project between research groups from different institutions, to guarantee ethical principles in social research on human beings. The informed consent form authorising the research team to publish the data collected was signed online by the participants prior to accessing the questionnaire.

Data analysis

Data was analysed using IBM SPSS Statistics 28.0. The statistical analysis consisted of calculating frequencies and percentages and Chi-square tests of independence to reveal the existence of significant differences ($p < .05$) according to the sexual orientation of the sample among the study variables. Corrected standardised residuals were calculated to identify categories with significant differences (± 1.96). To determine the effect size, Cramer's V was used as a measure of the strength of association, where ≥ .1, ≥ .3 and ≥ .5 represent a weak, moderate or strong association, respectively.

Results

Harassment in the Educational Context

Table 2 shows the percentages of harassment experienced by the whole sample and according to their sexual orientation. Globally, 48.9% of the population have experienced harassment at some point in their lives and 39.9% have experienced harassment in an educational context. Within this context, the most common form of harassment is

Table 2
Harassment experienced by participants on the basis of their sexual orientation.

	Entire sample	Lesbians	Gays	Bisexuals	Heterosexuals	X^2	*p*	*Cramer's V*
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)			
Harassment	473 (48.9)	100 (48.3)	**279 (60.1)**	79 (43.6)	**15 (12.9)**	87.505	**<.001**	.297
Harassment in the Educational Context	386 (39.9)	**66 (31.9)**	**251 (54.1)**	61 (33.7)	**8 (6.9)**	100.145	**< .001**	.322
Physical Harassment in the Educational Context	120 (12.4)	**9 (4.3)**	**91 (19.6)**	20 (11)	**0 (0)**	51.310	**< .001**	.230
Verbal Harassment in the Educational Context	327 (33.8)	**46 (22.2)**	**222 (47.8)**	52 (28.7)	**7 (6)**	95.378	**< .001**	.314
Gestural Harassment in the Educational Context	300 (31)	**45 (21.7)**	**199 (42.9)**	51 (28.2)	**5 (4.3)**	78.273	**< .001**	.284
Material Harassment in the Educational Context	72 (7.4)	6 (2.9)	**49 (10.6)**	17 (9.4)	**0 (0)**	23.091	**< .001**	.154
Cyberbullying in the Educational Context	60 (6.2)	8 (3.9)	33 (7.1)	**18 (9.9)**	**1 (0.9)**	12.656	**.005**	.114

Corrected standardised residuals ± 1.96 in bold.

verbal, followed by gestural, physical and, to a lesser extent, material or cyberbullying. In relation to sexual orientation, significant differences have been found among all types of harassment. Heterosexual students always exhibit lower percentages (in some cases non-existent, such as for physical or material harassment in the educational context) compared to the rest of the subgroups with a LGB sexual orientation. Whilst in the case of general harassment, there are differences between heterosexual and gay students (47 percentage points more), for harassment in the educational context (and all subtypes except cyberbullying), differences can be seen between heterosexual students (who experience it the least), lesbian students (who experience it to some extent) and gay students (who experience it the most). Finally, in relation to cyberbullying, there are differences between bisexual students (9.9%) and heterosexual students (only 0.9%).

Experiences in Physical Education

Analyses carried out to identify differences in participating students' experiences in PE (discrimination, harassment and/or avoidance) on the basis of their sexual orientation were significant for all but one item (preference for Corporal Expression content) (Table 3). The differences seen are always between LGB individuals and heterosexual individuals, demonstrating that discrimination, harassment and avoidance of the subject always affected LGB individuals more than heteronormative students. The group with the most negative experiences is gays, who have very negative results for almost all items. On the other hand, the data obtained from lesbian students is very similar to, or even more positive in some cases, than that reported by heterosexuals.

What was happening in the changing rooms?

In relation to use of changing rooms, 31.1% of gay students never used them at the end of sessions, compared to 17.9% of heterosexual students. Furthermore, whilst almost 65% of heterosexual students always, or almost always, undress in front of their classmates, this percentage does not exceed 48.1% in the case of LGB students.

Who avoided PE the most?

In general, LGB individuals were more likely to give excuses or reasons for avoiding PE compared to their heterosexual peers, although there were exceptions. For example, the percentages of heterosexual students (76.4%) and lesbian students (71.6%) who never faked an injury to avoid the subject are significantly higher than for gay students (59.4%) or bisexual students (56.2%). Forgetting equipment was also another strategy to avoid doing PE that is statistically significant among lesbians, gays and bisexuals. 3.8% of gay students reported using this technique always, or almost always, while 28.9% of lesbian students and 45.9% of bisexual students used it from time to time. Among those who started sessions, there was also a percentage who gave up and finished before the end of those sessions. This strategy was significantly more used from time to time by gay students (45.5% of cases recorded) than by lesbian students (26.5% of cases recorded). However, some of the participants in this study preferred to avoid facing PE teachers by opting to play truant and not attending classes in person. In this regard, there are differences between those who played truant from time to time, namely gay students (27.9% of cases recorded) and lesbian students (14.7% of cases recorded). Furthermore, in relation to percentage participation in excursions and extracurricular activities related to PE, while 74.8% of heterosexual students and 72.5% of lesbian students attended practically all the time, percentages for this item are reduced to 65.9% for bisexual students and 44.9% for gay students. All these absences and strategies used to avoid participating in the subject could have some influence on the failure rates reported by the sample studied. While 84.3% of heterosexual and 82.9% of lesbian students never failed PE, for gay students the percentage was 64.9%. In fact, for 31.1% of students, it was usual for them to fail PE from time to time.

How did teaching practice influence students?

There are also methodological aspects concerning the pedagogical practices implemented by PE teachers that discriminated against LGB individuals. Teachers were less likely to select gay students than heterosexual or lesbian students for demonstrations of the activities. Specifically, 25.2% of heterosexual students and 23.2% of lesbian students report that they have always, or almost always, been chosen, compared to 6.8% of gay students. In this regard, 37% of gay students stated that they were never chosen. In addition, differences are also found among the students themselves when it comes to volunteering for demonstrations. In this sense, 39.8% of heterosexual students and 37% of lesbian students always, or almost always, volunteered themselves, whilst only 18.7% of gay students did so. Finally, there are also differences in relation to being among the last people chosen when teams were formed (either by teachers or by peers themselves). Whilst this was never the case for 39.3% of lesbian students and 38.5% of heterosexual students, the percentage drops to 13.2% for gay students. In fact, 34.5% of gay students experienced this unpleasant situation always or almost always.

Table 3
Differences in the frequency of experiencing various situations in Physical Education according to students' sexual orientation.

	Lesbians			Gays			Bisexuals			Heterosexuals			X^2	*p*	*Cramer's V*
	Never	Rarely/ Sometimes	Almost always/ Always	Never	Rarely/ Sometimes	Almost always/ Always	Never	Rarely/ Sometimes	Almost always/ Always	Never	Rarely/ Sometimes	Almost always/ Always			
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)			
Changing rooms															
I washed myself in the schools' changing rooms at the end of each session	52 (24.6)	75 (35.5)	84 (39.8)	**146 (31.1)**	156 (33.2)	**168 (35.7)**	40 (21.6)	71 (38.4)	74 (40)	**22 (17.9)**	37 (30.1)	**64 (52)**	17.525	**.008**	.094
I got undressed in front of my classmates in the schools' changing room	47 (22.3)	**73 (34.6)**	91 (43.1)	121 (25.7)	134 (28.5)	215 (45.7)	54 (29.2)	42 (22.7)	89 (48.1)	**14 (11.5)**	29 (23.8)	**79 (64.8)**	25.556	**<.001**	.114
I avoided PE															
I faked some kind of injury	**151 (71.6)**	**56 (26.5)**	4 (1.9)	**279 (59.4)**	**169 (36)**	22 (4.7)	**104 (56.2)**	70 (37.8)	11 (5.9)	**94 (76.4)**	**28 (22.8)**	1 (0.8)	25.409	**< .001**	.113
I forgot to bring the right equipment and clothing	**149 (70.6)**	**61 (28.9)**	**1 (0.5)**	275 (58.5)	177 (37.7)	**18 (3.8)**	**96 (51.9)**	**85 (45.9)**	4 (2.2)	79 (64.2)	43 (35)	1 (0.8)	22.845	**< .001**	.107
I played truant to skip the class	**175 (82.9)**	**31 (14.7)**	5 (2.4)	**319 (67.9)**	**131 (27.9)**	20 (4.3)	129 (69.7)	49 (26.5)	7 (3.8)	97 (78.9)	25 (20.3)	1 (0.8)	21.428	**.002**	.104
I did not finish the session	**154 (73)**	**56 (26.5)**	**1 (0.5)**	**234 (49.8)**	**214 (45.5)**	22 (4.7)	114 (61.6)	63 (34.1)	8 (4.3)	78 (63.4)	40 (32.5)	5 (4.1)	38.091	**< .001**	.139
I failed PE as a subject	**175 (82.9)**	**31 (14.7)**	5 (2.4)	**305 (64.9)**	**146 (31.1)**	19 (4)	136 (73.5)	38 (20.5)	11 (5.9)	**102 (84.3)**	**18 (14.9)**	1 (0.8)	38.515	**< .001**	.140
I participated in excursions and extracurricular activities organised by PE	**16 (7.6)**	**42 (19.9)**	153 (72.5)	**90 (19.1)**	**169 (36)**	**211 (44.9)**	23 (12.4)	**40 (21.6)**	**122 (65.9)**	**7 (5.7)**	**24 (19.5)**	**92 (74.8)**	72.718	**< .001**	.192
Methodological Aspects															
I was selected by the teachers to demonstrate the activities	**39 (18.5)**	123 (58.3)	**49 (23.2)**	**174 (37)**	264 (56.2)	**32 (6.8)**	56 (30.3)	103 (55.7)	26 (14.1)	20 (16.3)	72 (58.5)	31 (25.2)	66.819	**< .001**	.184
I volunteered to participate in the demonstrations proposed by the teachers	**36 (17)**	97 (46)	**78 (37)**	**154 (32.8)**	228 (48.5)	**88 (18.7)**	50 (27)	96 (51.9)	39 (21.1)	18 (14.6)	56 (45.5)	49 (39.8)	52.249	**< .001**	.163
I was the last person chosen when teams were formed	**83 (39.3)**	103 (48.8)	**25 (11.8)**	**62 (13.2)**	246 (52.3)	**162 (34.5)**	45 (24.3)	100 (54.1)	40 (21.6)	47 (38.5)	63 (51.6)	12 (9.8)	99.594	**< .001**	.225
Stereotypes and Preferences in PE															
People referred to me in a derogatory way using terms like "faggot" or "tomboy"	92 (43.6)	92 (43.6)	27 (12.8)	**148 (31.5)**	**253 (53.8)**	**69 (14.7)**	**94 (50.8)**	73 (39.5)	18 (9.7)	**96 (78)**	**27 (22)**	**0 (0)**	94.704	**< .001**	.219
I was very involved in content related to team sports	**21 (10)**	**50 (23.7)**	**140 (66.4)**	**115 (24.5)**	**244 (51.9)**	**111 (23.6)**	30 (16.2)	69 (37.3)	86 (46.5)	16 (13)	**35 (28.5)**	**72 (58.5)**	132.515	**< .001**	.259
I was very involved in content related to corporal expression	38 (18)	101 (47.9)	72 (34.1)	108 (23)	246 (52.3)	116 (24.7)	35 (18.9)	88 (47.6)	62 (33.5)	18 (14.6)	63 (51.2)	42 (34.1)	12.412	.053	.079

Corrected standardised residuals ± 1.96 in bold.

Insults

With regard to verbal harassment experienced in PE on the grounds of sexual orientation, there are significant differences between students. When observing the reality of students who have never received insults, the percentage varies according to whether students define themselves as gay (31.5%), bisexual (50.8%) or heterosexual (78%). In fact, no heterosexual individual claims to have always, or almost always, received insults.

Preferences for specific content

Finally, in relation to involvement in specific content in PE classes, significant differences emerge in content related to group sports, but not in corporal expression. Specifically, 66.4% of lesbian students report always, or almost always, being involved in team sports compared to 58.5% of heterosexual students and 23.6% of gay students. Similarly, the chi-square test carried out to analyse the most enjoyable PE content according to the sexual orientation of the students (Table 4) demonstrated significant differences ($X^2_{(15)} = 49.094$, $p < .001$, Cramer's V = .226). The corrected typed residuals indicated that Sports was a more enjoyable content area for lesbian and heterosexual students (59.6 and 49.6%, respectively) than for gay students (16.5%). Furthermore, the highest percentage preference for Games content was obtained by gay students (28.1%), compared to lesbian students (13.9%) and heterosexual students (10.9%). Corporal expression content was least enjoyed by lesbian students (only chosen by 4.8%) and Outdoor activities was chosen more frequently by gay students (27.7%) compared to lesbians (only 12%). With regard to Physical fitness and health, no differences were obtained according to the comparison group. Finally, the highest percentage who chose "none at all" for most enjoyable content in PE lessons were gay students, specifically 7.8%.

Discussion

In general terms, although both students and teachers perceive the environment in Spanish schools as calm (De Stéfano, 2017), some qualifications should be made in this respect. Thus, several studies and other reflective texts have pointed to PE as a subject that promotes masculine values associated with sport, relies on heteronormativity and creates a context that does not respect sexual diversity (Clarke, 2012; Gill et al., 2010; Hortigüela-Alcalá et al., 2022; Larsson et al., 2011; Sáenz-Macana & Devís-Devís, 2020). As such, in one way or another, the homophobic environment marginalises LGTBI students and makes their experiences associated with this subject less than rewarding (Hortigüela-Alcalá et al., 2022; Kosciw et al., 2020; Lynch et al., 2022). However, when taking sexual orientation as a reference point, the findings of previous studies have been corroborated, wherein lesbian students have less hostile experiences in PE (Müller & Böhlke, 2023) and in sport settings (Soler-Prat et al., 2022). To this end, the new data serves to further evaluate PE and its educational role. Despite significant progress, such as the use of inclusive language (Piedra et al., 2013; Sáenz-Macana & Devís-Devís, 2020), the willingness of teachers to create safe spaces (Sáenz-Macana & Devís-Devís, 2020) and the emerging continuous teacher training on diversity (Piedra et al., 2014), the perception of students is often still worrying. It follows, then, that the perception of a respectful environment in our classrooms is due more to the normalisation and invisibilisation of homophobia than to its eradication (De Stéfano, 2017).

Thus, when comparing all the information on the experiences reported by heterosexual students, compared to students with a different sexual orientation, there can be no doubt: PE continues to promote students who meet specific standards (Lynch et al., 2022) associated with hegemonic masculinity, as can be seen in the review by Sáenz-Macana & Devís-Devís (2020). In the words of lisahunter (2019), PE continues to perpetuate remarkably conservative values.

Table 4
Most enjoyable PE content by group.

	Lesbians	Gays	Bisexuals	Heterosexuals
	n (%)	*n* (%)	*n* (%)	*n* (%)
Sports	**124 (59.6)**	**76 (16.5)**	67 (36.6)	**59 (49.6)**
Games	**29 (13.9)**	**130 (28.1)**	43 (23.5)	**13 (10.9)**
Corporal expression	**10 (4.8)**	45 (9.7)	2 (10.9)	9 (7.6)
Outdoor activities	**25 (12)**	**128 (27.7)**	34 (18.6)	24 (20.2)
Physical fitness and health	14 (6.7)	47 (10.2)	14 (7.7)	10 (8.4)
None at all	6 (2.9)	**36 (7.8)**	5 (2.7)	4 (3.4)

Corrected standardised residuals ± 1.96 in bold.

In this regard, the difference between many of the scores of lesbian and gay students is highlighted. In general, lesbian students have satisfactory experiences, even to the extent that they outperform heterosexual students on many items. In concrete terms, it is gay students who have the worst experience of PE, both in the changing rooms and when it comes to "modelling" activities or being chosen in group formation. This fact corresponds with the heteronormative system that advocates that heterosexuality is "natural". Homosexuality contradicts this association, and men's homosexuality is seen as a betrayal of the hegemony of masculinity (Borrillo, 2001). This reasoning explains why homosexual students, especially gay students, deploy different strategies in order to absent themselves from PE or, if they do attend, not to participate, as Hortigüela-Alcalá et al. (2022) have previously reported. Homophobia is gendered, and it is this variable that explains why gay men experience more harassment than their female classmates, as previous studies have shown (Ayvazo & Sutherland, 2009; Morrow & Gill, 2003). Thus, it has been verified that heteronormativity functions differently according to gender, with lesbians' experiences differing from those of their gay counterparts. Recognising that LGBTI individuals' experiences are not uniform in PE (Landi, 2020; Müller & Böhlke, 2023) and in the sport environment (Soler-Prat et al., 2022) is essential.

This homophobic environment, whether overt or implicit, materialises, for example, in the formation of groups (Hortigüela-Alcalá et al., 2022), as this is where the affinities that are created can be observed. Thus, the fact that students perceived as "less able" and/or "traitorous" to their gender are chosen last is indicative of their status in the web of social relations among students. And it is here that gay students are the most disadvantaged. Behind this lies the naturalisation of ways of proceeding which, as in the case of the formation of groups through the election of "captains", reinforces the hidden curriculum and perpetuates discrimination (Martos-García et al., 2023), in this case of a homophobic nature.

Another important factor explaining the problematic relationship between non-heterosexual students and PE is their content preference. Thus, while heterosexual students prefer sports, gay students prefer games and outdoor activities, which are less regulated and less masculine. This association reinforces the reasoning behind hegemonic masculinity, whereby students learn to identify with aggression, intense activities or contact; and moving away from these values is seen as a transgression of the sex-gender order (Larsson et al., 2011). This masculinity is represented in PE by sports, whilst other activities, such as dance or corporal expression, are considered more appropriate for females (Sánchez-Hernández et al., 2022). Perhaps this is why the latter are rejected by lesbian students, as for them it can be a way of escaping from these stereotypes. In one way or another, PE continues to reproduce gender stereotypes (Hortigüela-Alcalá et al., 2022); in this case, in clear intersection with sexual orientation.

Finally, some study limitations should be highlighted. Firstly, no analysis has been carried out according to the gender identity of the participants. Despite the fact that the sexual orientation of gays and lesbians provides some comparison between men and women, this is not the case for bisexual and heterosexual participants. Gender and intersectional perspectives should be taken into account when addressing individuals' experiences during their schooling. Secondly, and although it does not affect the statistical level, the distribution between the different groups should be more balanced. Thirdly, this is a retrospective study carried out on individuals with a wide age range, such that the recall of experiences during schooling may be varied in some cases.

Conclusions

The data presented here supports the existence of a homophobic environment, as has been reported in other previously published studies. This could be aggravated by the recurrent sport orientation of PE and teachers' decisions, which are suggested as future lines of research. In this case, the data also detail how this environment affects the development of the subject itself, for example, when it comes to forming groups or preferences for certain content. In this respect, lesbian students experience fewer difficulties than gay students, who are seen to "betray" male hegemony. As a result, gay students deploy different strategies to opt out.

For all these reasons, it is important to a) reflect on the consequences of teaching practices and be self-critical, b) address harassment and discrimination based on sexual orientation, and c) try to improve initial and continuous teacher training in order to develop a PE that is more responsive to the diversity of students.

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Factors that influence the physical and sports participation of adolescent girls: a systematic review

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Boat Zero and Patriot Sail on a Glamour Barcelona Day.
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Abstract

Dropout from physical activity during adolescence is a public health problem, especially for girls. The aim of this study was to analyse the scientific literature in order to identify the factors that encourage sustained participation in physical activity habits and those that lead girls to dropout of sports practice. A search of articles published in the Web of Science database from 2010 to December 2022 was conducted using the keywords: (*Physical activity* OR *Physical exercise* OR *Sport*) AND (*Adolesc** OR *Children*) AND (*Female* OR *Gender* OR *Girl* OR *Wom**) AND (*Barrier** OR *Facilitator**). The PRISMA declaration was adopted for the development of the study. Inclusion criteria were: i) the age of the participants in the studies (up to 21 years of age), ii) the language (Spanish, Catalan or English) and iii) the type of document (article). A total of 597 papers were obtained, from which 29 articles were selected for this review. The results revealed different internal and external factors influencing girls' dropout or sustained participation in sport activity during adolescence: motivation, self-perception, self-presentation, sport identity, changes during adolescence, sport environment, educational environment, social support, role models and stereotypes. At the end of the study, strategies are proposed to reverse the trend for adolescent girls to dropout of the practice of physical activity and sport.

Keywords: adolescence, barriers, dropout, factors, physical activity, sport, women.

Introduction

Regular physical activity (PA) is an important protective factor for the prevention and treatment of non-communicable diseases, such as cardiovascular diseases, type 2 diabetes and several types of cancer (WHO, 2020a). In addition to the benefits it provides for physical health, its effect on academic and cognitive performance has been evidenced (Chacón-Cuberos et al., 2020), proving beneficial for maintaining mental health and preventing cognitive decline and symptoms of depression and anxiety, and contributing to general well-being. The WHO guidelines on PA and sedentary habits (2020a) indicate that, during adolescence, an average of at least 60 minutes of PA should be carried out daily, including vigorous-intensity aerobic activities and activities that strengthen the musculoskeletal system at least 3 days a week. However, according to global health statistics (2020b), 4 out of 5 school-aged adolescents aged 11-17 years (81%) do not meet PA recommendations, with the proportion of girls (84.7%) not meeting this threshold being higher than that of boys (77.6%). This demonstrates that the trend of physical inactivity and, consequently, its associated diseases, continues to increase in adolescence, creating an alarming public health problem (Escalante, 2011).

