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ORIGINAL ARTICLE

Exploring the role of sex and maturation in a bio-banding competition: Insights into pre-competition anxiety in youth handball

Exploration du rôle du sexe et de la maturité biologique dans une compétition en fonction de l'âge biologique : aperçu de l'état d'anxiété pré-compétition chez les jeunes handballeurs

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KEYWORDS
Maturity ;
Sex ;
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Summary
Objective. — The present study analysed the impact of biological maturity status and sex on pre-competitive anxiety, self-confidence and perception in young handball players under the bio-banding competition.
Equipment and methods. — The sample consisted of 87 handball players (46 boys and 41 girls) aged 13—17 years. Anthropometric data (height, body mass and self-reported biological parent's height) were collected to calculate maturity level using the percentage of predicted adult height (Khamis-Roche equation). The players were classified as early, on-time and late maturers (*Z*-score distribution). Furthermore, a psychological assessment was carried out using a validated Spanish version of the CSAI-2R and a post-competition perception questionnaire. Multivariate analyses (MANOVA) were conducted to estimate the impact of sex and biological maturity status on psychological constructs and perception.

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Results. — Higher cognitive and somatic anxiety levels in girls ($P < 0.05$, both) and self-confidence in boys ($P < 0.001$) were found. Moreover, higher cognitive anxiety levels were identified in early maturing girls than in on-time maturing girls ($P < 0.05$). According to the bio-banding perception, boys showed higher understanding ($P < 0.001$) and enjoyment ($P < 0.05$) levels. In girls, late maturing girls showed higher enjoyment levels than the rest of the counterparts ($P < 0.05$). Furthermore, enjoyment and self-confidence were positively correlated ($P < 0.01$).
Conclusions. — The findings suggest that bio-banding may offer a valuable strategy for creating equitable competitive environments by aligning challenges with players' maturity status. Practical recommendations include tailoring competitive experiences, addressing psychological needs — particularly in female athletes — and fostering safe developmental pathways. These insights provide actionable guidance for coaches and stakeholders to enhance the effectiveness of talent identification and development programs.

MOTS CLÉS
Maturité ;
Sexe ;
Anxiété ;
Confiance en soi ;
Sports d'équipe

Résumé
Objectif. — La présente étude a analysé l'impact de la maturité biologique et du sexe sur l'anxiété pré-compétitive, la confiance en soi et la perception chez les jeunes joueurs de handball dans le cadre de compétition en fonction de l'âge biologique.
Matériel et méthodes. — L'échantillon était composé de 87 enfants (46 garçons et 41 filles) âgés de 13 à 17 ans. Les données anthropométriques (taille, taille assise, masse corporelle et taille déclarée du parent biologique) ont été recueillies pour calculer le niveau de maturité en utilisant le pourcentage de la taille adulte prédite (équation de Khamis-Roche), en classant les joueurs en matures précoces, précoces et tardifs (distribution des *Z*-scores). En outre, une évaluation psychologique a été effectuée à l'aide d'une version espagnole validée du CSAI-2R et un questionnaire post-compétition a été réalisé pour tester la perception du bio-banding par les joueurs. Des analyses multivariées (MANOVA) ont été réalisées pour estimer l'impact du sexe et du statut de maturité biologique sur les constructions psychologiques et la perception.
Résultats. — Les résultats ont montré des niveaux d'anxiété cognitive et somatique plus élevés chez les filles ($p < 0,05$, dans les deux cas) et une plus grande confiance en soi chez les garçons ($p < 0,001$). En outre, les niveaux d'anxiété cognitive étaient plus élevés chez les filles à maturation précoce que chez les filles à maturation tardive ($p < 0,05$). Selon la perception du bio-banding, les garçons ont montré des niveaux de compréhension ($p < 0,001$) et de plaisir ($p < 0,05$) plus élevés, tandis que chez les filles, les filles à maturité tardive ont montré des niveaux de plaisir plus élevés que les filles à maturité tardive et précoce ($p < 0,05$). En outre, le plaisir et la confiance en soi étaient positivement corrélés ($p < 0,01$).
Conclusions. — Les résultats suggèrent que le bio-banding peut constituer une stratégie précieuse pour créer des environnements compétitifs équitables en alignant les défis sur le niveau de maturité des joueurs. Les recommandations pratiques incluent l'adaptation des expériences compétitives, la prise en compte des besoins psychologiques — en particulier chez les athlètes féminines — et la création de parcours de développement sécurisés. Ces résultats offrent des orientations concrètes aux entraîneurs et aux parties prenantes pour améliorer l'efficacité des programmes d'identification et de développement des joueurs.