According to the scientific literature, among girls, sedentary and unhealthy lifestyles are a trend that becomes significant from adolescence onwards (Troiano et al., 2008). A number of studies have also investigated factors affecting PA habits among adolescent girls and have highlighted various influences. Therefore, in order to understand their reduced participation in PA and sport, the factors that influence this situation should be analysed.

One of the biggest social influences is the media. Gómez-Colell (2015) argues that women's sport is invisibilised by the media because it is considered less important. This is a further difficulty in encouraging adolescent girls to take up sport. There are a lack of female role models at this stage of life, which reinforces the message that sport is for men. Moreover, in many sports media, the few women who do appear in the coverage do so not because of their leading role as athletes, but as male companions. They are what Sáinz de Baranda (2010) refers to as "guests": women who are not athletes but appear in sports coverage as partners, celebrities or amateurs accompanying the male protagonist (2010, p. 130). These women are featured in the media on account of their beauty or for being romantically involved with athletes, sending adolescent girls stereotypical messages and insights into their place in sport. For their part, Rodríguez and Miraflores (2018) account for the reduced participation of women in sport through the influence of myths that are preserved in the public perception and which defend, on the one hand, that PA masculinises women and, on the other, that girls are less interested in sport than boys. It is also important to note that the social sexism that has traditionally defined adolescent girls as weaker and less skilled in sport also permeates through the hidden curriculum of secondary school Physical Education (PE) classes, which further encourages the development of negative attitudes or indifference towards PA among adolescent girls (Granda-Vera et al., 2018). Finally, adolescent girls are additionally unable to find support in their immediate environment, especially in their families, so girls in this age group begin to prioritise types of activities other than sport. For all these reasons, the sporting sphere remains linked to masculinity not only in public perception, but also in practice. This leads adolescent girls to consider it to be a space that not only does not belong to them, but also one where they feel less valued, less competent and which presents fewer opportunities for participation and development (Flores-Fernández, 2020).

In light of these studies, it is clear that the factors influencing adolescent girls' sustained participation in PA and sport are abundant and increasingly subtle and difficult to detect, making it more costly to design and implement interventions to improve the situation. For all of the above reasons, the aim of this systematic review (SR) is to identify the factors that influence adolescent girls to remain in or dropout of PA and sport.

Materials and methods

In order to guarantee the methodological rigour of this SR, the 27 items included in the updated PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (Page et al., 2021) were applied.

Search strategy

In order to carry out the review, a search was conducted for scientific articles indexed in the Web of Science (WoS) database, which guarantees the impact index of the information sources and, therefore, their quality and scientific rigour. The search strategy aimed to identify articles that examined factors associated with PA and sport participation and dropout among adolescent girls. A search was carried out for articles in which a combination of the following keywords appeared in the abstract: (*Physical activity* OR *Physical exercise* OR *Sport*) AND (*Adolesc** OR *Children*) AND (*Female* OR *Gender* OR *Girl* OR *Wom**) AND (*Barrier** OR *Facilitator**).

Eligibility criteria

The inclusion criteria were: i) original, experimental articles addressing factors associated with adolescent girls' participation or dropout from sport, ii) articles published between January 2010 and November 2022, iii) research with a sample of individuals up to 21 years of age, and iv) articles published in English, Spanish or Catalan. All research that: i) was not an original, experimental study; ii) was published prior to 2010, and iii) included participants outside the indicated age range, was excluded.

Procedure

In line with the PRISMA statement (Page et al., 2021), three stages (identification, screening and inclusion) were established in the article eligibility process. The identification phase resulted in a total of 597 items. In order to narrow the search and limit access to only sources of information of interest according to the purpose of the study, articles were filtered by areas of knowledge (Psichology, Behavioral Sciences, Educational Research, Sport Sciences, Social Issues, Women Studies). Following this, 11 studies were eliminated for being duplicates and 17 for being in a language other than English, Spanish or Catalan. The 3 review authors participated jointly in the screening phase, filtering by title and abstract, and 55 articles were selected. In order to comply with the participant age criteria, 3 participants were excluded. In the inclusion phase, relevant articles were selected through reading the full texts and determining their eligibility for the study. As a result, 29 articles were finally included. Subsequently, to extract the key information from the selected sample (n = 29), a content analysis was carried out by the three review authors in order to obtain the resulting data table (Table 1). Each of the authors entered information independently and the information was then cross-checked and contrasted in order to ensure that there was no bias in the information collected. Finally, after analysing the research, the essential variables on which to base the synthesis method were determined. Figure 1 shows a flow chart reflecting the process of searching for and selecting research for inclusion in this SR.

Figure 1
PRISMA 2020 flowchart for Systematic Reviews

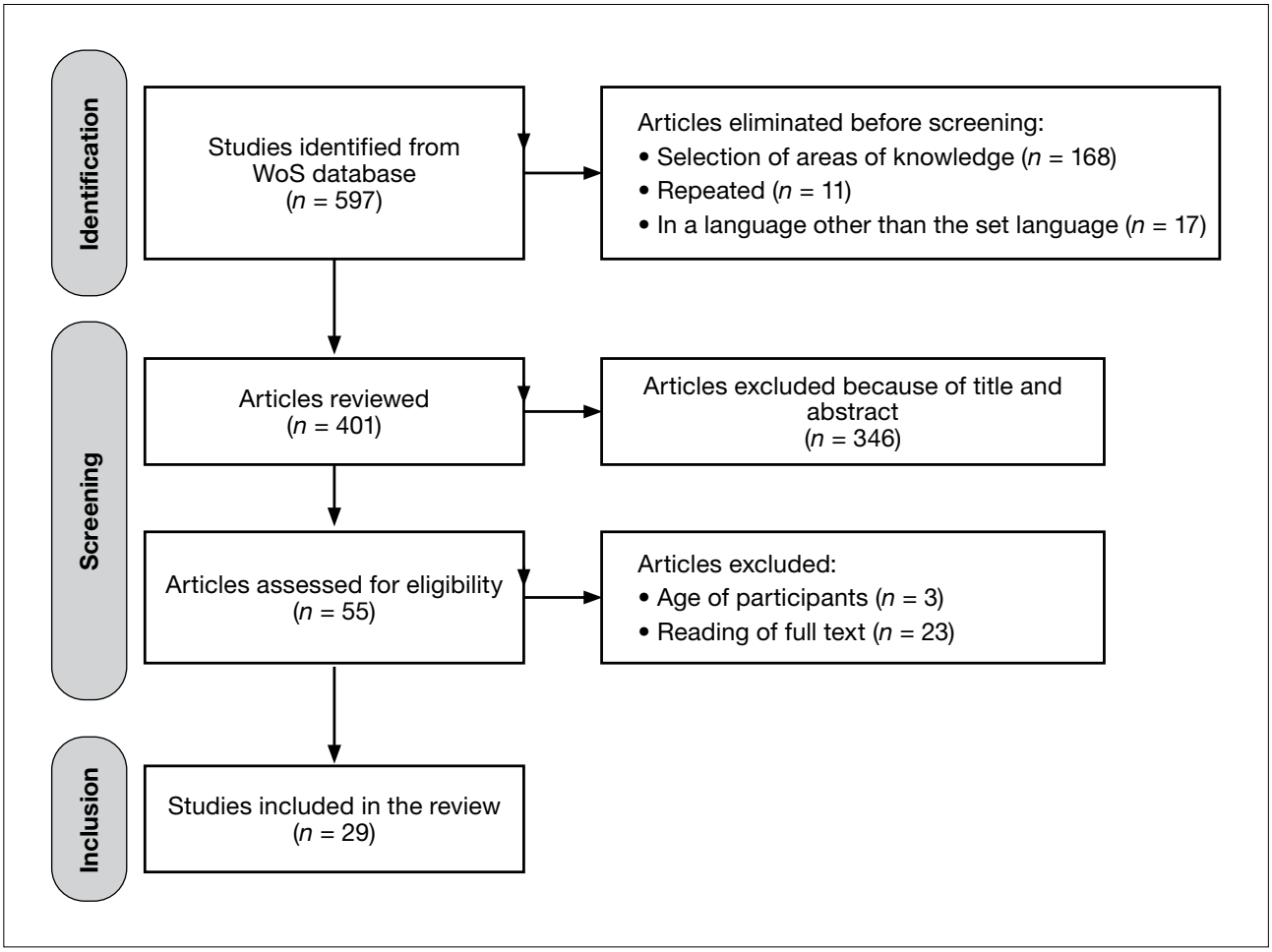

Table 1
Characteristics and results of the selected studies (in alphabetical order)

Author (year)	Factors	Sample Population	*N*[1]	Design	Instrument	Relevant Results
Ahmed et al. (2020)	1-2-8	Athletes between the ages of 11-21	382	Quantitative Cross-sectional	Sport Motivation Questionnaire	The motivational factor "health" is ranked higher for girls and the factor "social status" for boys.
Amado et al. (2015)	1-2-8-9	Athletes between the ages of 10-16 Parents	321 321	Quantitative Cross-sectional	NPB[2], Parental Support, Motivation and Enjoyment of Sport Questionnaires	Parental pressure is negatively related to NPB satisfaction. NPB is a positive predictor of intrinsic motivation. Motivation is a predictor of enjoyment of PA.
Beasley & Garn (2013)	1-2-7	Girls in Year 8, 9 and 10	34	Quantitative Cross-sectional	Motivation and Self-perception Questionnaires	Extrinsic motivation is directly related to physical self-concept, but not to PA.
Bevan et al. (2021)	6-7-8-9-10	Girls involved in "male sports" between the ages of 13-17	34	Qualitative	Focus Group and Interview	The reasons behind adolescent girls' participation in PA can be summarised as: social connection, club mentors (elite representatives) and female role models in the media.
Bevan & Fane (2017)	2-7-8-9-10	Female athletes between the ages of 13-17	34	Qualitative narrative	Focus Groups and Interviews	Increasing lack of role models for girls. Gender discrimination is apparent in the nature of the language used and the organisation of school sport. Girls perceive themselves as "less competent" than boys.
Budd et al. (2018)	7-8	Girls in Year 6	1,721	Quantitative Cross-sectional	Accelerometer and Enjoyment of PA, Social Support and School Environment Questionnaires	Girls' enjoyment of PA was significantly impacted by: teachers, boys, family and neighbourhood. Only the social support of friends has a direct effect on PA.
Castro-Sánchez et al. (2016)	1-7-8	Adolescents between the ages of 15-18	2,134	Quantitative Cross-sectional	PA, Family PA and Motivation Questionnaires	Girls gear PA towards leisure and recreation and boys towards the competitive factor. Girls exhibit higher scores in the task-oriented environment and boys in the ego-oriented environment.
Cowley et al. (2021)	2-3-5-6-7-8-9-10	Girls between the ages of 13-17	48	Qualitative	Questionnaire and Focus Groups	Girls' PA is influenced by intrapersonal (being judged and changing priorities), interpersonal (pressures and social support) and organisational (sport environment) factors.
Davison et al. (2010)	1-2-5-6-10	Girls aged 13	151	Quantitative Longitudinal	Accelerometer, Stethoscope and Enjoyment and Sport Motivation Questionnaires	Lack of competence is the most common reason for disliking PA, followed by perceived effort or fatigue. The least common are physical impact, identity and lack of opportunities.

Note. [1]*Sample size;* [2]*Basic Psychological Needs*

Table 1 (Continued)
Characteristics and results of selected studies (in alphabetical order)

Author (year)	Factors	Sample Population	*N*[1]	Design	Instrument	Relevant Results
Dawes et al. (2014)	1-2-6-7	Young Europeans	986	Quantitative Longitudinal	Value of Sport, Self-perception and Sport Participation Questionnaires	Men participate more in organised sports and have higher scores for self-competition. Gender does not predict informal participation. Perception of competence influences participation.
Diaconu-Gherasim & Duca (2018)	8	Adolescents between the ages of 12-15	120	Quantitative Cross-sectional	Attachment and Interpersonal Relations Questionnaires	Girls perceive themselves to be more prosocial than boys. Secure attachment with parents has an impact on the quality of friendships and social competence in the team environment.
Drummond et al. (2022)	1-2-5-6-7-8 I	Secondary School Students Faculty Parents	2,189 11 5	Explanatory Sequential Mixed	Focus Groups, Interviews and PA, Motivation, Resilience, Self-esteem, and Body Appreciation Questionnaires	Changing priorities during adolescence, lack of time and financial cost limit PA participation. Fun, friendship, empowerment and competition are motivators for girls' PA. The role of coaches and parents is very important.
Eime et al. (2015)	2-5-6-7-8	Students in Year 7 and 11	440	Quantitative Longitudinal	Questionnaires on Perceived Competence, Self-efficacy, PA, Support, Environmental and Socio-economic factors	Lack of time and energy as factors, as well as the importance of the educational environment, increase with age. Support from family and friends and perceived competence have a decreased importance over time.
Eime et al. (2016)	2-4-5-6-7-8-9	Students in Year 7 and 11	729	Quantitative Longitudinal	PA Questionnaire and Diary	With age, non-competitive-organised sports environments have an increased importance (lack of time). Support from family and friends has a decreased importance over time.
Frömel et al. (2022)	1-2-3-7	Girls and boys	1,558	Quantitative Cross-sectional	Motivation and PA Questionnaires	Boys are more motivated than girls in all respects, except when it comes to aesthetic appearance. Enjoyment, competition and appearance as motivators increase PA participation the most.
Gil-Madrona et al. (2014)	7-10	Girls and boys in Year 6	250	Quantitative Cross-sectional	Questionnaire on PA at school	28.5% of girls feel that they are neglected when playing with boys. Many girls feel that they are chosen last. 25% of the participants differentiate between sports exclusively for boys and girls.

Note. [1]*Sample size;* [2]*Basic Psychological Needs*

Table 1 (Continued)
Characteristics and results of selected studies (in alphabetical order)

Author (year)	Factors	Sample Population	*N*[1]	Design	Instrument	Relevant Results
Gil-Madrona et al. (2017)	7-10	Girls and boys in Year 6	1,094	Quantitative Cross-sectional	Questionnaire on PA at school	Girls feel that boys do not let them play and feel more neglected than boys. Boys are more likely to agree that there are different games for boys and girls.
Kirby et al. (2012)	6-7	Girls in Year 2 and 4 CSE School principals	1,978 123	Quantitative Cross-sectional	Girls' and School Survey on school PA	PE is the predictor that most increases PA participation in adolescent girls. Adolescent girls in schools with a greater variety of clubs are more likely to be physically active.
Knowles et al. (2014)	1-2-3-4-5-8-10	Adolescent girls	14	Qualitative narrative	Narrative Interviews	During adolescence, perception of competence decreases and there are changes in motivation and a loss of sense of purpose regarding PA. Body shape is of greater concern when boys are present. Dominant social values contradict the active identity.
Kopcakova et al. (2015)	1-2-8	Students aged 11, 13 and 15	9,018	Quantitative Cross-sectional	PA Questionnaire and Motivators for PA	Social and health motivators (body image and weight control) are ranked more highly by girls; and being a "good male" and achievement motivates boys.
Lawler et al. (2022)	3-8	Adolescents between the ages of 12-17	995	Quantitative	PA Diary and Support, Pressure, Social Acceptance and Teasing Questionnaire	Support from friends is more influential than parental support. Girls feel more parental pressure than boys. Girls are more likely to be teased than boys.
Mac-Pherson et al. (2016)	2-4-6-8	Athletes between the ages of 13-17	8	Qualitative Narrative Enquiry	Photocompetition and Interviews	Positive influence of interactions with peers in the sport context on the development of the psychological (commitment, self-esteem, etc.), social (extroversion, humour, etc.) and physical (body image) self.
Mateo-Orcajada et al. (2021)	8-10	Students between the ages of 12-16 Parents	965 1,599	Quantitative Cross-sectional	PA Student Questionnaire and PA and Stereotypes Parent Questionnaire	The educational level of mothers is related to the PA of their sons and daughters. Fathers' PA is related to their children's PA. Gender stereotypes of mothers are related to girls' PA.

Note. [1]Sample size; [2]Basic Psychological Needs

Table 1 (Continued)
Characteristics and results of selected studies (in alphabetical order)

Author (year)	Factors	Sample Population	*N*[1]	Design	Instrument	Relevant Results
Mitchell et al. (2015)	1-2-3-7-8	Girls "disengaged" from PE between the ages of 12-13	5	Qualitative Longitudinal	Interviews	Existence of psychological factors (lack of motivation, low perception of competence), environmental factors (equipment, changing rooms, etc.) and social factors (PE teachers, male peers). Lack of choice is the main reason for girls dropping out of sport. Girls participate more in single-sex settings.
Morano et al. (2020)	2-3-5-6-10	Female athletes between the ages of 14-21	261	Quantitative Cross-sectional	Self-perception, Anxiety, Sport Performance and Bio-psychosocial States Questionnaires	Athletes who play individual sports score lower on confidence and higher on worry than athletes who play team sports.
O'Reilly et al. (2022)	2-3-5-7-8-10	Girls between the ages of 12-15	104	Qualitative	Focus Groups	Importance of gender stereotyping, choice of activities, empowerment and inequalities in PA and sport in increasing adolescent girls' PA.
Owen et al. (2019)	1-2-5-6-7-8	Adolescent Girls	110	Mixed	PA Questionnaire and School PA Perception and Focus Group	Factors hindering sport participation: lack of time, motivation and options. Increased fun and motivation when participating with friends. Importance of non-competitive PA. Adolescent girls perceive favouritism in PE classes. Importance of autonomy and teamwork.
Zook et al. (2014)	2-5-6-8	Students in Year 8	561	Quantitative Longitudinal	Accelerometer, Survey, Scale, Measuring Table and Geographic Information System	High physical self-concept, social support (family and friends), and a shorter distance between home and a park increase the likelihood of maintaining active habits. Early pubertal development (menstruation) may decrease PA.
Zucchetti et al. (2013)	1-2-6-8	Female athletes between the ages of 10-14	127	Quantitative Cross-sectional	Motivation, Sport enjoyment, Social Self-efficacy and Coaching Behaviour Questionnaires	Enjoyment is positively associated with motivation. Social support and coach leadership styles increase motivation. Autocratic styles negatively affect motivation.

Note. [1]Sample size; [2]Basic Psychological Needs

Results

Of the 29 articles reviewed, seven were qualitative research, two were mixed studies and the rest were quantitative research with very different designs.

Ten influential factors for the physical and sports participation of adolescent girls were identified and classified into internal or personal factors, with personal characteristics mainly related to self-determination and self-awareness, and external characteristics to environmental or contextual factors (Accardo et al., 2019). The internal factors appearing in the SR articles were: motivation (1), self-perception (2), self-presentation (3), sport identity (4) and changes associated with developmental stage (5); while the external factors were: sport environment (6), educational and PE environment (7), social support (8), role models (9) and gender stereotypes (10). Table 1 also lists each of the factors addressed in the articles included in this SR.

Discussion

The aim of this SR was to analyse the factors that influence participation in PA and sport among adolescent girls. A review of the 29 studies revealed multiple factors explaining girls' sport involvement during this stage of life. Because of their large number, they are grouped into internal and external factors. In addition, for each factor or variable that conditions or hinders the participation of adolescent girls in PA and sport, proposals for improvement are provided that seek to reverse the trend of girls dropping out of sport during adolescence.

Internal factors

One main internal factor is motivation. Lack of motivation is a major barrier to sustained participation in PA and sport for adolescent girls. Some studies demonstrate that adolescence leads to a loss of motivation for PA (Knowles et al., 2014) and that boys are more motivated than girls. This situation is recurrent except when the motivation is linked to aesthetics (Frömel et al., 2022), where girls score higher, perhaps due to the social pressure that adolescent girls face in relation to their physical appearance. In this regard, Budd et al. (2018) demonstrate how intrinsic motivation, independent of external stimuli and related to one's own enjoyment of the activity, is an important predictor of participation in PA (Frömel et al., 2022). However, girls are more extrinsically motivated, for example, by social and health-related issues (Kopcakova et al., 2015). Therefore, to prevent girls from dropping out, motivational differences between the sexes should be considered and interventions should be implemented that take into account the factors that motivate girls and boys, in order to provide them with PA experiences linked to their interests (Zucchetti et al., 2013). In addition, it is vital to conduct further research into why girls do not perceive the practice of PA as an end in itself.

A second internal factor is self-perception in sports practice. Self-perception is a person's appreciation of him/herself and it is formed through experiences with the environment (Shavelson et al., 1976). Negative self-perception and lack of confidence in one's own abilities are barriers to adolescent girls' participation. Cowley et al. (2021) explain that girls feel a greater lack of confidence and also embarrassment doing PA in public. Conversely, a sense of competence and a higher physical self-concept have been shown to increase the likelihood of maintaining and acquiring active habits (Zook et al., 2014). In order to avoid dropout, it is therefore necessary to promote a sporting context that focuses on developing positive self-perception in adolescent girls, where they obtain positive results that improve their self-perception, and to design activities that are centred around them (Beasley and Garn, 2013).

Another factor to consider is self-presentation, the process by which people try to influence and control others' impressions of them. Knowles et al. (2014) report that girls are more concerned about self-presentation when doing PA with boys. When they compare themselves with their male peers, they feel that they are not as skilled as them (Bevan and Fane, 2017) and experience discomfort, insecurity and worry (Knowles et al., 2014; Cowley et al., 2021; O'Reilly et al., 2022), which can be an added difficulty for them, especially in co-educational PE classes. Recent studies focusing on adolescent girls have found that girls often prefer to take PE lessons separately from boys (Cowley et al., 2021), so this should be seriously considered. It is not a question of reverting to the segregation of students by gender, but of considering the establishment of certain tasks or sessions in different groups working on the same content, so that all students have the possibility of participating with peers who do not have a physical starting advantage, creating situations that offer them positive experiences in relation to the possibility of success.

On the other hand, sport identity, defined as the degree of strength and exclusivity with which a person identifies with the role of athlete, is another factor influencing sustained participation in PA and sport. In their study, Eime et al. (2016) explain how for boys it is relatively easy

for their sport identity and their masculine identity to align, while for girls this relationship is not straightforward. This mismatch between female stereotypes and the traditional sport model is a further obstacle to their participation and adherence (Bevan et al., 2021). Adolescent girls must negotiate between gender norms and their enjoyment of sport. Therefore, future studies should address this issue and work towards the eradication of gender stereotypes, as well as promote a sporting model different to the hegemonic one, in which girls find their place and with which they can identify.

Finally, another internal factor detected in several of the articles is the physical, emotional and social changes that accompany adolescence (Davison et al., 2010). During puberty and adolescence, significant bodily changes occur. In the case of girls, these include the widening of the pelvis, accumulation of fat in the legs and hips, breast enlargement and the onset of menstruation. In this regard, Zook et al. (2014) demonstrated how early pubertal development and menstruation can decrease PA practice. Pubertal physical changes pose an added difficulty for girls, as they have to expose themselves in public spaces where they believe that their bodies are looked at, commented upon and evaluated (Fredrickson and Roberts, 1997). In addition to bodily changes, this period brings new commitments linked to leisure, work and study, which also lead to a change in priorities. Thus, during adolescence a distancing from sport activities takes place (Eime et al., 2015, 2016), and girls are more prone to this (Dawes et al., 2014). This shift in priorities, understood as an internal factor, can be explained by taking into account external factors, such as gender expectations and social norms. In line with Ana de Miguel, at the adolescent age, cultural gender norms, with their different associations for boys and girls, are very effective. Among the contradictory messages that girls receive socially in adolescence, those related to the practice of PA are not a priority or relevant. On the other hand, they are bombarded with notions of pleasantness and beauty and, in recent years, particularly with hypersexualisation (De Miguel, 2016, p. 65). Advertising recreates images of stereotypical women committed to always looking beautiful, made-up and well-groomed, which is incompatible with sport. These representations hinder their potential, whilst boys are encouraged to develop their personality and identity (Valcárcel, 2008, pp. 192-198). It is vital that schools work on these aspects in PE classes. Teaching adolescents to be critical is fundamental in order to free them from the gender norms that constrain and limit them, particularly in the case of girls.

External factors

Among the external factors influencing participation in PA and sport, society is a determining factor. Generally, girls' contribution to sport is often underestimated in all respects, leaving them feeling less valued (Cowley et al., 2021). Sport is a phenomenon that was designed by and for men, so women have had to adapt to a model which, in many cases, they do not feel aligned with and in the design of which they did not participate, nor were they taken into account. In this sense, girls feel "invited" to participate in a field that does not belong to them, and which represents a handicap when it comes to establishing stable and deep ties with the activity.

Along these lines, Eime et al. (2015) argue that adolescent girls should be fully involved in decisions about their sporting lives and should do so in an environment where they feel respected, empowered and have a voice, key strategy for keeping them physically active. This environment should provide alternatives to traditional and competitive sports, and incorporate other activities that enhance social aspects, as well as be a space in which the level of skill is not set by males (Davison et al., 2010; Owen et al., 2019).

Despite advances in feminism, gender stereotypes continue to be a factor that negatively influence adolescent girls' PA (O'Reilly et al., 2022). Social and cultural pressures instil in girls perceptions of activities "more appropriate to their sex" (Gil-Madrona et al., 2017), inhibiting them from participating in sports traditionally considered masculine. Bevan and Fane (2017) explain that girls turn away from the sporting pathway because they feel the need to conform to gender norms and social expectations, as they observe that those who oppose these norms are marginalised and linked to masculinity, aspects that have a deterrent effect on their participation (Bevan et al., 2021). It is therefore absolutely necessary to include gender and feminist education in the training programmes of all sport professions. Only in this way will adolescent girls find it easier to maintain their sporting careers and reduce the dropout rate from PA.

Another external factor identified is the lack of role models, which also leads girls to accept sport as a male domain (Bevan et al., 2021). Research by Cowley et al. (2021) looks at how differences between female and male athletes in all aspects mean that girls see no chance of progressing in sport. In addition, Bevan et al. (2021) highlight the need for the media to be used to promote role models, as having role models at a high level is one way for adolescent girls to realise that they have the possibility to grow within the world of sport (Drummond et al., 2022). Therefore, teachers in schools should be committed to counteracting the negative influence of the media by providing socially male

and female role models in equal quantity and frequency, and eliminating stereotypes so that girls also have their own role models and see examples of successful women in the field of sport.

In this regard, the school is an ideal environment for the promotion of PA, as the structured nature of the school day provides numerous opportunities for its practice (PE, active transport, extracurricular sport...) (Owen et al., 2019). Specifically, Beasley and Garn (2013) consider that PE is the subject that most influences sustained participation in PA, although its presence in the school curriculum does not guarantee a lifestyle (Castro-Sánchez et al., 2016). This subject has historically been considered a male space dominated by boys for physiological reasons (Gil-Madrona et al., 2014). Given the predominance of traditionally male-dominated activities and their androcentric approach (Ahmed et al., 2020), PE may be another contributor to adolescent girls' lack of interest. In PE classes, girls experience a lack of encouragement from teachers, greater bias and favouritism towards their male peers (Owen et al., 2019), the use of sexist language (Bevan and Fane, 2017) and an emphasis on sports that are considered masculine (O'Reilly et al., 2022). Therefore, in order to increase girls' interest in PA inside and outside the classroom, recent studies have demonstrated the importance of the PE teacher (Flores-Rodriguez and Alvite-de-Pablo, 2023). The educational institution and teaching staff play an important role in the eradication of gender stereotypes in PA and sport (O'Reilly et al., 2022). It is therefore up to them to help put an end to stereotypical beliefs and sexist behaviour in sport by motivating adolescent girls further and, above all, more effectively. However, without the necessary training, this progress is impossible and several studies have analysed the scarce or non-existent feminist teacher training in the curricula of Physical Activity and Sport Science degrees (Serra et al., 2018). This is an aspect that should be taken into account by teacher training centres, where the feminist perspective and the study of women should be cross-cutting content in all subjects, as adolescent girls make up half of the student body.

In addition, adolescent girls do not report high levels of support for PA from their families, friends and teachers (Eime et al., 2016). According to MacPherson et al. (2016), social interactions that take place in the sports environment have a decisive impact on the sustained participation of adolescent girls, so it is essential to promote the development of groups of girls who have positive psychosocial experiences in sport in order to facilitate their adherence. Social connection with peers is vital and maintains adolescent girls' interest (Bevan et al., 2021). However, in the early stages, the family is a key agent in helping girls to develop sport habits that will last during later stages (Castro-Sánchez et al., 2016). In this sense, adolescents with active parents are more likely to engage in regular PA (Mateo-Orcajada et al., 2021). In addition, Diaconu-Gherasim and Duca (2018) demonstrate that support from mothers and fathers increases the interest and motivation of adolescent girls.

Conclusions

This SR summarises the evidence collected on the factors that influence the sustained participation or dropout from PA and sport among adolescent girls. Internal factors include motivation, self-perception, self-presentation, sport identity and integral changes associated with adolescence and puberty. External factors include the sport environment, the educational context and PE teachers, social support, role models, and gender stereotypes and roles in sport. Taking into account the influence that these factors have on the physical and sports participation of adolescent girls, a multifactorial response that addresses these psychological, social and environmental components in a holistic way is necessary, in order to create sports policies focused on maintaining adolescent girls' sustained participation in PA and for sport to be effective.

Limitations

This study does have some limitations. One of these is publication bias. The available research may not be a thorough representation of existing research, given that a single database has been used and studies that do not obtain optimal or significant results are not included. On the other hand, in studies with participants of both sexes, some factors mentioned in the review may not only affect girls. This may pose difficulties in targeting future interventions that take into account the sex/gender system. Finally, another limitation is the great heterogeneity of PA populations, methodologies and contexts reflected in the papers included in the review, which may affect the results of the study.

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Influence of Ludotechnical Model and Teaching Games for Understanding on Roller Hockey Player Motivation

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Boat Zero and Patriot Sail on a Glamour Barcelona Day.
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Abstract

The aim of this study was to analyze the effect of an intervention program based on Ludotechnical Model and Teaching Games for Understanding (TGfU) on roller hockey players' motivation. The intervention consisted of 14 training sessions. A quasi-experimental study was developed with a pre-post design with 11 roller-hockey players from the under-10 category (M = 7.18, SD = 0.83) from a Spanish school club. The Sport Motivation Scale was used to analyze the types of motivation. Overall, results revealed an increase in some autonomous forms of motivation and a decrease in controlled motivation, as it was hypothesized. Regarding autonomous motivation, the intervention had a positive effect on intrinsic motivation to know and intrinsic motivation to experience stimulation. On the other hand, results showed a decrease in players' introjected and external regulations. Therefore, the intervention seemed useful to diminish the most negative types of motivation established in self-determination theory. This study provides initial evidence that a hybrid Ludotechnical/TGfU unit can be implemented in a sport like roller hockey to produce significant improvements in players' motivation.

Keywords: hybrid unit, Ludotechnical Model, motivation, roller hockey, Teaching Games for Understanding.

Introduction

In team sports, in which open motor skills predominate, it is required that players continuously co-adapt their actions to the movements of opponents and teammates to ensure a functional collective behavior. Thus, players need to be attuned to informational game constraints to decide what to do and how to do it (Chow et al., 2016). Specifically, roller hockey combines the complexity of the characteristics of invasion, implement and sliding sports. These characteristics make this sport an attractive and recommended practice for formative ages (Canton et al., 2021). On the other hand, it presents differences with other collaboration-opposition sports (e.g., soccer or basketball) due to the particularity of moving on skates and carrying an implement, the stick. These issues will influence the development of sport and, consequently, its teaching-learning process. Buszard et al. (2016) highlight the importance of adapting the sport to the participants, considering their age and level of experience, as well as the learning processes. In this way, faster learning of skills, better movement patterns and performance, greater self-efficacy and higher level of involvement and motivation to practice will be encouraged. Therefore, it seems interesting to study in detail how to develop teaching-learning processes in this peculiar invasion sport where players move on skates and, in addition, carry a stick in their hands, and how to keep the participants motivated during this process.

A theoretical framework that has been widely used to examine motivation in the sport context is self-determination theory (SDT; Ryan & Deci, 2020). This theory proposes that people have three innate and universal basic psychological needs (BPN), autonomy, competence, and relatedness, which must be satisfied by the social environment to promote well-being and different growth manifestations such as intrinsic motivation and internalization (Vansteenkiste & Ryan, 2013). In sport, autonomy is satisfied if coaches take the athletes' perspective in consideration, allowing them to choose some aspects of the process. Competence is promoted if athletes perceive that they have enough ability to face the different sport challenges. Relatedness refers to maintaining good relationships with teammates and the coach. Alongside these BPN, recent studies grounded in the SDT framework (González-Cutre et al., 2016) have discussed the possibility of considering novelty as a potential additional fourth BPN. Novelty can be defined as the need to experience something not previously experienced or excluded from the daily routine (González-Cutre et al., 2016). In this way, athletes' BPN satisfaction or frustration would be related to different forms of motivation, organized in a continuum of self-determination. Recent research shows that more autonomous forms of motivation, characterized by enjoyment and valuation of the activity, are likely to appear when athletes/players feel that there is an environment that supports their BPN (Vasconcellos et al., 2020). Instructional interventions have been one of the most widely studied factors from self-determination theory, with a direct impact on athletes/players' motivation and positive outcomes through BPN satisfaction and frustration (Mossman et al., 2022).

In previous studies, emphasis has been placed on the degree of autonomy support provided during sport instruction. An autonomy-supportive environment leads to more adaptive patterns of responses such as BPN satisfaction, autonomous motivation, general well-being, positive affect, life satisfaction, vitality, self-esteem, resilience/persistence, effort, performance and achievement, teamwork, engagement and physical activity participation, and less maladaptive outcomes such as negative affect, burnout, and depression (Mossman et al., 2022). In opposition, a controlling style restricts players' autonomy and choice using demanding and domineering language and excessive critical feedback (Aelterman et al., 2019). Controlling style leads to BPN frustration, controlled motivation (related to feelings of guilt and external factors, such as rewards or punishments) and lack of motivation, which would be associated with decreased interest, boredom, and dropout (Haerens et al., 2018). Despite psychosocial variables being important factors for improving athletes' experiences, sport teaching has traditionally been undertaken via a direct instruction pedagogical model (Metzler, 2017), which is not very autonomy supportive.

The direct instruction model has been criticized by researchers due to its narrow focus on sports techniques (Kirk, 2013). For a long time, the teaching of technical skills in sports has focused on teaching stereotyped sports movements that reproduce execution models of proven effectiveness (Valero-Valenzuela et al., 2009). This "traditional" methodology (Metzler, 2017) seeks to improve the technique and achieve motor patterns, prevailing a practice that benefits young people with a higher coordination and conditional level. Consequently, many children report low levels of autonomous motivation, satisfaction, and learning (Morgan et al., 2005), causing to abandon physical activity and sport participation (Gómez-López et al., 2019). As an alternative to the direct instruction model, Metzler (2017) proposed a range of pedagogical models. These pedagogical models have

key design features that promote opportunities to solve problems and make decisions, all of which can potentially lead to higher levels of autonomous motivation (Metzler, 2017).

The Ludotechnical Model was created and developed by Valero-Valenzuela and Conde (2003) for individual sports with technical predominance (specifically, athletics). This model uses played forms and modified games to encourage the practice of individual disciplines among young people, providing a set of rules that allow them to gradually acquire the technique while they are immersed in the dynamics of the playful activity practiced, developing the motor, cognitive, social, and affective areas (Valero-Valenzuela & Gómez-Mármol, 2013). The Ludotechnical Model session structure is divided into four consecutive parts: a) Presentation and challenge; b) Ludotechnical proposals; c) Global proposals; and d) Reflection and sharing. Even though this model was created for individual sports, there is current research that uses it in invasion sports to improve the technique of complex skills with an adequate motivational climate (Rubio-Castillo & Gómez-Mármol, 2016).

Teaching Games for Understanding (TGfU) is a pedagogical model developed by Bunker and Thorpe (1982). The objective of this model, based on the pedagogical principles of modified games (Small-Sided and Conditioned Games-SSCG; modified game through representation and modified game through exaggeration) and on questioning (interrogative feedback), is to understand the game through tactical knowledge (Tan et al., 2012). Specifically, modified games (SSCG) are played on reduced pitch areas, using adapted rules, and involving a smaller number of players. In formative stages, empirical evidence supports the use of SSCG (Ometto et al., 2018) and the manipulation of constraints (through approaches such as the TGfU) (Renshaw & Chow, 2019) as supportive tools for learning. In roller hockey, the modifications that have been proposed consist of adapting the playing space, the heights or location of the goals, the size and weight of balls and equipment, number of players, duration of the game or scoring systems (Timmerman et al., 2017). Regarding questioning, a basic and essential aspect of the TGfU model, Bunker and Thorpe (1982) point out that this is also a methodological tool that develops knowledge of game tactical skills. This technique consists in asking the player a series of questions that explore the critical dimension required to effectively execute a technical-tactical skill. This process requires coaches not to tell players the execution pattern that they must carry out but, instead, to ask the players to analyze their own tactical responses during the execution of the tasks, based on the key points present in the training situation (Vickers, 2007). Likewise, some of the intervention programs used are based on explicit learning (e.g., Raab, 2003). Therefore, technical skills are developed alongside tactics in the contextualized situations of the SSCG and are practiced when needed within "skill drills" (Harvey & Jarrett, 2014). In addition to designing and manipulating the learning environment, players are engaged in the process of inquiry through the coaches' use of questioning. In this sense, coaches do not use a controlling style, telling the players how to act. Instead, coaches ask questions about what to do and how, with respect to tactical complexity tasks, where the complexity is adapted to the athletes' execution level (modified games) by manipulating the task constraints. Consequently, using TGfU, coaches may develop an autonomy-supportive learning environment leading players to report high levels of autonomous motivation and more adaptive outcomes (Andrianto, 2023).

Although the Ludotechnical Model and TGfU have different features, both pedagogical models share common pedagogical processes, such as using questioning to engage players in their learning. Likewise, one of the major common features for both pedagogical models is the shift of the coach's role to one of facilitator of learning, and the related increase in responsibility and decision-making away from the coach to the players (Stran et al., 2012). Consequently, hybridizations could be an effective mechanism for achieving higher quality learning outcomes (González-Víllora et al., 2019). Therefore, the aim of the present study was to analyze the effect of an intervention program based on the Ludotechnical Model and Teaching Games for Understanding (TGfU) on players' motivation in roller hockey. We hypothesized that the intervention would increase the players' autonomous motivation and decrease their controlled motivation and amotivation.

Material and methods

Design and participants

The participants were 11 roller hockey players (8 males and 3 females) from the under-10 category (6-9 years old; M = 7.18 yrs. and SD = 0.83) from a Spanish school club. All participants had the same level of expertise (i.e., average-low skill level) and belonged to the same team. In this regard, these players had not been selected as the best of their category and their participation in the club was recreation and education oriented.

An intra-group, quasi-experimental design was used. Players had two weekly training sessions of one hour each one. The intervention was based on a hybrid Ludotechnical/TGfU models' program. Participants had no prior experience with these models. The coach who participated in this study was a 25 year old man and had taught roller hockey through direct instruction in the last four seasons to players in formative stages. In these seasons, the selection of content, their presentation, and the task structure were controlled by him. He was the "leader" in unit instruction, monitoring practice and presenting students with a model of the desired movement. The sessions were highly structured and based on the repetition of technical skills. Student learning tasks were carried out in segmented blocks of time, and the teacher controlled the pace of activities and the time between task progressions.

The research project was fully approved by the Ethics Research Committee of a Spanish University (approval code: UNNE-2022-008). The participants and their parents were informed of the study and an informed written consent was obtained from the parents/guardians. Participants were treated in agreement with the ethical guidelines of the American Psychological Association with respect to participant assent, parent/guardian consent, confidentiality, and anonymity.

Instrument

Types of motivation. The Spanish version (Núñez et al., 2006) of the Sport Motivation Scale (SMS; Pelletier et al., 1995) was used. The SMS begins with the question "Why do you participate in roller hockey?", and it is composed of 28 items that measure seven forms of motivation: intrinsic motivation to know (e.g. "For the pleasure it gives me to know more about the sport that I practice"), intrinsic motivation to experience stimulation (e.g. "For the pleasure I feel in living exciting experiences"), intrinsic motivation to accomplish (e.g. "For the pleasure that I feel while executing certain difficult movements"), identified regulation (e.g. "Because it is a good way to learn lots of things which could be useful to me in other areas of my life."), introjected regulation (e.g. "Because I must do sports to feel good"), external regulation (e.g. "To show others how good I am at my sport") and lack of motivation (e.g. "I don't know anymore; I have the impression of being incapable of succeeding in this sport"). The items were anchored on a Likert scale ranging from 1 (it does not correspond at all) to 7 (it corresponds exactly).

Procedure

The current study was conducted in one Spanish roller hockey club setting where the coach had not any experience in applying both models (Ludotechnical Model and TGfU). Thus, he completed a training course about these pedagogical models, which was developed in the four months prior to the intervention, as it has been developed in previous studies (Harvey et al., 2010). The first and the last authors led the training process. During the first week, the coach spent approximately 6 hours reading papers about the Ludotechnical Model (e.g., Valero-Valenzuela & Gómez-Mármol, 2013) and the TGfU model (e.g., Harvey et al., 2010). In the second week, authors conducted two meetings with the coach lasting for two hours each to discuss their content and began discussions about planning the intervention program using both models and the structure that would be followed (phases and the model of each session). In the third week, the coach designed the program, and its content was discussed, specifically, the prioritized technical skills and the session objectives (see Table 1). Finally, in the last week, the coach designed the first four training sessions.

Once the coach training process was completed, initial evaluation was conducted, and after that, the intervention began. The first author was present when the questionnaire was administered and answered any questions that arose from participants. All participants completed the questionnaire in a 20-25-minutes period in the absence of the coach. The intervention was conducted over a period of 14 training sessions (seven weeks), which were scheduled for 1 hour twice a week. When the intervention phase was completed, final evaluation data were collected.