1. Introduction

The training objective is one of the main actions of handball clubs within talent identification and development programmes, especially between the ages of 7—8 and 17—18 [1]. At these stages, players often enjoy a wide range of high-quality sporting experiences with a positive impact both for the player themselves (e.g., increased game knowledge) and for the club (e.g., gain in reputation) [2]. Nevertheless, during the sports transition process, certain factors may alter the sporting talent development, such as the maturity status [3]. Specifically, considering the common practice of grouping players in team sports (annual or biennial cycles), it would be reasonable to suggest the existence of a maturational differential in the formative categories, or in other words, the coexistence of players with different maturity status within the same competition category [4,5].

Biological maturation is defined as the rate of progress towards adulthood, which is based on three constructs: (i) ''status'', referring to the maturational level at the time of observation; (ii) ''timing'', related to when it specifically occurs; and (iii) ''tempo'', associated with the rate of progress towards maturity [6]. This concept has become increasingly relevant in talent development systems when evaluating the implications that it could have on the player's

training process [7]. Previous scientific literature confirmed biological age differentials of 5 or 6 years within the same age group [8], as well as significant sex-related differences associated with the time they experience peak height velocity (PHV) [9]. These differences in maturity can result in uneven competition categories. Therefore, it seems necessary to reflect on how these situations could affect young players who are in sensitive stages of their sporting transition.

Individual characteristics related to the maturation process have proven to be critical and fundamental for professionals and stakeholders involved in recruiting young talented players for their sports organizations' structures [10]. For example, Johnson, Farooq and Whiteley [11] identified that early maturers were more likely to be selected in elite English football academies as they got older, and moreover, these players tended to be retained in the system about 20 times more than on-time and late maturers. Therefore, this evidence suggests a formative and/or competitive inequality resulting from the differential in maturity level that could endanger the balanced development of the player, both in those considered early maturers and in those termed late maturers [7].

One organizational strategy used in the sports context to reduce or eliminate maturational inequality is the grouping of young players by maturational bands, which is referred to as the ''bio-banding'' [4]. This format aims to provide an experience tailored to the players' maturational level, generally involving them in three levels or bands (early, on-time and late maturers) [5]. Bio-banding has been particularly implemented in football contexts [12], examining its impact in different areas associated with the sports talent development, such as technical-tactical, psychosocial, and physical-anthropometric [13,14]. However, this grouping strategy is beginning to be used in other team sports such as basketball [15] and handball [16]. Specifically, bio-banding in handball could become a grouping method that can be extrapolated to competition in order to (i) equalise the conditional game factor due to a high number of physical contacts [17] and (ii) reduce the drop-out rate of talented players who are required to face challenges misaligned with their maturity level [18]. However, scientific evidence on bio-banding in handball remains limited, leaving room for further research into other areas of performance during formative periods in sport, such as game-specific demands assessed through inertial devices. However, scientific evidence on bio-banding in handball is low, allowing research into other areas of performance in sport formative periods, such as game-specific demands based on inertial devices. While the results are not homogeneous, players' perceptions about the implementation of this grouping strategy have generally been positive [19—21].

Considering the impact of maturation on the player's transition process, it is worth questioning whether it is an individual factor that can affect an athlete's psychological responses to stressful stimuli, such as competition in a novel format (i.e., bio-banding). In this conceptual framework, it becomes essential to incorporate the finding that more mature players exhibit a more adaptive motivational profile, with more affirmative perceptions about their physical image and higher self-esteem compared to their less mature counterparts [4,20]. Thus, it is presumed that athletes who are more advanced in maturation tend to perceive a better motivational climate, which, according to Gómez-López, Chicau, Marques da Silva, Granero-Gallegos and González-Hernández [22], is positively associated with self-confidence and inversely with cognitive and somatic anxiety. On the other hand, relatively older athletes typically demonstrate more advanced cognitive and social development, allowing them to effectively solve problems and manage the social pressures inherent in sports competitions, assuming leadership roles (e.g., team captain) [23]. All of this seems to be a limiting factor for late maturing athletes in developing the necessary psychosocial skills to face competition, whose absence could trigger negative impacts based on anxiety (i.e., decreased competition and training performance, increased risk of injuries, delay and obstruction in the rehabilitation period, and increased risk of relapse or recurrence) [24].