Intervention

The intervention program, based on the application of the Ludotechnical and TGfU models, was designed according to the following structure: phase 1 (the ball as the center of attention; the objective was to keep the ball possession, without any specific goal or directionality), phase 2 (progression to the goal), phase 3 (orientation in the field) and phase 4 (game principles and rules). Each phase was composed of four sessions (except for the fourth phase, which had two sessions) that followed the same sequence: the ball, the ball and teammates, the ball and opponents, and the ball, teammates, and opponents. Table 1 shows these phases with objectives and contents developed on each training session during the intervention phase.

Table 1
Session's objectives and contents for each session.

Phase	*N*	Model	Session objective	Tactical Principles	Technical skills
Phase 1: the ball as the center of attention	1	LM	To keep the ball alone (individually)	None	Dribbling
	2		To keep the ball with teammates		Dribbling Static passing
	3	TGfU	To keep the ball against opponents	Width and depth in attack, creating lines of pass, keeping possession	Dribbling Protection
	4		To keep the ball with teammates and against opponents		Passing Dribbling
Phase 2: progression to the goal	5	LM	To progress with the ball	None	Speed dribbling
	6		To progress with the ball with the presence of teammates		Dynamic passing Dribbling
	7	TGfU	To progress with the ball against opponents	Attacking the goal, creating an advantage in space and number	Dribbling
	8		To progress with the ball with the presence of teammates and against opponents		Dynamic passing Dribbling
Phase 3: orientation in the field	9	LM	To orient myself with the ball	None	Ball control Skill dribbling
	10		To orient myself with the ball with the presence of teammates		Dribbling Passing Ball control
	11	TGfU	To orient myself with the ball against opponents	Interchange of positions and occupation and creation of space	Ball control Dribbling
	12		To orient myself with the ball with the presence of teammates and against opponents		Dribbling Passing Ball control
Phase 4: game principles and rules	13	SSCG and questioning	All previous	All previous	All previous
	14		All previous		All previous

*LM = Ludotechnical Model; TGfU = Teaching Games for Understanding; SSCG = Small-Sided and Conditioned Games

Table 2
Session's plan based on the Ludotechnical and TGfU models.

Time	Ludotechnical Model	TGfU Model
5'	Introduction to the session objective, the technical skill to be developed and the challenge proposed	Introduction to the session objective and the tactical principle to be practiced
10'	Ludotechnical proposal 1	Small-sided game 1
10'	Ludotechnical proposal 2	Small-sided game 2
10'	Ludotechnical proposal 3	Small-sided game 3
20'	Global proposal	Small-sided game 4
5'	Pooling to resolve the challenge	Pooling to share knowledge

The first two sessions of each phase were designed based on the Ludotechnical Model and the last two sessions, in which there were opponents, based on the TGfU model. Lastly, two sessions were developed from a SSCG perspective, trying to link all previous technical and tactical contents. However, both models followed a similar structure (see Table 2).

Regarding the Ludotechnical Model (Valero-Valenzuela & Conde, 2003), each learning task was designed focused on the learning of a technical skill. Specifically, the coach split the skill in parts through ludotechnical proposals to unify all of them at the end with a global proposal. All these tasks tried to answer the initial questions (challenge). Regarding the level of difficulty of the model (Valero-Valenzuela & Gómez-Mármol, 2013), it could be placed at "intermediate complexity", since the session was focused on one phase (e.g., the ball as the center of attention) but more than one technical skill could appear in the session tasks: dribbling and static passing (see Session 2).

Regarding the TGfU model (Bunker & Thorpe, 1982), each learning task (small-sided and conditioned games) had the objective to practice a tactical principle and to improve the technical skills developed in the previous sessions. These tasks were designed according to the characteristics of this model (modification representation, tactical complexity, and modification exaggeration; Tan et al., 2012). Modification representation (e.g., smaller formats such as 1 vs. 1 to 4 vs. 4) was used to increase the players' game involvement; tactical complexity (e.g., small-sided games with numerical superiority of players in attack such as 2 vs. 1 or 4 vs. 3 or using floorball sticks or balls) was used to adapt the complexity of the task according to the player's skill level; and modification exaggeration (e.g., replace goals by zones to arrive to promote dribbling) was used by the coach to modify game rules to emphasize specific tactical and technical learning objectives.

Finally, in both models, the coach also provided feedback to the players, through questioning (Vickers, 2007), emphasizing individual improvement and regulating the players' learning according to their personal capabilities.

Instructional and treatment validity

The fidelity of the hybrid Ludotechnical/TGfU models' program was assessed using a checklist (Table 3; Hastie & Casey, 2014). To assess the intervention, checklist items 1, 3, 5, 7, 9 and 2, 4, 6, 8, 10 enabled researchers to measure coach fidelity to the characteristics of the Ludotechnical and TGfU model, respectively. Two observers were trained in several sessions in which videos were viewed and the different items that made up the checklist were clearly defined. A sample of two training sessions for each model was finally observed (randomly selected), more than 12.5% of the total sample (Tabachnick & Fidell, 2013). 100% agreement was reached between the two observers who assessed the presence or absence of each item. Each observer therefore confirmed that all key aspects included in the instructional checklist (see Table 3) were performed by the coach in each of the observed training sessions.

Statistical analysis

The statistical program SPSS v24.0 (Chicago, IL) was used for data analysis and processing. First, preliminary assumption testing was conducted to check for homogeneity of variances and normality. Shapiro-Wilk test (for samples of 30 or less) was performed and verified that the sample distribution did not follow a normal distribution ($p < .05$), establishing the need to use non-parametric statistical methods. Second, to verify any existing differences between the different measures (pre-intervention and post-intervention) in dependent variables (types of motivation), an inferential analysis was performed using the Wilcoxon test for related samples. We calculated the effect size (ES) with Cliff's delta calculator (Macbeth et al., 2011). A Cliff's delta value of .147 is considered small, a value of .33 is considered medium, and a value of .474 is considered large (Romano et al., 2006).

Table 3
Instructional checklist.

		Present	Absent
1	The coach introduces the session and proposes a question/challenge related with a technical skill.		
2	The coach introduces the session and explains the tactical principles to practice.		
3	Ludotechnical proposals followed by a global proposal are developed.		
4	All the tasks are small-sided games (contextualized context).		
5	The learning is focused on technical skills.		
6	The learning is focused on tactical skills.		
7	Interrogative feedback is focused on the execution skill.		
8	Interrogative feedback is focused on the decision-making skill.		
9	At the end of the session, the challenge question has been answered.		
10	At the end of the session, the tactical skills have been reviewed.		

Table 4
Descriptive statistics and within-group analysis of each variable.

	Pre		Post		*p*	*Cliff's delta* |δ|	*Effect Size Interpretation*
	M	SD	M	SD			
IMtK	5.52	1.08	6.70	0.33	.008*	.68	Large
IMtES	5.98	1.27	6.80	0.40	.017*	.40	Medium
IMtA	5.89	1.23	6.23	1.03	.149	.17	Small
Identified	5.34	1.33	5.66	0.85	.496	.09	Negligible
Introjected	5.20	0.91	4.09	0.82	.005*	-.66	Large
External	5.36	1.32	3.50	1.19	.003*	-.72	Large
Amotivation	3.50	1.15	2.66	0.32	.052	-.52	Large

Note. IMtK: intrinsic motivation to know; IMtES: intrinsic motivation to experience stimulation; IMtA: intrinsic motivation to accomplish; * = significant difference ($p < .05$)

Results

The descriptive and inferential analysis between pre-intervention and post-intervention measures is presented in Table 4. The results showed a significant increase in intrinsic motivation to know ($p < .05$, large ES) and intrinsic motivation to experience stimulation ($p < .05$, medium ES), and a significant decrease in introjected and external regulations ($p < .05$, large ES). Non-significant differences were found in intrinsic motivation to accomplish ($p > .05$, small ES) and identified regulation ($p > .05$, negligible ES). Changes in amotivation were not significant ($p > .05$), but the effect size was large.

Discussion

The aim of the present study was to analyze the effect of an intervention program based on the Ludotechnical Model and Teaching Games for Understanding (TGfU) on players' motivation in roller hockey. Overall, results revealed an increase in some autonomous forms of motivation and a decrease in controlled motivation, as it was hypothesized. Regarding autonomous motivation, the intervention had a positive effect on intrinsic motivation to know and intrinsic motivation to experience stimulation. These results could be explained considering the focus of the TGfU model in the conceptual, cognitive, and tactical aspects of sports learning and the focus of the Ludotechnical Model in providing fun experiences that stimulate players. Previous research in other physical education and sport contexts also showed increases in intrinsic motivation after implementing an intervention with the TGfU (Gil-Arias et al., 2021) and Ludotechnical (Yupa-Pintado & Heredia-León, 2021) models. These pedagogical models are characterized by an autonomy supportive teaching that could satisfy basic psychological needs and promote intrinsic motivation. However, no significant effects were found for intrinsic motivation to accomplish in the present study. Considering the peculiar characteristics of this sport, in which players move on skates and carry a stick in their hands, a longer intervention may be needed to achieve higher improvements in the development of technical skills that promote intrinsic motivation. Research in this area is still scarce and the present study is the first one in roller hockey.

The intervention also had no significant effect on players' identified regulation. This could be because the intervention through these pedagogical models was not especially centered in showing the importance of sport for other areas of life. It would have been interesting to include some reflections to display the transference of the technical and tactical aspects that they have learnt to other collaboration-opposition sports.

As expected, we also found a decrease in players introjected and external regulations. This is an interesting result because players presented moderate scores in these variables before the intervention and these types of motivation are related to sport dropout (O'Neil & Hodge, 2020). In line with previous research, implementing new models that are different from the traditional methodology that the players knew helped them to reduce their objectives linked to self-approval, ego-oriented, and focused on external incentives (Valero-Valenzuela et al., 2009). Amotivation was also reduced with a large effect, but it was not significant probably due to the sample size. Therefore, the intervention seemed useful to diminish the most negative types of motivation established in self-determination theory.

Despite the strengths, several limitations and future research directions should be considered. Firstly, the effects of only a short hybrid Ludotechnical/TGfU program were examined in this study. Consequently, it would be valuable to longitudinally analyze the effect of a similar intervention during one season. Secondly, we only measure motivation as an outcome. More variables should be included in future research to analyze the complete sequence established in the self-determination theory. In this regard, it would be interesting to test if an intervention through these pedagogical models positively affects the player's perception of their coach's

autonomy support, satisfies their basic psychological needs, improves their motivation, and all of this contributes to achieve positive consequences like engagement, enjoyment, and performance, and to prevent negative consequences such as boredom, anxiety, fear of failure and dropout. Furthermore, it would be of interest to develop research that uses other instruments for collecting results (e.g., semi-structured interviews) to carry out qualitative or mixed-method studies. We have to admit that the reliability of the instrument used in this study cannot be confirmed due to the small sample size. Considering this issue, the short age of the participants (that could make the questionnaire difficult to understand), and the lack of control group, the results should be interpreted as exploratory. Further studies should be developed with a higher number of participants and different age and levels of expertise to improve the understanding of this hybrid proposal.

This study provides initial evidence that a hybrid Ludotechnical /TGfU unit can be implemented in a sport like roller hockey to produce significant improvements in players' motivation. Specifically, findings showed that the intervention increased intrinsic motivation to know and intrinsic motivation to experience stimulation and decreased introjected and external regulations. Future research in this line is necessary to provide scientific knowledge that helps coaches to improve their sports programs with the objective to manage better the motivational process of training.

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Declarative Tactical Knowledge and Playing Position in a Professional Football Club: Real Sociedad

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Boat Zero and Patriot Sail on a Glamour Barcelona Day.
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Abstract

There is a need to characterise playing positions in football, as well as to investigate the relationship between declarative (DTK) and procedural (PTK) tactical knowledge. For these reasons, the aim of the study was to analyse the influence of playing position on the DTK of 163 players (16.7 ± 2.4 years) in the academy of a professional football club. The "TESTACTICO for F7" tool was used to assess the DTK of the participants, analysing the results obtained according to their positions (goalkeepers, central defenders, external defenders, midfielders, wingers and forwards), and ensuring an adequate effect size (f = 0.28) via G*Power. ANOVA analysis of variance was implemented, using Tukey's HSD test for multiple *post hoc* comparisons, by assessing the magnitude of the differences found by pairs of positions through the Cohen's d effect size. Macro level comparisons between positions revealed no significant differences in overall offensive and defensive scores. Significant differences were found between groups at the meso level ($p \leq .05$) in the operational principle "Progress towards rival area" and the fundamental principle "Width and length". However, the *post hoc* pairwise comparison revealed non-significant differences in both variables. The same happened at the micro level with the behaviours "dribble to beat the rival" and "give depth to the attack by positioning in length". In conclusion, the DTK values did not allow for differentiation between players according to their position, which casts doubt on a direct relationship between DTK and PTK.

Keywords: decision making, football training, performance, positional role, talent.

Introduction

Due to the highly demanding nature of football matches, different tactical roles of the players are needed in order for the team to act as a whole (Gréhaigne et al., 1997). These various roles are influenced by the playing position assumed by each player in the match (Machado et al., 2019; Padilha et al., 2013). In each position, there are behaviours that are more important than others, either because they occur more frequently or because they are particularly relevant (Sánchez-López et al., 2023a). For this reason, studies (Berber et al., 2020; Mota et al., 2023) have been aimed at defining attributes for positional profile characterisation in football. Similarly, in recent years, the effects of playing position during football training on different variables such as: visual search strategies (Dambroz et al., 2022); tactical behaviours in reduced and conditioned games (Machado et al., 2019); offensive and defensive tactical performance (Gonçalves et al., 2017); workload demands in matches and reduced games (Beenham et al., 2017); advanced biological maturation (Sweeney et al., 2023); injury incidence rate (Hall et al., 2022) and the ability to repeat sprints (Çetin & Koçak, 2022) have been investigated.

Regarding tactical knowledge, a distinction can be made between Procedural Tactical Knowledge (PTK) and Declarative Tactical Knowledge (DTK). PTK is closely linked to motor action (Kirkhart, 2001; Teoldo et al., 2011; Williams & Davids, 1995), to "know-how". DTK, understood as the explicit knowledge that is stored in memory, is associated in game terms with "knowing what to do" (Thomas et al., 1986), i.e. with the player's decision making in a theoretical game situation. In recent years, the relationship between declarative and procedural approaches has been studied in relation to the tactical performance of football players, leading to the conclusion that more tactically skilled players obtain higher scores in terms of decision making (Vítor de Assis et al., 2020), and that selected players are faster and make better decisions than those who are not selected (Machado et al., 2023). In this sense, analysing the impact of playing position on players' DTK may verify whether there is a relationship between knowing what to do and doing it in specific game aspects, given that procedurally there are tactical behaviours that are better developed by players who occupy certain positions (e.g. shooting in forwards or tackling in defenders).

Regarding the relationship between playing position and DTK, a study (Giacomini et al., 2011) conducted with 221 young football players in an amateur context revealed no significant differences in players' DTK according to the playing position occupied on the field. Nor were significant differences in the quality of responses found in another study (Andrade et al., 2021), with a sample of 30 U-13 players in regional competition. Although work that has assessed the DTK of players in academies of professional football clubs already exists (Sánchez-López et al., 2023c), no studies have been found that assess DTK according to playing position. Furthermore, it would be interesting to include different tactical dimensions in the DTK assessment, from those that have to do with the particular behaviours of the players (micro level), those linked to the socio-motor role and the principles of the game (meso level) and those that involve the set of behaviours that define the player's performance, both in offensive and defensive phases of the game (macro level).

Therefore, the aim of this study was to analyse the influence of playing position on the DTK of players in the academy of a professional football club. A first hypothesis was that no significant differences would be found according to playing position at the macro level. A second hypothesis was that there would be significant differences according to playing position at meso and micro level in some game aspects. In addition, a third hypothesis that players' mental representations may not be in line with what they actually do was presented. In other words, those game aspects that players perform best, and which are most linked to their playing position in procedural terms, need not be those aspects that they manage best declaratively. Addressing these hypotheses could help to further clarify the relationship between declarative and procedural aspects, and consequently improve learning processes.

Method

Design

To obtain each participant's DTK score, selective methodology was used in accordance with the following requirements (Anguera, 2003): the mental representations of the sample were accessed through the participants' direct interventions; a standardised multiple response test was used; the variables of interest were selected prior to the study; the possible covariance relationships between the variables were analysed; and it was nomothetic, as the test was applied extensively to a set of participants.

Table 1
Levels of concretion and variables of "TESTACTICO for F7" via Football Competence Observation System (FOCOS).

Attack	Dependent Variables	Defence
Player's Declarative Tactical Knowledge		
MACRO LEVEL		
Offensive score	Global Score	Defensive Score
MESO LEVEL		
Attacker with the ball	Roles	Defender in the intervention space
Attacker without the ball in the game center		Defender in game center
Attacker without the ball out of the game center		Defender out of game center
Ball control	Own Action of the Sub-Role	Tackling
Driving		Interception
Dribble		Dissuading
Passing		Relocating
Shooting		
Move off-the-ball		
Positioning		
Maintain ball possession	Operational Principles	Regain Possession
Progress towards rival area		Prevent opponent's progression
Achieving the goal		Protect the goal
Penetration	Core Principles or Specific Principles of Football	Delay
Offensive coverage		Defensive coverage
Depth mobility		Balance
Width and length		Concentration
Offensive unity		Defensive unity
MICRO LEVEL		
A1 - Control the ball ahead of previous action (*)	General Tactical Behaviours	D1 - Make a tackle to the rival
A2 - Control the ball at the same height or behind the previous action (*)		D2 - Intercept, clear or divert a pass
A3 - Control the ball in the rival area or in front of the last defender (or surpassed this one)		D3 - Block a shot
A4 - Driving the ball forward (*)		D4 - Redirect the opponent's attack
A5 - Driving the ball backwards, right, or left (*)		D5 - Do not give the opponent a shot option without entering him (avoid possible shot)
A6 - Driving the ball in the rival area or in front of the last defender (or surpassed this one)		D6 - Take care of the partner's back in the intervention space in a staggered manner
A7 - Dribble to beat the rival (*)		D7 - Move to create superiority in the game center or mark/ watch opponents
A8 - Dribble without progress avoiding rival tackle (*)		D8 - Create uncertainty in the last opponent line or reduce the effective playing space
A9 - Dribble in the rival area or in front of the last defender (or surpassed this one)		D9 - Relocation in the last defensive line reducing the effective playing space
A10 - Pass the ball forward (except to assist)		D10 - Increase the protection of the goal, marking or watching opponents
A11 - Pass the ball backward, right, or left (except to assist)		
A12 - Assist teammate to score goal		
A13 - Shoot at goal		
A14 - Move giving close option ahead of the ball		
A15 - Appear in a space suitable to scoring a goal (near the teammate with the ball)		
A16 - Take care of the back of the partner with the ball or give option close to the right / left		
A17 - Move away from the ball appearing between rival lines or behind the defense		
A18 - Appear in a space suitable to scoring a goal (away from the teammate with the ball)		
A19 - Give depth to the attack by positioning in length		
A20 - Give amplitude to the attack by positioning in width		
A21 - Relocate in coordination with the teammates on the last line		

(*) Except in the rival area or in front of the last defender (or surpassed this one)

Table 2
Sample characteristics and DTK scores (macro-level) according to playing position.

Playing Position	N	Age (in years)	Experience (in years)*	In the club (years)	Global DTK	Offensive DTK	Defensive DTK
Goalkeeper	17	16.4 ± 2.3	7.9 ± 2.1	3.6 ± 2.1	8.7 ± 0.6	9.0 ± 0.6	8.0 ± 0.9
Central defender	27	16.8 ± 2.6	8.0 ± 2.0	3.9 ± 2.3	8.8 ± 0.5	9.0 ± 0.6	8.3 ± 0.9
External defender	33	16.9 ± 2.6	8.0 ± 1.9	3.9 ± 2.8	8.6 ± 0.7	8.8 ± 0.9	8.2 ± 0.9
Midfielder	38	16.7 ± 2.4	8.0 ± 1.8	3.7 ± 1.9	8.6 ± 0.7	8.8 ± 0.7	8.1 ± 1.0
Winger	26	16.9 ± 2.2	8.3 ± 2.1	3.8 ± 2.2	8.7 ± 0.6	9.0 ± 0.6	8.3 ± 1.0
Forward	22	16.7 ± 2.6	8.4 ± 1.6	3.3 ± 1.9	8.5 ± 0.9	8.8 ± 0.8	8.0 ± 1.4

* Experience of more than 10 years was considered exactly 10 years.

The test was completed by the participants in May, at the end of the 2021-2022 season. Then, using an associative strategy, a retrospective comparative design approach was implemented (Ato et al., 2013), which determined the possible influence of the independent variable on the dependent variables. In this case, the playing position acted as the independent variable and the dependent variables were the 67 DTK-based scores of the participants, according to three levels of specificity, from the most general to the most specific aspects. A first level, or macro level, which enables the analysis of the total test scores (overall, offensive and defensive); a second level, or meso level, comprising the criteria category systems (roles, subrole actions, operational principles and fundamental or football-specific principles) that make up the observation system used as a reference; and a third level, or micro level, with more specific scores based on general tactical behaviours (see Table 1).

Participants

A total of 163 football players (16.7 ± 2.4 years) aged 12 to 22, who were members of the men's teams in the Real Sociedad de Fútbol's Academy, formed the sample for this study. According to the Participant Classification Framework (McKay et al., 2022), the sample can be categorised at level 3: "Highly Skilled/National Level". This level includes team sport athletes competing in national and/or state leagues/tournaments (= ~0.014% of the world population). Table 2 contains further information on the sample grouped by playing position, in order to illustrate the context of the academy and to ensure consistent replicability of the study in other clubs.

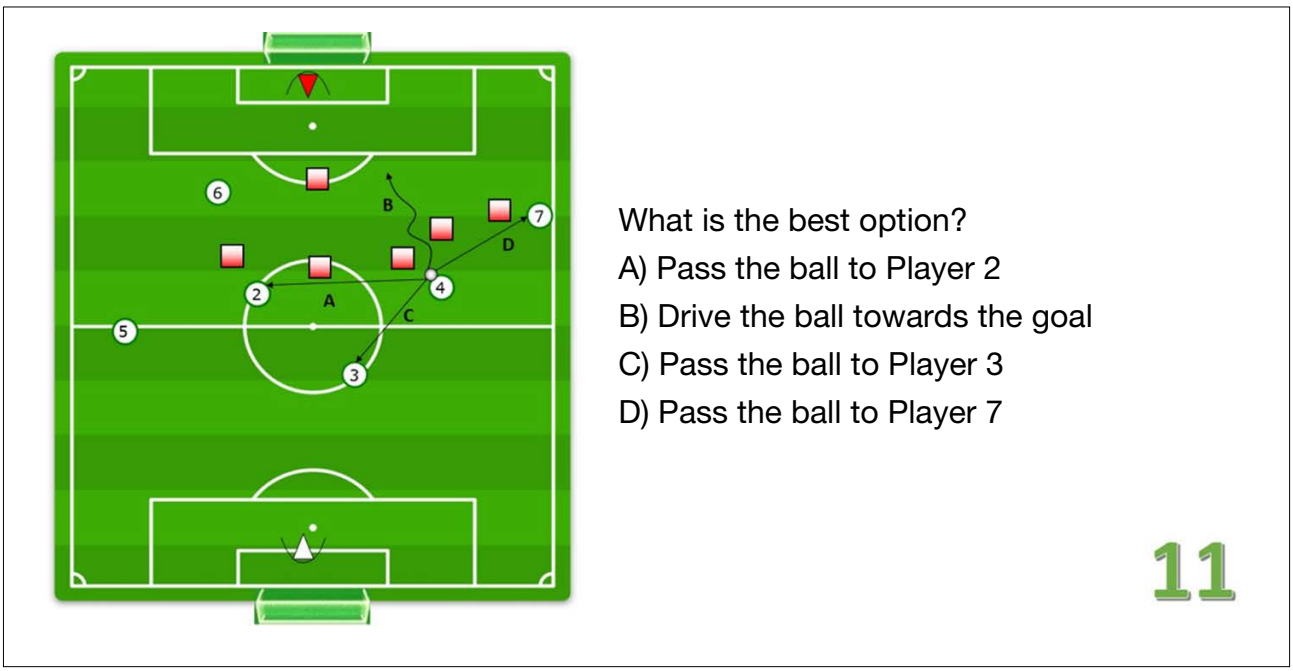
The study was conducted according to the Declaration of Helsinki Guidelines (Bošnjak, 2001; Tyebkhan, 2003) and Organic Law 15/1999 on the Protection of Personal Data (BOE 298, 14 December 1999), to ensure ethical considerations in scientific research involving humans. All data in this study has been provided by Real Sociedad de Fútbol Club, guaranteeing the anonymity of the participants. The protocol was approved by the Ethics Committee for Research Involving Human Subjects (CEISH) of the UPV/EHU, with reference number M10_2022_328.

DTK Assessment Tool

TESTACTICO for F-7 (football-7) (Sánchez-López et al., 2023b) can be included within the range of instruments classified as multiple-choice tests with static images of game situations that allow DTK assessment. It was designed based on the findings of a systematic review (Sánchez-López et al., 2022), yielding evidence of content and construct validity, as well as reliability and generalisability. These processes were discussed in detail in a recent publication (Sánchez-López et al., 2023b). The tool is composed of 62 game situations classified according to the Football Competence Observation System —FOCOS— (Sánchez-López et al., 2021).

In each situation, the participant has to put himself in the place of one of the football players and choose from the four options presented, with one correct and three incorrect solutions. Each game situation simultaneously addresses a role, a certain action resulting from the acquired subrole, an operational principle, a fundamental principle and a general tactical behaviour (see Figure 1).

Figure 1
Game-play situation #11: DTK assessment of Attacker with the ball (role), Passing (sub-role action), Maintain ball possession (operational principle), Width and length (core principle) and Pass the ball backward, right, or left, except for assisting (general tactical behaviour)



Procedure

In order to assess the participants, a specific room at the Zubieta Academy was used. The participants took the test using a laptop, they were separated so that they were unable to see each other's answers, and they were supervised by the Club's coaches. After arriving in the room, they received a link to a Google Form containing the assessment test.

Once on the form, and after receiving a brief explanation of the test, participants filled in their demographic data, as well as other data of scientific interest, which would serve as independent variables in future studies. Subsequently, they were faced with 62 game situations comprising the test, which lasted approximately 25-45 minutes depending on age, so that it could be carried out quickly and sustainably.

Immediately after completion of the test, participants were able to access their overall score (from 0 to 62 points), and the researcher received the raw data, which were exported to an Excel file for cleaning, processing and organising. Following this process, each variable studied was presented on a scale from 0-10 for the macro and meso levels, and 0-2 for the micro level.

Statistical Analysis

An Excel database containing the data obtained from the DTK assessment test was created and organised for processing. The Google Colab environment's Python programming language was used to process and visualise the results obtained using the libraries *numpy*, *pandas*, *seaborn* and *matplotlib*. SPSS v.19 software was also used to explore significant evidence according to playing position. ANOVA analysis of variance was used, using Tukey's HSD test for multiple *post hoc* comparisons. The sample was analysed according to playing position (n = 6), using G*Power v3.1 software to determine the robustness of the test. A one-way fixed effects ANOVA design was implemented, analysing sensitivity based on the following parameters ($\alpha = 0.05$, robustness = 0.80, total sample = 163, number of groups = 7). Sensitivity detects the minimum effect size of the test (Cardenas & Arancibia, 2014) which was adequate ($f = 0.28$) for the study conducted (Cohen, 1988).

Following the procedure implemented in the study in which the tool used was validated (Sánchez-López et al., 2023b), and in order to control the family-wise error rate per category system in each criterion, the following references were used for statistical significance, to establish comparisons

between playing positions: total scores ($n = 3$, $p \leq .017$), roles ($n = 6$, $p \leq .008$), subrole actions ($n = 11$, $p \leq .005$), operational principles ($n = 6$, $p \leq .008$), fundamental or football-specific principles ($n = 10$, $p \leq .005$) and general tactical behaviours ($n = 31$, $p \leq .002$). The Cohen's *d* effect size was also calculated (Cohen, 1988) to assess the extent of the differences found in the study groups. Differences based on effect size are descriptively referred to as either very large ($d \geq 2$), large ($2.0 > d \geq 1.2$), moderate ($1.2 > d \geq 0.6$), small ($0.6 > d \geq 0.2$) or trivial ($0.2 > d \geq 0$) (Hopkins et al., 2009).

Results

The results are presented in different sections, starting with the macro level (total scores), followed by the meso level (roles, subrole actions, operational principles and fundamental or football-specific principles), and finishing with the micro level (general tactical behaviours).

Macro Level

The test scores at the macro level (on a scale from 0 to 10) did not reveal significant differences in any of the three variables studied: overall score ($p = .76$, $F = 0.53$), offensive score ($p = .72$, $F = 0.58$) and defensive scoring ($p = .81$, $F = 0.46$). Table 2 displays the average and deviation of the scores obtained according to playing position.

Meso Level

The meso level (on a scale from 0 to 10) refers to the category systems of the criteria (roles, subrole actions, operational principles and fundamental or football-specific principles) of the Football Competence Observation System (Sánchez-López et al., 2021). Analysing each criterion separately, the following results were obtained. No significant differences were found in the role criterion categories.

For subrole actions, "positioning" was the category with the greatest differences ($p = .06$, $F = 2.11$), although these did not reach the threshold for sufficient statistical significance ($p \leq .05$). The *post hoc* pairwise comparison revealed non-significant differences ($p = .12$) between central defenders (8.4 ± 1.4) and forwards (7.2 ± 2.0) of moderate effect size ($d = 0.66$).

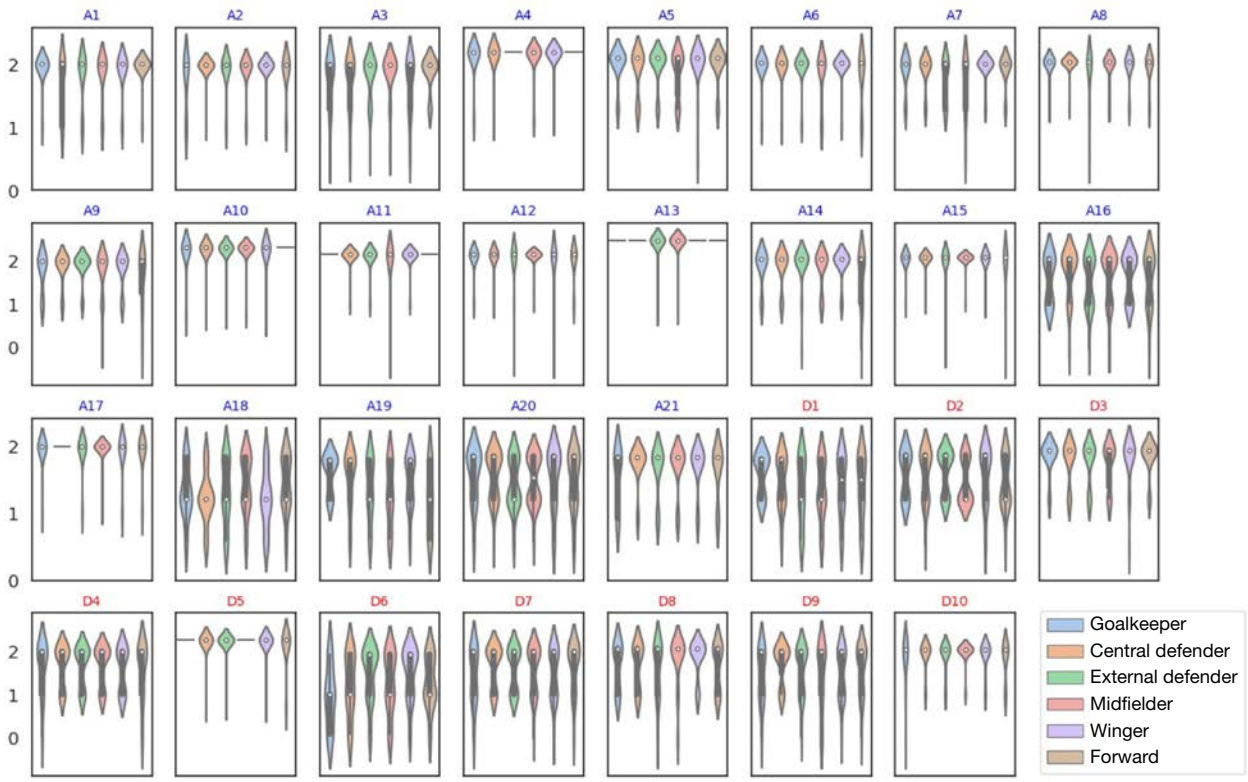
Regarding operational principles, significant differences were found in progress towards rival area ($p = .05$, $F = 2.26$). The *post hoc* pairwise comparison revealed that goalkeepers (9.4 ± 0.6) and midfielders (8.7 ± 0.9) displayed non-significant differences ($p = .09$) of moderate effect size ($d = 0.91$).

For fundamental or football-specific principles, there were significant differences between groups when it came to Width and length ($p = .03$, $F = 2.58$). "Defensive coverage" ($p = .08$, $F = 1.99$) also revealed differences between playing positions, although these were above statistical significance ($p \leq .05$). On the one hand, the *post hoc* pairwise comparison for "Width and length" revealed non-significant differences ($p = .18$) of small effect size ($d = 0.55$) between central defenders (9.0 ± 1.1) and midfielders (8.4 ± 1.1). On the other hand, goalkeepers scored lowest in "defensive coverage" (4.7 ± 3.7), whilst external defenders (7.6 ± 3.3) and wingers (7.7 ± 3.2) scored the highest. The differences were of moderate effect size ($d = 0.83$ y $d = 0.87$), but were not statistically significant ($p = .07$ y $p = .08$).

Micro Level

Finally, the micro level (on a scale from 0 to 2) represents the highest level of detail and is linked to the general tactical behaviours of the study framework. In this case, significant differences were found in the following behaviours: "Dribble to beat the rival" ($p = .01$, $F = 2.98$) and "positioning to give depth to the attack" ($p = .01$, $F = 3.17$). The *post hoc* pairwise comparisons for "Dribble to beat the rival" revealed non-significant differences ($p = .02$) of moderate effect size ($d = 0.84$) between wingers (1.9 ± 0.3) and midfielders (1.5 ± 0.6). Regarding "Give depth to the attack by positioning in length", goalkeepers (1.7 ± 0.5) and central defenders (1.6 ± 0.7) scored best, and midfielders (1.1 ± 0.8) and forwards (1.0 ± 0.8) the worst. The *post hoc* pairwise comparisons revealed non-significant differences between goalkeepers and midfielders ($p = .07$), goalkeepers and forwards ($p = .03$), and central defenders and forwards ($p = .08$). The differences were of moderate effect size ($d = 0.9$, $d = 1.04$ and $d = 0.8$, respectively). An overview of all the results obtained at the micro level is displayed by violin plots in Figure 2, which demonstrates the density of the scores in each assessable section.

Figure 2
DTK Scores based on General Tactical Behaviours according to Playing Position.



General Offensive Tactical Behaviours:

A1 - Control the ball ahead of previous action (*)
A2 - Control the ball at the same height or behind the previous action (*)
A3 - Control the ball in the rival area or in front of the last defender (or surpassed this one)
A4 - Driving the ball forward (*)
A5 - Driving the ball backwards, right, or left (*)
A6 - Driving the ball in the rival area or in front of the last defender (or surpassed this one)
A7 - Dribble to beat the rival (*)
A8 - Dribble without progress avoiding rival tackle (*)
A9 - Dribble in the rival area or in front of the last defender (or surpassed this one)
A10 - Pass the ball forward (except to assist)
A11 - Pass the ball backward, right, or left (except to assist)
A12 - Assist teammate to score goal
A13 - Shoot at goal
A14 - Move giving close option ahead of the ball
A15 - Appear in a space suitable to scoring a goal (near the teammate with the ball)
A16 - Take care of the back of the partner with the ball or give option close to the right / left
A17 - Move away from the ball appearing between rival lines or behind the defense
A18 - Appear in a space suitable to scoring a goal (away from the teammate with the ball)
A19 - Give depth to the attack by positioning in length
A20 - Give amplitude to the attack by positioning in width
A21 - Relocate in coordination with the teammates on the last line

(*) Except in the rival area or in front of the last defender (or surpassed this one)

General Defensive Tactical Behavious:

D1 - Make a tackle to the rival
D2 - Intercept, clear or divert a pass
D3 - Block a shot
D4 - Redirect the opponent's attack
D5 - Do not give the opponent a shot option without entering him (avoid possible shot)
D6 - Take care of the partner's back in the intervention space in a staggered manner
D7 - Move to create superiority in the game center or mark/watch opponents
D8 - Create uncertainty in the last opponent line or reduce the effective playing space
D9 - Relocation in the last defensive line reducing the effective playing space
D10 - Increase the protection of the goal, marking or watching opponents

Y-axis Scores:

2 - Participants know what to do
1 - Participants are not sure
0 - Participants do not know what to do

Discussion

The aim of this study was to analyse the influence of playing position on the DTK of players in the academy of a professional football club. The first hypothesis of the study was confirmed, as, at the macro level, no significant differences were found according to playing position. This finding is consistent with results published in previous studies (Andrade et al., 2021; Giacomini et al., 2011), where no differences in the quality of declarative decision making according to playing position were found.

The second hypothesis suggested that there would be significant differences according to playing position at the meso and micro levels in some aspects of the game. This assumption was partly confirmed, since the results of the study revealed significant differences ($p \leq .05$) between positions at the meso and micro levels. However, no statistically significant pairwise differences were obtained according to the tool reference values (Sánchez-López et al., 2023b). This implies that the following findings should be treated with caution and should not be applied to other populations.

Being at the centre of the game (Gréhaigne et al., 1997), i.e. in the vicinity of the ball (10-12 m), or being outside of it, produces different behaviours in players during the course of the game. Regarding the actions linked to socio-motor subroles, central defenders were better than forwards at "positioning", which is linked to knowing what to do in situations that occur outside the centre of play connected to giving depth, width or repositioning in the defensive line. This may be because central defenders have a privileged view of the movements of all their team-mates and play a very important role in communicating how to organise the team and where to position the defensive line.

With regard to operational principles, goalkeepers scored better than midfielders for "progress towards rival area". This result differs from expectations because, in attack, the midfielders are mainly associated with the process of construction and the teams' advance into the opponent's half (Andrade et al., 2021). Perhaps, the fact that in some cases they prioritise the need to defend in order to protect possession of the ball may have played a role.

In terms of fundamental or football-specific principles, goalkeepers were worst at the fundamental principle of "defensive coverage" and no significant differences were found among the other playing positions. The latter differs from findings in a study at the procedural level (Rechenchosky et al., 2017), which revealed that defenders showed greater on-field efficiency than midfielders in terms of "defensive coverage". In addition, central defenders scored higher than midfielders for the fundamental principle of "width and length". This finding is in line with the results of a study (Praça et al., 2020) on the impact of all-rounder players in different contexts in reduced games, as it was found that midfielders took actions linked to width and depth without the ball in terms of PTK less frequently. However, another study (Andrade et al., 2021) revealed that midfielders showed a greater ability to read the game and make quicker decisions compared to defenders in terms of DTK. In this respect, because of their playing position, central defenders, unlike midfielders, tend to have more time and a better position for anticipating their team-mates' positions on the pitch.

At the micro level, wingers had a higher DTK than midfielders in situations involving the behaviour "dribble to beat the rival", which could be due to the fact that wingers have a greater impact in areas close to the opponent's goal, usually occupying an open position and making more assists and dribbles than players in other positions (Izquierdo et al., 2023). It was also revealed that goalkeepers and central defenders scored higher than forwards and midfielders in situations linked to the general tactical behaviour of "Give depth to the attack by positioning in length". Paradoxically, goalkeepers and central defenders are the furthest away from those spaces that condition the depth of the team, and it is the forwards who must understand how to manage these spaces in order to provide depth to the team. It is true that goalkeepers and centre-backs will often have to look wide to play direct, and, perhaps because of this, they had a greater declarative knowledge of how best to exploit the depth of space.

The third hypothesis that the players' mental representations may not be in line with what they actually do, was confirmed. To arrive at this finding, an analysis of whether or not the actions linked to the socio-motor subroles that players perform best on the field are those that they manage best declaratively was carried out, bearing in mind that each playing position requires different skills. The results demonstrated that there were no significant differences by playing position. However, it is interesting to analyse certain results of some positions.

In the case of goalkeepers, it is striking that they scored higher than outfield players (given that the tool evaluates outfield players' game situations), and in some variables they were even the position with the highest scores. This may

be because the goalkeeper's position provides a very good field of vision from which to observe the game and, therefore, they can be more receptive to what their teammates are doing and even anticipate their behaviour. However, the results revealed some very peculiar findings at the defensive level. In the actions "tackling" and "interception", goalkeepers obtained the highest scores, whilst, in "dissuading and relocating", goalkeepers obtained the lowest scores. The fact that goalkeepers scored the worst for actions that occur away from the ball ("relocating") raises a debate as to whether it is the goalkeeper who should lead the coordination of defensive movements or whether the defence should organise itself. The results suggest that goalkeepers focus their attention on the ball. Therefore, goalkeeping coaches could help them to focus on what is happening outside the centre of play (for example, the opponents' movements on their weak side, surveillance and marking in possible finishing areas, clearances behind their defensive line...) from the privileged position they usually occupy.

Central defenders scored the highest for the action "dribbling", followed by wingers. Although "dribbling" is obviously not an action specific to central defenders, these players could have a high DTK of situations related to this action, given that they have to deal with it regularly because of their opponents, and it is closely linked to "tackling". It is precisely the central defenders who scored higher for "tackling" than the rest of the outfield players. They also stood out from the other playing positions defensively in the "relocating" action, which is closely linked to movements used to reorganise themselves with their teammates and facilitate the joint action of protecting their own goal.

The external defenders, together with the wingers, obtained the highest scores for the action "driving", although there were no significant differences in relation to the other playing positions. In contrast to the central defenders, the external defenders obtained the lowest scores for "dribbling" and outperformed the midfielders only for the action "tackling". These results seem to differ from what is happening at a procedural level, because it is usually the backs who are the first to deal with attempts by the opposing wingers to advance.

The midfielders did not stand out for "passing", as might have been expected, given that they account for most of the passes made by the team during the match, an they are key players in this respect (Oliveira et al., 2016). In addition, this position scored worst for the actions "tackling", "driving", "dribble and interception". However, midfielders scored highest for the actions "move off-the-ball and dissuading", which are closely linked to the management of space around the ball.

The wingers scored highly in "driving" and "dribble", actions linked to their playing position. However, together with the forwards, they scored worst at the action move off-the-ball which is also closely linked to their playing position.

Forwards scored highest in "shooting", as did wingers, centre-backs and goalkeepers. The backs and midfielders scored very highly, but did not obtain the top scores. These types of situations, so close to the opponent's goal, seem to be very easy to solve, at a declarative level, for highly skilled football players, so it is not possible to make an assessment with this type of sample. For "ball control", the forwards scored the best and the central defenders the worst.

From the above, although certain relationships between declarative and procedural aspects in the playing positions studied were described, it should be emphasised that no significant differences were found according to playing position. In this regard, it can be argued that although DTK is a characteristic of football competence (Williams & Davids, 1995), high DTK does not always imply high football competence. Whilst how to play can be learnt by playing, i.e. through practice, declarative aspects can be learnt in other non-motor ways (visualisation, reflection, questioning...). In other words, DTK and PTK address two very different dimensions, the non-motor and the motor, or, in other words, knowledge and know-how.

In terms of study limitations, some of them can be summarised. On the one hand, although the quality of the sample relates to players at the highest level of competence for their age, as they are all enrolled in the same professional football academy, it would be interesting to have had a larger number of participants. In addition, it would have been interesting to access a sample of younger players, e.g. < 12 years old, potentially revealing other types of relationships between declarative and procedural aspects, before there is a very clear positional specialisation. It would also have been interesting to access response time in declarative decision making, as differences at the positional level have been described (Andrade et al., 2021).

In terms of the practical application of the findings, no significant differences were found between playing positions with respect to position-specific DTK. As this is the first study of this kind, further work is needed to advance the understanding of how players claim to behave and how they actually behave.

Conclusions

This study revealed that players in a professional football academy did not exhibit significant macro level differences (overall, offensive and defensive scores) in their DTK according to playing position. At the meso level (roles, subrole actions, operational principles and fundamental or football-specific principles), significant ($p \leq .05$) differences were found according to position in the operational principle "progress towards rival area" and the fundamental principle Width and length. However, the *post hoc* pairwise comparison revealed no significant differences in both variables. Finally, at the micro level, the same was true for the general tactical behaviours dribble to beat the rival and "give depth to the attack by positioning in length". In conclusion, it is possible to find players who, in aspects linked to their own playing position, present a lower DTK than that shown by players who play other positions, which calls for the need to continue rethinking the degree of relationship between DTK and PTK.

Conflict of Interests

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Cardiocirculatory, metabolic, and perceptual responses in elite wheelchair fencing competition

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Boat Zero and Patriot Sail on a Glamour Barcelona Day.
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Abstract

Wheelchair fencing is a sport characterized by intermittent bursts of effort in which the speed of actions is at its maximum. However, there is a lack of literature concerning the evolution of fatigue in this sport when compared to the available information related to the Olympic discipline. The objective of this study was to calculate the cardiocirculatory, metabolic, and perceptual values in an international wheelchair fencing competition in order to enhance the resources for specific training for this sport. A total of 16 fencers from categories A (7) and B (9) competed. The participants were monitored for heart rate, blood lactate, and perceived exertion during each phase of the competition. Both heart rate (p = .014) as well as blood lactate (p = .037) and perceived exertion (p = .04) increased more in the direct elimination phase than in the pool phase and stabilized during the final portion of the competition. In conclusion, all the parameters analyzed tended to increase after the pool phase and reached their maximum values during direct elimination bouts. Despite the metabolic values slightly exceeding the aerobic threshold, there is a need to create training strategies to delay fatigue, and thereby prevent coordination errors, as preventing said errors is particularly important in this Paralympic discipline, as it requires heightened accuracy at maximum speeds.

Keywords: heart rate, lactate, Paralympic fencing, perceived exertion.

Introduction

Olympic fencing is an acyclic sport with an elevated number of high-speed actions. In terms of energy demand, in a competition involving multiple bouts within a total interval of 3-4 hours, the aerobic system contribution is about 80-90% (Bottoms et al., 2023). This aspect is more pronounced in direct eliminations, with an estimated energy expenditure of 8.6 ± 0.54 metabolic equivalents (Milia et al., 2014); therefore, improving this system, exemplified by adaptations such as increased size and number of mitochondria, will help maintain intensity over a longer period (Yang et al., 2022).

This sport is of an intermittent nature, demanding a vast amount of energy from the phosphagen system (Turner et al., 2014). From an analytical perspective, alactic anaerobic stimuli occur during a bout due to a series of actions within a unit of time, with blood lactate values reaching 4 $mmol \cdot L^{-1}$ (Turner et al., 2017b), bearing in mind the initial pool classification rounds and the following direct elimination rounds, until the end of the competition, in which the difficulty of the rivals increases.

Calculating the intensity at which a fencer competes from a cardiorespiratory perspective is key to planning their physical training. While the demands of a wheelchair competition are lower than those of standing fencing, and similar in direct elimination bouts (Iglesias et al., 2019), it is not comparable to other wheelchair sports like basketball (Vaquera et al., 2016) due to the type of exertion that each entail.

Taking Olympic fencing as a reference, energy input in absolute terms (Passali et al., 2015) indicates that the contribution of the aerobic system is very similar across the various competition phases (pools: 185.55 ± 36.43 kJ; 1st elimination bout: 185.46 ± 28.81 kJ 2nd elimination bout: 186.62 ± 27.70 kJ). In the case of phosphagens, a higher contribution occurs in pools (28.70 ± 10.09 kJ) than in direct elimination rounds (1st: 19.53 ± 9.49 kJ; 2nd: 22.25 ± 9.27 kJ). Lastly, the glycolytic system is far superior in pool rounds (16.42 ± 6.47 kJ) as compared to the following 2 rounds (1.20 ± 1.32 kJ and 1.34 ± 1.84 kJ, respectively).

In terms of relative energy, the aerobic system contributes less ($p < .05$) in pool bouts (80.57 ± 4.45%) than in comparison to the first and second 15-touch direct elimination bouts (90.02 ± 4.69% and 88.8 ± 4.28%), respectively. On the other hand, the glycolytic system takes on greater prominence in the first round (6.97 ± 2.53%) than in the following two rounds (0.63 ± 0.73% and 0.60 ± 0.80%). In the case of phosphagens, these remain stable with some fluctuation (pools: 12.44 ± 6.67%; 1st direct bout: 9.35 ± 4.30%; 2nd direct bout: 10.60 ± 4.52%) (Franchini, 2023).

The unit of measure typically used for taking measurements during these competitions is related to the heart rate reserve and the level of VO_2 max., an aspect challenged by various authors who indicate that the latter value is overestimated (for example in sports such as cycling or running) and should therefore be carefully considered (Guimarães et al., 2019). This has been confirmed by other researchers who indicate that this correlation is individual and due to intrinsic characteristics that cannot be generalized (Ferri Marini et al., 2022), as benefits from other capacities may influence this, such as the fact that strength training may contribute to improving strength resistance in combat sports (Cid-Calfucura et al., 2023).

In this respect, there is indeed a consensus regarding the use of perceptual and heart rate values, given the proven high correlation between perceived exertion and beats per minute after exercise (r = .84- .98), during exercise (r = .73 - .85), and during its respective phases (r = .82-.92) (Turner et al., 2017a).

Scales have been shown to be good indicators of intensity, even in strength training exercises, for which the correlation sits at r = .8 (Lagally & Costigan, 2004), even for the precision assessment of the impact of an activity in individuals in wheelchairs (Zhao et al., 2022), and therefore have been shown to be a reliable system for regulating intensity in this capacity. Models such as the OMNI-RES picture system scale can be used in strength training exercises by both men and women. When strength increases, this is reflected in the scale items, which vary according to the exercise (Gearhart et al., 2009). This is relevant because it gives trainers or coaches tools to indicate areas for improvement according to the physiological systems involved (Lagally et al., 2009).

With this in mind, it should be possible to create a competition strategy that addresses fatigue and allows for the incorporation of resources that enable the onset of said fatigue to be delayed, as occurs with nutritional resources: mouth rinsing carbohydrate solution enables skill level to remain the same, though it does not have the same effect on reaction speed in high-level fencers (Rowlatt et al., 2017). In this regard, dehydration is common and represents a very significant risk, though more so in men than in women. This means fluid replacement is fundamental, otherwise pulse is impacted and subsequently rises (Eda et al., 2022), even if it does not have any direct effects on lactate levels (Chryssanthopoulos et al., 2020).

In addition, Olympic and Paralympic fencing have three different disciplines (épée, foil, and saber), with differing action and resting times that also require different energy substrate demands (Tarragó et al., 2023). Some studies have focused on analyzing simulated competitions; for example,

in simulated foil competitions, higher beats per minute and ratings of perceived exertion (RPE) values have been observed in direct elimination bouts (163 ± 13 bpm^{-1} and 3.7 ± 1.2 RPE in pool and 170 ± 10 bpm^{-1} and 5.6 ± 1.6 RPE in direct elimination) (Bottoms et al., 2023). Similar values have been observed in simulated épée competition, but with fewer differences between elimination rounds (168 ± 12 bpm^{-1} in and 169 ± 14 bpm^{-1} in direct elimination) (Oates et al., 2019). Assessments during official competition have not been widely studied in the literature, however heart rate and blood lactate levels have been described in men's épée bouts with values of 166 ± 8 bpm^{-1} and 3.2 ± 0.7 $mmol \cdot L^{-1}$, and in women's foil bouts, with values of 173 ± 7 bpm^{-1} and 4.2 ± 0.9 $mmol \cdot L^{-1}$ (Iglesias & Rodríguez, 1995).

The current literature has little specific data on wheelchair fencing in competition settings. One of the most recent studies described oxygen consumption values in training bouts of 23.3 ± 6.1 $ml \cdot min^{-1} \cdot kg^{-1}$ with peak values of 32.1 ± 7.9 $ml \cdot min^{-1} \cdot kg^{-1}$. The heart rates recorded during these training bouts corresponded to a mean intensity of 72.7 ± 10.3% of the fencers' maximum heart rate. Likewise, the recorded lactate levels were 3.5 ± 3.6 $mmol \cdot min^{-1}$ and RPE was 4.8 ± 3.2 (Oates et al., 2019).

Given the scarce diversity of studies with which to establish a comparison for the quantification of energy output and perception in official competition wheelchair fencing, the aim of this study was to focus on calculating cardiocirculatory (heart rate, heart rate reserve [Bok et al., 2023], WINT index [Sowan et al., 2023]), metabolic (blood lactate), and perceptual values over the course of an international competition with participation from elite category A and B athletes from Finland, Hungary, Peru, Romania, and Spain. Categories A and B correspond to the functional classifications for Paralympic fencing competition.

These calculations will help identify the training loads for these types of fencers and optimize competition-focused physical training programs to counteract fatigue while also contributing to more in-depth knowledge about this Paralympic sport.

Methodology

Participants

An international wheelchair fencing tournament was organized with the épée chosen as the weapon. Within the tournament, 3 different competitions were held with the total number of participants ($n = 16$): i) one with category A athletes ($n = 7$), these being the most functional with good sitting balance, trunk mobility, and good control of their fencing arm; ii) a second with category B athletes ($n = 5$), with impairment of the legs, trunk, or fencing arm, and iii) a third and last competition with less-experienced category B athletes ($n = 4$). The participating countries were Hungary (1), Finland (2), Romania (1), Peru (1), and Spain (11). The sample characteristics are described in Table 1.

The study was approved by the Research Ethics Committee (REC) of the Catholic University of Valencia with Resolution No. UCV/2022-2023/107 and was based on the guidelines described in the Declaration of Helsinki regarding the ethical principles for medical research involving human subjects, and all the individuals participating in the study signed the corresponding informed consent.

Table 1
Characteristics of the sample of wheelchair athletes participating in the study.

Variable		
n		16
Age (years)		34.94 ± 12.94
Sex (*n*)	Male	9 (56.25 %)
	Female	7 (43.75 %)
Height seated		0.85 ± 0.08
Arm span (*m*)		1.65 ± 0.22
Category (*n*)	Class A	7 (43.75 %)
	Class B	9 (56.25 %)
Experience		5.11 ± 5.37
Laterality	Right-handed	13 (81.25)
	Left-handed	3 (18.75)

Materials and methods

Each athlete underwent two specific anthropometric measurements: calculation of seated height and arm span. Neither of the regular height and weight measurements were taken due to the impossibility of taking them in most cases.

For seated height, the participants sat on a 44 cm-high stool. Sitting upright, the head was maneuvered into the Frankfort angle and the stadiometer (Seca 213, Hamburg, Germany) was placed on the vertex of the head. The height of the stool was subtracted from the result to obtain the final height.

To measure arm span, the subject was seated on a backless stool against a wall with the hips and shoulders touching the wall. The subject was instructed to perform a shoulder abduction and elbow extension with the fingers extended. The maximum length between the middle fingers of both hands was measured.

Heart rate (HR), heart rate reserve (HRR), WINT aerobic index (WI), and RPE data were analyzed to determine the fatigue accumulated over the course of a competition. For the physiological values, heart rate was monitored during the competition using a coded armband heart rate sensor (Moofit, Shenzhen, Guangdong, China), and the data were collected using the Pulsemonitor software (Pulsemonitor, Michalowice, Poland). With the previously recorded age and baseline heart rate data, heart rate reserve was obtained using the following equation:

$$HRR = Maximum\ HR\ in\ bout * \frac{100}{220 - Age}$$

And the WINT aerobic load index using the calculation below:

$$WI = Max.\ HR - HR\ \frac{Previous}{220 - Age} - Previous\ HR$$

An épée competition was held according to the regular phases: an initial round of 5-touch, 3-minute pool bouts and a second phase of 15-touch, 9-minute direct elimination bouts. To measure metabolic stress, after each phase the participants' lactate levels were measured 3 minutes after the end of each bout, performed on the earlobe using the Lactate Pro2 analyzer (Arkray Inc., Kyoto, Japan).

While these samples were being taken, RPE was recorded at each interval using the OMNI-RES scale from Robertson et al. (2003), with the aim of establishing a correlation between physiological and perceptual indicators. These procedures are summarized in Figure 1.

Statistical analysis

The data were described using means and standard deviation, as well as medians and interquartile ranges for the continuous quantitative variables and using proportions for the qualitative variables.

The model was adjusted as per the Zuur and Ieno protocol (2016). First, the data structure error was determined by adjusting beyond the optimal model. In the case of the models for determining changes in heart rate and lactate accumulation, the model was adjusted as follows:

$$Y \sim Phase * (Experience + Category + Sex) + 1(1|ID)$$

For the model used to determine changes in perceived exertion, this was adjusted in the following manner:

$$Y \sim Phase * (Experience + Category + Sex) + HR + Lactate + (1|ID)$$

This allowed for consideration of all the factors studied and the first-level interactions between the sociodemographic factors and the competition phase.

Second, the random effects model was adjusted using the individual (ID), estimating the coefficients with the restricted maximum likelihood (REML) method. Subsequently, the fixed effects model was adjusted with the ML method, repeatedly eliminating interactions until the model could no longer be improved. Lastly, the optimal model was generated estimating the coefficients with the REML method. To interpret the model, the coefficients and the results of the type II ANOVA were considered. For the significant categorical factors, post-hoc comparisons were made using the emmeans package.

All the nested models were compared among themselves using the corrected Akaike information criterion (AICc). In all cases, the assumptions of the linear models were checked, visually inspecting the residuals and the DHARMa residuals. The models were adjusted using the lme4 v.1.1-30 and lmerTest v.3.1-3 packages.

All the analyses were carried out with R (R Core Team, 2013) v.4.2.2. The openxlsx v4.2.5 package was used to read the data tables (for xlsx files) and/or the haven v.2.5.0 package (for sav files). The graphs were created using ggplot2 v.3.3.6 ggpubr v.0.4.0 and other functions included in the previously mentioned programs. For all the analyses, $\alpha = .05$ was used.

Figure 1
Software for recording heart rate, lactate samples, description of the OMNI-RES scale protocol.

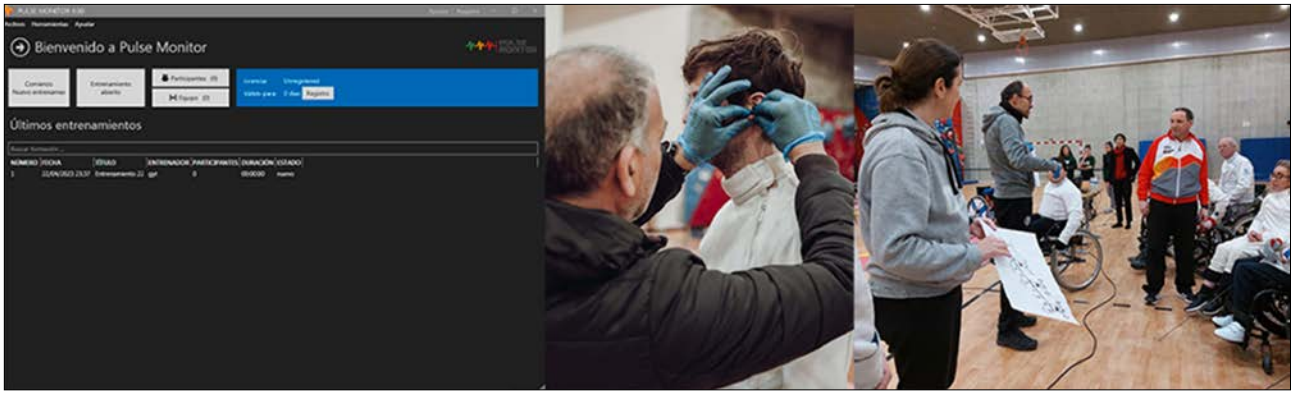

Figure 2
Variation in heart rate during pool and direct elimination phases (F8, F4 and F2).

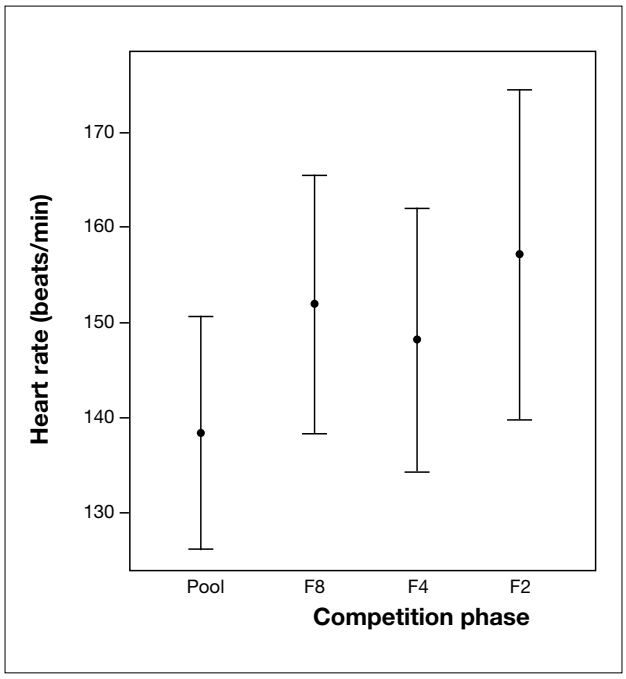

Figure 3
Variation in heart rate and perceived exertion during the pool and direct elimination phases.

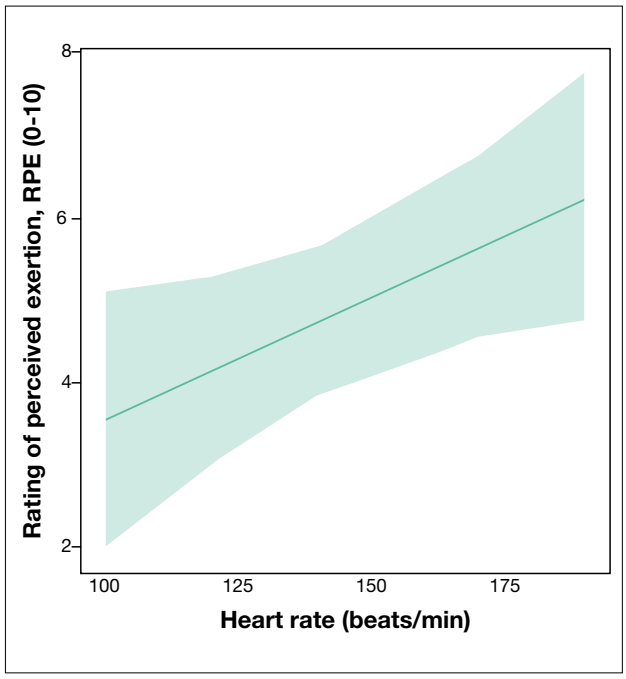

Table 2
Differences in accumulation of lactate between competition phases.

	contrast	estimation	SE	df	T ratio	*p* value
1	Pool	-0.161	0.358	27.443	-0.450	.655
2	F8 - F4	-1.101	0.500	28.378	-2.202	.088
3	F8 - F2	-1.578	0.606	28.582	-2.602	.037
4	F4 - F2	-0.476	0.580	28.285	-0.821	.692

Note: Tukey's test to analyze differences in lactate accumulation.

Results

The initial heart rate values prior to competition were 87.88 ± 23.29 bpm^{-1} and lactate values 2.36 ± 0.84 mmol·L^{-1}. Figure 2 shows the evolution of heart rates across each of the phases and how heart rate values were significantly higher in the direct elimination phases, but without any differences between the sexes (p = 605). Tukey's test indicated significant changes between both phases of the competition (p = .014). These data present a high correlation with two variables dependent on this value, in the case of heart rate reserve r = .90 and the WINT aerobic load index, r = .76.

Table 2 shows the difference in lactate accumulation between the pool phase and direct elimination phases. As with the heart rate, there were no differences between men and women (p = .792).

Figure 3 shows the differences in perceived exertion in pool bouts versus the rest of the tournament (F8, F4, F2). A significant effect was detected indicating that perceived exertion was 1.34 ± 0.43 points higher in the competition phases than in the previous phase.

Bearing in mind the different competition phases, significant differences were observed between the initial phase and subsequent phases (p = .028 and p = .002), though this significant increase did not occur between phases F4 and F2 nor were any differences between the sexes reported (p = .535).

Discussion

It is important to identify the physiological responses resulting from real competition settings, as this helps define the training needs of athletes.

The characteristics of each of the bouts were similar to an interval training exercise, wherein there is a high degree

of uncertainty due to the intermittent pattern. In settings in which measuring respiratory parameters such as VO_2 max. is not possible, having cardiocirculatory, metabolic, and perceptual records is sufficient (López-Chicharro & Vicente-Campos, 2018) for detecting and subsequently addressing the resulting needs for improvement. Along this line of reasoning, Iglesias et al. (2023) presented a study on wheelchair fencing in which they state that it is possible to use heart rate to estimate oxygen consumption by assuming a certain degree of underestimation (9.9%) but with good correlation indices ($r = .843$, $p < .001$).

Over the course of the competition, the average heart rate was 14.08 ± 5.33 beats higher in the direct elimination than in the pool phases, thereby confirming that reported by Turner et al. (2017b), who indicated that this phase, with 15 touches per bout, conditions the contrast for this value ($p = .014$) between phases, only to later stabilize until the end of the competition (F8-F4 $p = .875$, F8-F2 $p = .830$, F4-F2 $p = .561$). This finding shows that both Olympic and Paralympic fencing present similar behaviors in terms of cardiocirculatory response. Fatigue increases progressively in both disciplines and presents a high correlation with heart rate reserve ($r = .90$) and the WINT aerobic load index ($r = .76$). This analysis should be taken into consideration in relation to respiratory rate, which increases with respect to other physical exercises, given that nasal airway resistance following a bout is 0.28 ± .16 $Pa^{cm3/s}$. Without it, in normal physical exercise, the mean value was 0.24 ± .15 $Pa^{cm3/s}$, meaning significant differences were observed between using or not using a fencing facemask before and after sporting activities ($p < .05$) (Passali et al., 2015).

In terms of the metabolic profile, there was no significant difference in lactate accumulation between phases ($p = .656$): a marginally significant effect was observed between the first and second phase of the competition (F8-F4) ($p = .037$). When analyzing the effect of the competition phase on lactate accumulation, this was greater in the last portion of the competition than the first. This data is in line with that described in Olympic fencing competition (Turner et al., 2017b), in which values exceeding 4 $mmol \cdot L^{-1}$ were recorded in the final portion of the tournament.

Likewise, no significant variations ($p = .089$) were observed when considering the category: category A accumulated slightly more than B (1.307 ± 0.715). It is important to bear in mind that more experience correlated with less increase (reduction of 0.127 ± 0.064 $mmol \cdot L^{-1}$), which could be related to the fact that elite fencers are capable of generating greater speeds than lower-level fencers, despite increases in their blood lactate (Weichenberger et al., 2012) compared to those lower-lever athletes. This is important because the resulting peripheral fatigue comes with coordination impairment that can inhibit precision when performing technical movements requiring maximum speed (Varesco et al., 2023).

The RPE followed a similar path as heart rate. This increased as the competition progressed and was most notable between pools and direct elimination bouts ($p = .004$) and each of the subsequent phases (F8-F4 $p = .028$; F8-F2 $p = .002$), with the exception of the last one (F4-F2 $p = .212$). This increase occurred in a parallel manner to that of heart rate (.03 ± .014 for each heart rate unit). This confirms the relationship between perception and heart rate, which in Olympic fencing has obtained a very high correlation during competition ($r = .82$-92) (Turner et al., 2017a), confirming that direct elimination bouts require greater physiological demand (Bottoms et al., 2023). In this regard, no consistent relationship between subjective perceived exertion and increase in blood lactate has been found.

Conclusions

The main conclusions that can be gathered from the cardiocirculatory responses are that the highest heart rate recordings occur in direct elimination phases and these stabilize towards the end of competition. In terms of the metabolic profile, no differences in lactate accumulation occur between phases, rather a gradual increase can be observed. Lastly, perceptual values increase progressively over the course of a tournament. Understanding the responses that occur during real wheelchair fencing competitions make it possible to adapt training programs to athletes' specific physical and technical/tactical needs without the need to make adaptations to the Olympic fencing discipline, as has been done until now.

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Sex-Related Differences in Physical Determinants of Young High-Performance Tennis Players' Serve Velocity

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Abstract

Maximum isometric force-time curve variables are positively related to tennis serve velocity (SV), especially in short time frames and specific movements. This influence could vary depending on gender. For this reason, this study aimed at: a) examining differences between anthropometrics and force-time curve variables in male and female young high-performance tennis players, and b) analyzing associations between these variables and SV. Forty-five players were asked to execute two maximal voluntary isometric contractions (MVIC) in joint positions (shoulder internal rotation [SHIR] and shoulder extension [SHE] at 90 degrees) involved in the serve motion. Results indicated significant greater values for males in SV, SHE peak rate of force development (PRFD), SHIR impulse (IMP) 0 to 150 ms and SHE IMP 0 to 150, 200 and 250 ms. Males presented significant correlations between SV, SHIR and SHE MVIC, PRFD, SHIR RFD at 100, 150, 200, 250 ms and SHE RFD at 50 ms. Females showed positive associations between SV, body mass (BM), SHE MVIC, SHIR RFD at 30, 100 and 150 ms, SHIR IMP at 150, 200 and 250 ms and SHE IMP 150, 200 and 250 ms. Males SV seems to rely on maximal absolute and relative strength values, while females SV may be affected to a superior degree by a combination of greater body mass, maximal levels of force production and accumulation in short time frames.

Keywords: impulse, power, rate of force development, serve, strength.

Introduction

Recent research has established isometric force-time curve variables representing maximum isometric and explosive strength as essential factors that are positively related to serve ball velocity (SV) (Baiget et al., 2021; Colomar et al,, 2022a; Colomar et al., 2022b). These indicators have a strong association with the capacity of hitting the ball faster, especially in specific joint positions involved in the serve kinetic chain. Particularly, the capability of developing maximal strength values (Baiget et al., 2016) and force in short time frames (< 250 ms) in motions such as the shoulder internal rotation (SHIR), shoulder extension (SHE), wrist flexion (WF) or the isometric mid-thigh pull (IMTP) seem of high importance in both competition (Baiget et al., 2021) and young players (Colomar et al., 2022a). Diverse variables can be derived from the force-time curve, but essentially high levels of maximal voluntary isometric contraction (MVIC) in SHIR and SHE motions will positively impact the buildup of force and increase the rotational upper arm acceleration during the swing to impact, improving the subsequent SV (Baiget et al., 2016, 2021; Colomar et al., 2022a; Hayes et al., 2018). Moreover, variables depending on force application over time such as the rate of force development (RFD) or impulse (IMP) have also been established as crucial factors affecting the final SV outcome (Colomar et al., 2022b). Both early (< 100 ms) or late (> 100 ms) phases from the onset muscle contraction time are important to determine the angular velocity achieved by body segments involved in the kinetic chain alongside building a greater momentum and a final high-speed racquet motion (Baiget et al., 2021; Colomar et al., 2022a).

Literature states the importance of explosive force production in both older more experienced players and in young population (Colomar et al., 2022a). Nevertheless, no studies have compared the significance of these variables in male and female participants. Certain differences arise when comparing genders in determinant physical indicators that influence SV (Colomar et al., 2022b). For example, body height (BH) shows large associations with SV in both genders, although stronger ratios in male competitors (r = .48 - 0.64 vs. .48 - .59) are observed (Baiget et al., 2022; Fett et al., 2020; Vaverka & Cernosek, 2013), while in female players body mass (BM) or body mass index (BMI) are more important anthropometric influencing factors (Colomar et al., 2022a; Fernandez-Fernandez et al., 2019; Fett et al., 2020; Wong et al., 2014). In this line, muscle strength, power, and range of motion (RoM) have also shown significantly different values depending on the players age (Fett et al., 2020), maturational status (Fernandez-Fernandez et al., 2021), level (Colomar et al., 2020), or sex (Fernandez-Fernandez et al., 2019). Specifically, regarding sex-related differences, male players seem to rely more thoroughly on physical qualities such as upper body power values (i.e., medicine ball throws) and shoulder isometric strength in specific serve positions, while resultant SV in female participants seems to be more influenced by anthropometric characteristics (i.e., BM and BMI) (Fernandez-Fernandez et al., 2019). Besides, when comparing racquet and ball kinematics, although a big number of variables seem similar between male and female professional players, some aspects such as a lesser shoulder internal rotation executed by females differ between both sexes (Elliott et al., 2013). Also, from a tactical perspective, female players tend to hit more serves to the opponents body, while males are more likely to aim to the corners of the service box (Hizan et al., 2015). These results restate that SV is a multifactorial ability influenced by several characteristics and that they highly vary depending on the individuals analyzed (Colomar et al., 2022b). Following this idea, differences may also exist when analyzing explosive force production variables in specific joint positions involved in the serve action, making for interesting studies in this regard that may offer coaches information on how to approach training programs depending on the addressed population. We hypothesized sex-related differences would exist in RFD, IMP and MVIC, which would result in a significant greater SV in male players.

Thus, the goals of this study were a) to examine the differences between anthropometrics and force-time curve variables in male and female young tennis players, and b) to analyze the strength of the associations between these variables and SV in both genders.

Methodology

Participants

Forty-five (15 female and 30 male, [Table 1]) high-performance junior tennis players (ITN = 2.7 ± 2.1 and 2.9 ± 0.3, respectively) volunteered for the study. Participants had a training volume of 20 h·week^{-1} comprising 3 h of technical and tactical tennis practice and 1 h of fitness training per day from Monday to Friday. The player's competitive level (ITN) was established by the consensus of three coaches accredited with the Professional Tennis Register (Registro Profesional de Tenis, RPT) level 3, following the ITN Description of Standards (ITN, 2019). Four participants were left-handed while all others had a right dominant extremity. Inclusion criteria included to have at least 1 year of participation in a structured strength and conditioning program and a minimum of 5 years of tennis training and competition. Exclusion criteria were any back, upper or lower extremity distress or to have undergone rehabilitation or surgery in the past 3 months.

Table 1
Participant characteristics and group differences.

	Male (*n* = 30)	Female (*n* = 15)	Difference		
			p-value	Cohen's *d*	%
Age (years)	16.1 ± 1.2	15.9 ± 1.5	.675	0.138	1.2
Height (cm)	177 ± 6	169 ± 6	< .001	1.377	5.0
BM (kg)	69.4 ± 5.7	58.9 ± 5.8	< .001	1.832	17.8
BMI	22.1 ± 1.1	20.7 ± 2.1	.011	0.877	6.6
Competitive level (ITN)	2.9 ± 0.3	2.7 ± 2.1	.597	0.174	1.9
Training background (years)	8.5 ± 1.6	7.2 ± 1.1	.006	0.942	18.3

Values are mean ± SD. BM = body mass; BMI = body mass index; ITN = international tennis number.

All participants and their parents were informed about the particularities of the study and signed an informed consent form. Since the participants were underaged, their legal tutors signed the agreement. The study was conducted following the ethical principles for biomedical research with human beings established in the Declaration of Helsinki of the AMM (2013) and approved by the Ethics Committee of the Catalan Sports Council (15/CEICGC/2020).

Materials and instruments. Procedure

The testing was divided into two sessions performed on the same day and separated by 10 minutes. Participants performed the force-time curve variable testing followed by the SV evaluation. Due to academy schedule organization, participants did not exercise for at least 18 h before the protocol took place. They were indicated to maintain their regular routine, to avoid excitatory substances and vigorous exercise during the previous hours to the testing sessions. All measurements were performed in the morning, approximately from 8:00 am to 9:00 am. The experiments were executed during the competition period of the season.

Force-time characteristics assessment

Participants were asked to execute two upper body MVIC tests of muscle actions in joint positions involved in the forward swing of the service motion. Positions tested were the SHIR with the elbow flexed and the shoulder abducted 90º and the 90º SHE and fully extended elbow. Prior to testing, and as a warm up, participants performed two submaximal attempts of 3 seconds of the selected positions at approximately 50 %-75 % of MVIC, separated by 60 seconds (Comfort et al., 2019). Tests were performed similarly to Baiget et al. (2016) on an Ercolina machine (Technogym Company, Cesena, Italy), participants sat with a 90º hip flexion and their back resting on a bench and fastened with a harness to avoid extra movement of other body sections. Only the dominant extremity was registered. The force-time curve was registered using a strain gauge sampling at 80 Hz (Chronojump, Boscosystem, Barcelona, Spain). MVIC and peak rate of force development (PRFD) were defined as the peak value attained during the 5 seconds. Relative MVIC was calculated by dividing the MVIC result of the 5 seconds by the participants body weight in kilograms. Furthermore, force outputs from 0 to 50, 100, 150, 200 and 250 ms from the start of the pull were determined for each trial to obtain RFD and IMP values (Comfort et al., 2015). RFD was calculated with the equation: RFD = ΔForce / ΔTime. Participants performed two trials spaced by a 2 min-rest between attempts and 5 between positions. Both positions were measured randomly, and the best score was used for analysis. The force-time curve variables assessed showed acceptable levels of reliability (ICC = > 0.753; CV = < 20%), in accordance with previous similar research (Baiget et al., 2021; Colomar et al., 2022a).

Serve ball velocity (SV)

SV was assessed on a tennis clay court under stable wind conditions (< 2 $m \cdot s^{-1}$) and using new tennis balls (Head ATP Pro, Spain). Before the evaluation, participants performed a warm-up including mobility exercises, 5 minutes of free rallies and 10 progressive serves. Each player executed 8 flat serves against no opponent (4 serves on each side of the court) with 2 minutes of rest between sets and 10 seconds between serves. Only the serves that landed in the serve box were included in the examination. SV was determined using a hand-held radar gun (Stalker ATS II, USA, frequency: 34.7 GHz [Ka-Band] ± 50 MHz), registering ball speed after impact. The radar was positioned 2 m behind the center of the baseline and at a height of 2 m. Players were asked to hit "as hard as possible into the serve box" and direct feedback was given to provide support. Mean peak velocity of the valid serves was used for the analysis. The SV measurement showed good levels of reliability (ICC = 0.787; CV = 4.4%).

Data Analyses

Descriptive data were reported as mean ± standard deviation (SD). Normality of distributions was assessed with the Shapiro-Wilk test ($p < .05$). Intra-session reproducibility was assessed using a two-way average measure of the intraclass correlation coefficients (ICCs) and the mean coefficient of variation (CV). The differences between male and female group mean values of SV, absolute and relative MVIC, PRFD, RFD, and IMP at different time frames during a SHIR or SHE were tested with an independent samples *t*-test. Also, absolute percentage change was included as group difference analysis. The magnitude of the differences in mean was quantified as effect size (ES) and interpreted according to the criteria used by Cohen (1988); < 0.2 = trivial, 0.2-0.4 = small, 0.5-0.7 = moderate, > 0.7 = large. Thirty-one preplanned comparisons were considered in this study. Accordingly, correction for multiple comparisons was performed using the Holm-Bonferroni method (Holm, 1979). In addition, Pearson correlation coefficient was used to examine the relations between SV, absolute and relative MVIC, PRFD, RFD, and IMP at different contraction times in the SHIR and SHE positions in male and female players. Correlations were classified as trivial (0-.1), small (.1-.3), moderate (.3-.5), large (.5-.7), very large (.7-.9), nearly perfect (.9), and perfect (1) (Hopkins et al., 2009). Following this analysis, we also calculated the coefficient of determination to further assess the explanatory power of the relationships observed. The level of significance was set at $p < .05$. All statistical analyses were performed using JASP (JASP 0.16.1, University of Amsterdam, Netherlands).

Results

Males SV analysis resulted in a mean value of 144.2 ± 8.4 km·h^{-1}, while female participants had a mean score of 124.9 ± 12.6 km·h^{-1}. Large SV differences (mean: 19.3 km·h^{-1}; $p = .031$, ES = 1.9, percentage change = 15.5 %) were found between boys and girls. Force-time curve variable sex-related differences are expressed in Table 2 and plotted in Figures 1 (SHIR and SHE MVIC), 2 (SHIR RFD and IMP) and 3 (SHE RFD and IMP). Significant differences favoring male participants were found in SHE PRFD, SHIR IMP from 0 to 150 and SHE IMP from 0 to 150, 0 to 200, and 0 to 250 ms.

Correlation coefficients between SV and isometric force-time variables of male and female participants are summed up in Table 3. In male participants, significant moderate-to-large correlations were found between SV, absolute and relative SHIR MVIC and SHE MVIC, SHIR and SHE PRFD, SHIR RFD from 0 to 100, 0 to 150, 0 to 200, 0 to 250 ms, and SHE RFD from 0 to 50 ms. Regarding female players, significant moderate-to-large positive correlations were found between SV, BM, absolute and relative SHE MVIC, SHIR RFD from 0 to 30, 0 to 100, and 0 to 150 ms, SHIR IMP at 150, 200 and 250 msand SHE IMP at 150, 200 and 250 ms.

Table 2
Male (n = 30) and female (n = 15) serve ball speed and joint-specific force-time curve differences.

Variables	Mean Difference	SD	ES	Descriptor	%
SV (km·h^{-1})	19.3*	3	1.9	Large	15.5
MVC (maximal voluntary contraction)					
SHIR MVIC (N)	22.8	5.7	0.45	Moderate	23.8
SHE MVIC (N)	23.1	0.8	0.45	Moderate	20.5
SHIR RMVIC (N/kg)	0.21	0.16	0.25	Small	13.0
SHE RMVIC (N/kg)	0.2	0.11	0.22	Small	10.5
RFD					
PRFD SHIR (N·s^{-1})	349.6	142.6	0.86	Large	66.1
PRFD SHE (N·s^{-1})	508.3*	139.3	1.12	Large	68.3
SHIR RFD 0-30ms (N·s^{-1})	285.4	179.6	0.67	Moderate	50.2
SHIR RFD 0-50ms (N·s^{-1})	251.3	171.9	0.67	Moderate	56.2
SHIR RFD 0-100ms (N·s^{-1})	134.2	98.2	0.61	Moderate	44.4
SHIR RFD 0-150ms (N·s^{-1})	50	50.5	0.34	Moderate	22.9
SHIR RFD 0-200ms (N·s^{-1})	23.6	18	0.22	Small	14.7
SHIR RFD 0-250ms (N·s^{-1})	33.5	13.8	0.5	Large	36.3
SHE RFD 0-30ms (N·s^{-1})	331.8	163	0.94	Large	53.7
SHE RFD 0-50ms (N·s^{-1})	290.5	146.1	0.94	Large	64.7
SHE RFD 0-100ms (N·s^{-1})	139.2	94.3	0.57	Large	42.6
SHE RFD 0-150ms (N·s^{-1})	40.2	32	0.22	Small	16.6
SHE RFD 0-200ms (N·s^{-1})	14.3	4.2	0.24	Small	7.5
SHE RFD 0-250ms (N·s^{-1})	26.2	17.1	0.44	Moderate	35.1

SD = Standard deviation; ES = effect size; SV = serve velocity; MVIC = maximal voluntary isometric contraction; RMVC = rrelative maximal voluntary isometric contraction; SHIR = shoulder internal rotation; SHE = shoulder extension; PRFD = peak rate of force development; RFD = rate of force development; IMP = impulse. * = $p < .05$

Table 2 (Continuation)
Male (n = 30) and female (n = 15) serve ball speed and joint-specific force-time curve differences.

Variables	Mean Difference	SD	ES	Descriptor	%
IMP					
SHIR IMP 30ms (N·s)	0.16	0	0.77	Large	49.8
SHIR IMP 50ms (N·s)	0.52	0.2	0.74	Large	59.1
SHIR IMP 100ms (N·s)	1.47	0.4	0.88	Large	56.9
SHIR IMP 150ms (N·s)	2.66*	0.6	1.16	Large	50.3
SHIR IMP 200ms (N·s)	1.1	0	0.25	Small	10.4
SHIR IMP 250ms (N·s)	1.4	0.2	0.29	Small	10.6
SHE IMP 30ms (N·s)	0.42	0.1	1.79	Large	153.1
SHE IMP 50ms (N·s)	0.91	0.3	1.6	Large	110.1
SHE IMP 100ms (N·s)	2.55	0.8	1.68	Large	108.6
SHE IMP 150ms (N·s)	3.27*	1.3	1.26	Large	60.3
SHE IMP 200ms (N·s)	4.73*	1.6	1.28	Large	48.6
SHE IMP 250ms (N·s)	5.6*	2.3	1.24	Large	43.3

SD = Standard deviation; ES = effect size; SV = serve velocity; MVIC = maximal voluntary isometric contraction; RMVC = relative maximal voluntary isometric contraction; SHIR = shoulder internal rotation; SHE = shoulder extension; PRFD = peak rate of force development; RFD = rate of force development; IMP = impulse. * = $p < .05$

Table 3
Male (n = 30) and female (n = 15) correlations between serve ball speed and anthropometric and specific-joint force-time curve variables.

Variables	MALES			FEMALES		
	r	*p*	r^2	*r*	*p*	r^2
Anthropometrics						
Height (cm)	.25	.228	.063	.465	.081	.216
BM (kg)	.3	.145	.090	.636	.011	.404
BMI	.144	.493	.021	.293	.289	.086
MVC						
SHIR MVIC (N)	.583	.002	.340	.439	.101	.193
SHE MVIC (N)	.423	.035	.179	.618	.014	.382
SHIR RMVIC(N/kg)	.556	.004	.309	.364	.182	.132
SHE RMVIC(N/kg)	.413	.04	.171	.521	.046	.271
RFD						
PRFD SHIR ($N \cdot s^{-1}$)	.464	.019	.215	.389	.152	.151
PRFD SHE ($N \cdot s^{-1}$)	.499	.011	.249	.07	.804	.005
SHIR RFD 0-30ms ($N \cdot s^{-1}$)	.237	.255	.056	.623	.013	.388
SHIR RFD 0-50ms ($N \cdot s^{-1}$)	.344	.092	.118	.509	.053	.259
SHIR RFD 0-100ms ($N \cdot s^{-1}$)	.446	.025	.199	.514	.05	.264
SHIR RFD 0-150ms ($N \cdot s^{-1}$)	.485	.014	.235	.533	.041	.284
SHIR RFD 0-200ms ($N \cdot s^{-1}$)	.495	.012	.245	.431	.109	.186
SHIR RFD 0-250ms ($N \cdot s^{-1}$)	.405	.045	.164	.16	.569	.026
SHE RFD 0-30ms ($N \cdot s^{-1}$)	.368	.071	.135	.466	.080	.217
SHE RFD 0-50ms ($N \cdot s^{-1}$)	.435	.03	.189	.238	.394	.057
SHE RFD 0-100ms ($N \cdot s^{-1}$)	.403	.046	.162	.267	.335	.071
SHE RFD 0-150ms ($N \cdot s^{-1}$)	.28	.175	.078	.399	.141	.159
SHE RFD 0-200ms ($N \cdot s^{-1}$)	.169	.344	.029	.44	.101	.194
SHE RFD 0-250ms ($N \cdot s^{-1}$)	.178	.396	.032	.088	.754	.008

SV = serve velocity; BM = body mass; BMI = body mass index; MVIC = maximal voluntary isometric contraction; RMVC = relative maximal voluntary isometric contraction; SHIR = shoulder internal rotation; SHE = shoulder extension; PRFD = peak rate of force development; RFD = rate of force development; IMP = impulse.

Table 3 (Continuation)
Male (n = 30) and female (n = 15) correlations between serve ball speed and anthropometric and specific-joint force-time curve variables.

Variables	MALES			FEMALES		
	r	*p*	r^2	*r*	*p*	r^2
IMP						
SHIR IMP 30ms (N·s)	.218	.296	.048	.172	.540	.030
SHIR IMP 50ms (N·s)	.116	.581	.013	.337	.219	.114
SHIR IMP 100ms (N·s)	.331	.106	.110	.281	.310	.079
SHIR IMP 150ms (N·s)	.368	.070	.135	.564	.028	.318
SHIR IMP 200ms (N·s)	.284	.169	.081	.581	.023	.338
SHIR IMP 250ms (N·s)	.219	.294	.048	.67	.006	.449
SHE IMP 30ms (N·s)	.208	.319	.043	.259	.352	.067
SHE IMP 50ms (N·s)	.211	.312	.045	.211	.451	.045
SHE IMP 100ms (N·s)	.138	.51	.019	.155	.070	.024
SHE IMP 150ms (N·s)	.208	.319	.043	.48	.004	.230
SHE IMP 200ms (N·s)	.384	.058	.147	.702	.006	.493
SHE IMP 250ms (N·s)	.37	.069	.137	.669	.017	.448

SV = serve velocity; BM = body mass; BMI = body mass index; MVIC = maximal voluntary isometric contraction; RMVC = relative maximal voluntary isometric contraction; SHIR = shoulder internal rotation; SHE = shoulder extension; PRFD = peak rate of force development; RFD = rate of force development; IMP = impulse.

Figure 1
*Male and female maximal voluntary contraction (MVIC) scores. * = p < .05.*

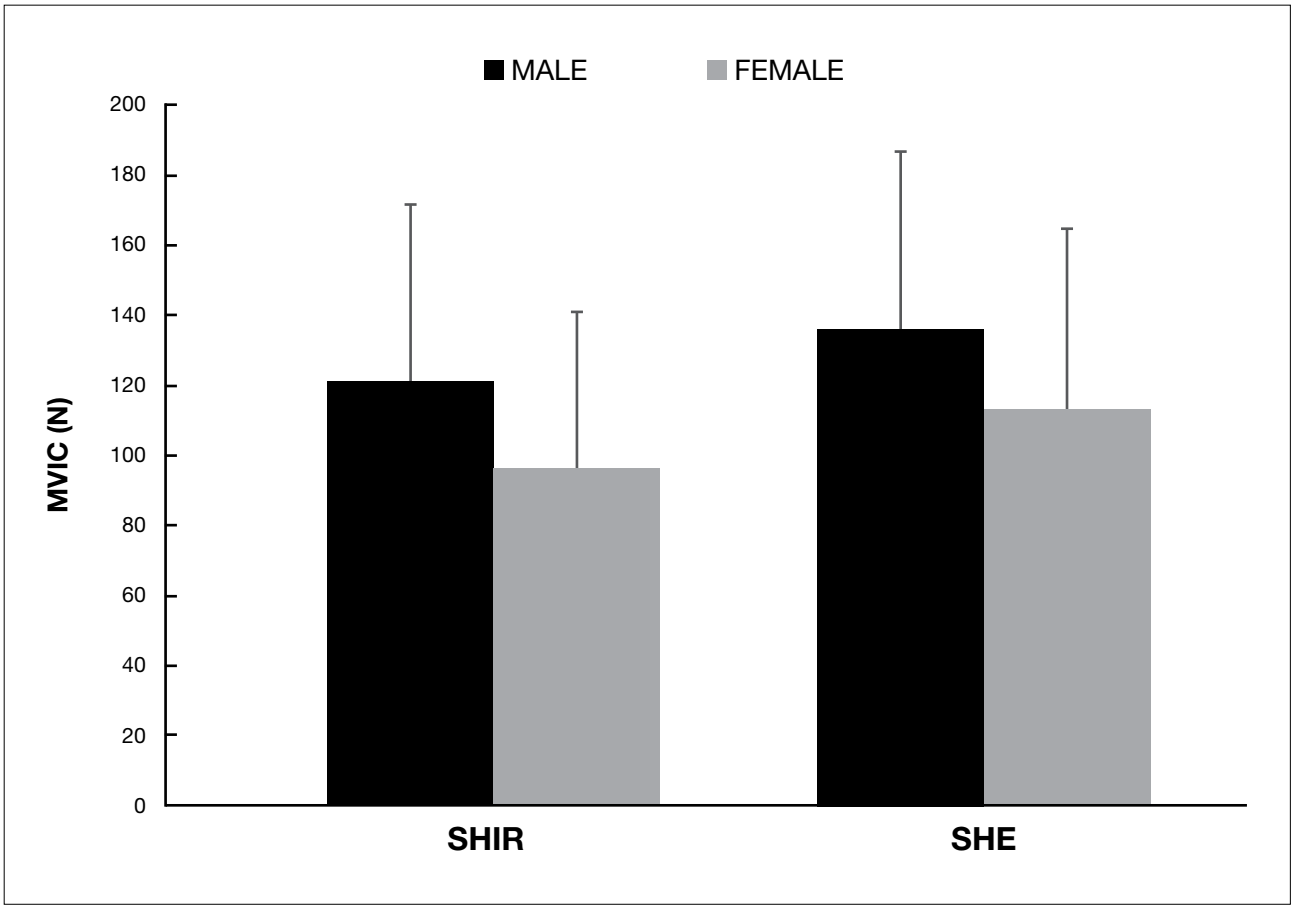


Figure 2
Male and female values of shoulder internal rotation (SHIR) rate of force development (RFD) and impulse (IMP) at different time frames.
* = p < .05.

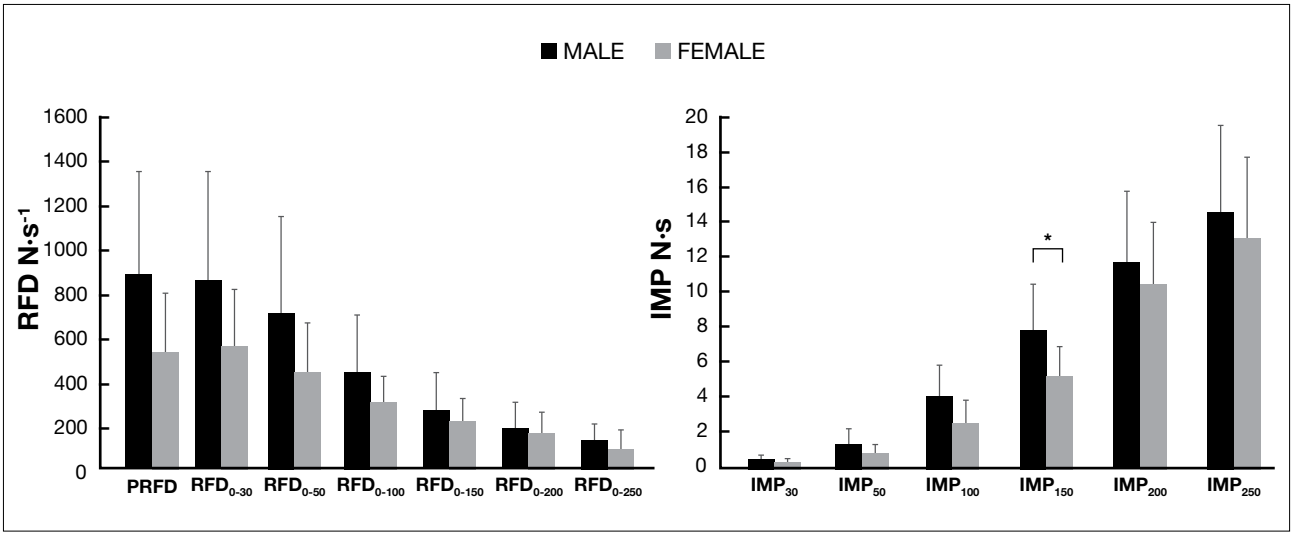
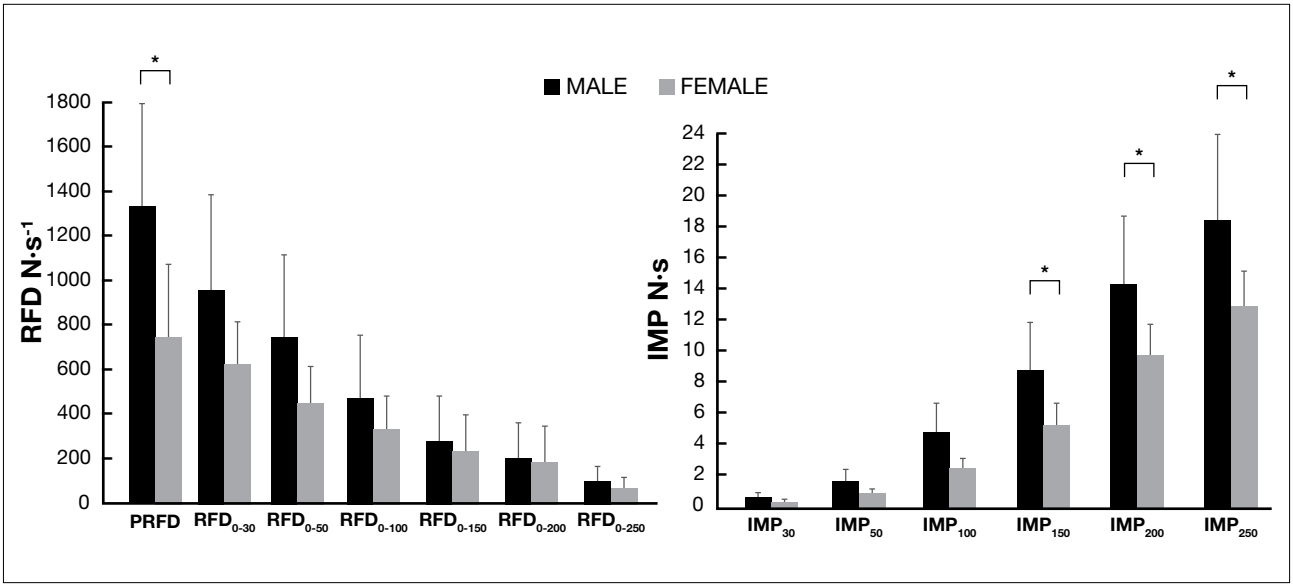


Figure 3
Male and female values of shoulder extension (SHE) rate of force development (RFD) and impulse (IMP) at different time frames.
* = p < .05.



Discussion

The main finding of this research was that SV sex-related differences existed between these competitors, probably due to higher values achieved by male players in key isometric force-time curve variables that influence the final speed of the serve (i.e., SHE PRFD and IMP). Also, the strength of the correlations between SV and the tested variables indicate that young male players may rely more thoroughly on maximal absolute and relative strength values (MVIC, RMVIC, and PRFD), while in female the competitor's SV seems to be affected to a greater extent by a combination of anthropometric characteristics (BM), maximal strength values (SHE MVIC), and force accumulation over time (IMP).

SV is highly influenced by strength values derived from the force-time curve while performing joint-specific actions present in the serve kinetic chain (Baiget et al., 2016, 2021; Colomar et al., 2022a). To our knowledge, results in this research are the first to examine differences regarding these variables in young male and female high-performance tennis

players. Outcomes of the analysis show that male players express greater scores in SHE peak values of explosive strength (PRFD), explosiveness (RFD) in what are considered early phases from the onset muscle contraction time (i.e., 150 ms) (Andersen et al., 2010), and SHE force accumulation over time (IMP) from 0 to 150, 200, and 250 ms. The serve is a highly dynamic action executed at high speeds in very short time frames. Although the total motion can last around 650 ms, the available time to produce force during the concentric muscle activation phase can be as short as 80 ms (Kibler et al., 2007). Therefore, it seems reasonable that the fact that males are capable of producing greater values in some variables such as PRFD, RFD, and IMP, especially in early contraction times, implies a higher capacity to increase arm acceleration in the swing to impact and angular momentum of the head of the racquet that will positively influence SV (Baiget et al., 2021). On the other hand, RFD, absolute and relative MVIC did not show significant sex-related differences. Early phases of contraction seem to be more determined by neural aspects such as motor unit discharge rate and intrinsic muscle properties, while overall maximal strength may be more important in the later time frames (Andersen et al., 2010; Andersen & Aagaard, 2006). This would explain how RFD values did not show statistically significant differences in any movement or time window, as maximal values of SHIR and SHE MVIC did not express dissimilarities between male and female participants. Nevertheless, non-significant results regarding MVIC are surprising, as literature has recurrently found sex-related differences in this variable (Cools et al., 2014; Fernandez-Fernandez et al., 2019; Johansson et al., 2022). Although non-significant, greater scores, moderate effect sizes and percentual changes of around 20% can be observed in favor of male participants. This may indicate that boys of this particular age and level show rather similar MVICs as their female peers, as their strength values are still increasing throughout adolescence (Johansson et al., 2022). In fact, results show even lower differences in RMVIC, which are in accordance with previous literature indicating that differences in overhead athletes' strength values may disappear when normalized to BM (Cools et al., 2016; Harbo et al., 2012). Another interesting aspect is that the maximum isometric force levels obtained in this study are specific to the angle analyzed (Oranchuk et al., 2019). This suggests that the observed correlation levels could vary depending on the joint angle analyzed. Therefore, the results of this study should not be extrapolated to other angles or positions.

Regarding the strength of the correlations between SV, anthropometric and force-time curve variables, male participants showed significant associations with all maximal strength values (i.e., SHIR and SHE absolute and relative MVIC and PRFD) and in SHIR RFD in contraction times over 100 ms, but not with the rest of RFD measurements or IMP. On the other hand, girls showed significant results in a reduced number of maximal strength variables (i.e., SHE MVIC and RMVIC), but most importantly with BM and measures of explosive strength such as SHIR RFD from 0 to 30, 100 and 150 msalongside SHIR IMP at 150, 200, 250 msand SHE IMP at 150, 200 and 250 ms. In accordance with previous research, male participants seem to rely thoroughly on maximal isometric values of strength in specific joint positions of the serve kinetic chain (Baiget et al., 2016, 2021; Fernandez-Fernandez et al., 2019). These associations seem stronger than values of explosiveness and accumulation of force throughout time that, although previously deemed important in young competitors (Colomar et al., 2022a), only showed significant correlations in SHIR RFD over 100 mstime frames in this sample of players. Regarding females, positive associations were found across variables that express maximal strength, but also BM, force output and accumulation with respect of contraction time. This is in line with the general idea that the tennis serve is a multifactorial action that requires multiple capacities to produce high speeds (Colomar et al., 2022b). Contrary to males, which seem to take advantage of enhanced maximal strength values, the existence of significant correlations between BM, MVIC, RFD and IMP in female players may indicate that velocity production of girls relies more thoroughly on the combination of several aspects rather than on one predominant strength indicator. Although verifying this idea was not the aim of this study, if it is confirmed in future research, this would indicate the need to guide service speed training differently depending on gender. Interestingly, IMP was strongly associated with SV, indicating also that the ability to build up energy over time and transfer it throughout the kinetic chain in a coordinated manner seems important for female participants. Alongside this, BM seems to have a strong influence on SV, as found in previous literature (Baiget et al., 2021; Fernandez-Fernandez et al., 2019; Fett et al., 2020). The increase in BM in girls that typically occurs when reaching adolescence (Malina et al., 2015) can increase torque production and have a positive influence on SV. Nevertheless, an adequate development of lean BM is encouraged, since an increase in this aspect should not highjack improvements in explosive strength variables that are key for velocity production (Colomar et al., 2022b).

Last, and as a limitation of this study, biomechanical proficiency has a great influence on SV, especially at young ages and during growth (Colomar et al., 2022a). Alongside certain anthropometric and strength variables tested here, kinematics most likely would explain how segment's force-generating capacity is managed as a function of time and space to generate maximum SV, since the same serve speed can be

achieved with different joint implications. Nevertheless, these aspects were not tested here, and their inclusion together with range of motion capacities (Fernandez-Fernandez et al., 2019) would be of great interest to examine the full spectrum of physical abilities that influence velocity production and the differences between genders. Also, the sampling rate of the strain gauge may have been relatively low for initial stages of contraction (< 100 ms), affecting results to some extent. Finally, different types of serves (topspin or slice) could influence the relevance and importance of the different variables tested, which makes it important to address these issues in further studies.

Conclusion

Male and female young tennis players of the same age, level and training characteristics that participated in this study showed significant differences in certain key isometric maximal and explosive strength variables that highly influence velocity production in the serve. Because of this, male competitors show greater values in a functional key parameter that affects performance such as SV. Correlations between SV and force-time curve variables indicate that, in order to guarantee velocity production, adolescent boys mainly rely on maximal absolute and relative strength values (MVIC, RMVIC, and PRFD) over explosiveness and accumulations of force over time. On the other hand, female competitors SV may be affected to a superior degree by a combination of diverse physical abilities, including anthropometric characteristics (BM), maximal levels of strength (SHE MVIC and RMVIC) and expressions of force production and accumulation in short time frames (i.e., RFD and IMP). In accordance with these results, when planning a SV improvement program, certain differences in training approaches between sexes may be important. On the one hand, when intending to improve the MVIC or PRFD in positions involved in the tennis serve kinetic chain, coaches are encouraged to use resistance training programs such as isometric interventions, as they have been established as a valid option to improve these qualities in short periods of time (Baiget et al., 2023). On the other hand, when intending to improve force production and IMP in short time frames, interventions that include fast rotations, specific movements from the kinetic chain and are performed with light to moderate weights seem the best option (Baiget et al., 2021).

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