Reflecting on the implications of maturity status and its possible influence on athletes' competition perceptions and psychological responses, especially in stressful contexts such as competition, crucial questions arise: how does biological maturation affect athletes' competition perceptions and psychological responses in bio-banding competitions? Is there a significant interaction between maturity status and sex in these psychological responses? Although studies in sports such as football have explored these aspects independently [14], to the best of our knowledge, there is a notable lack of research in handball that includes female samples. Therefore, the purpose of the present study was to analyze the impact of the biological maturity status and sex on the pre-competitive anxiety levels (cognitive anxiety, somatic anxiety, and self-confidence) and on the perceptions of young male and female handball players about the bio-banding competition format.

2. Method

2.1. Sample

The sample consisted of 87 handball players (boys, $n = 46$; girls, $n = 41$) belonging to the age groups U-13 ($n = 30$), U-14 ($n = 17$), U-15 ($n = 19$), U-16 ($n = 12$), and U-17 ($n = 9$) from the youth academy of a top-level Spanish handball club. Table 1 presents the main anthropometric characteristics of the players (height, weight, and body mass index [BMI]), as well as their distribution according to sex, age group, and biological maturity status (BMS). The inclusion criteria were having been trained in the club's academies or associated schools for at least 6 years, training handball regularly, at least three days per week, participating in federated competition, not having suffered or having a limiting injury that could bias the maturity and/or psychological assessment, and not having taken any medication or other dietary supplements not necessary. The athletes participated voluntarily in the study, and the parents and/or legal guardians of the underage players were duly informed through informed consent to extract, record, and use the data derived from it. The project and the scientific use of the data were approved by the Ethics Committee of the Polytechnic University of Madrid (2020-089; 2020-090; 2020-091) in compliance with the Declaration of Helsinki.

Table 1 Distribution by biological maturity status (anthropometric characteristics) of handball players according to sex and age group.

Sex	AG	BMS			Height X ± SD	Weight X ± SD	BMI X ± SD
		LM (*n*)	OM (*n*)	EM (*n*)			
B	U-13	12	2	0	161.30 ± 8.88	58.91 ± 3.80	22.83 ± 2.91
	U-14	5	7	0	167.40 ± 7.81	58.84 ± 2.45	21.10 ± 2.07
	U-15	0	7	3	167.68 ± 8.54	58.08 ± 2.29	20.75 ± 1.61
	U-16	0	0	10	171.06 ± 9.97	58.52 ± 5.53	20.07 ± 2.07
G	U-13	13	3	0	159.40 ± 1.97	53.86 ± 3.02	21.18 ± 0.68
	U-14	2	2	1	160.47 ± 3.27	55.53 ± 6.14	21.51 ± 1.45
	U-15	0	5	4	159.99 ± 3.02	54.28 ± 4.33	21.17 ± 0.88
	U-16	0	1	1	163.88 ± 8.66	58.80 ± 11.46	21.76 ± 1.96
	U-17	1	0	8	162.68 ± 6.96	55.22 ± 6.27	20.85 ± 1.71

B: boys; G: girls; AG: age group; U-13/U-17: under 13/under 17; BMS: biological maturity status; LM: late maturers; OM: on-time maturers; EM: early maturers; BMI: body mass index.

2.2. Procedure

2.2.1. Anthropometric evaluation

The height of the players was measured with a stadiometer with a precision of 0.1 cm (SECA, 216, Vogel & Halke, Hamburg, Germany). Body mass was measured with a precision of 0.1 kg on a digital scale (SECA, 876, Vogel & Halke, Hamburg, Germany). The BMI was calculated (kg/m^2). The height of the biological parents was provided in centimetres by each of the parents and was subsequently converted to inches and adjusted for overestimation using the equation from Epstein et al. [25]. All anthropometric measurements of the players were taken three days before (on 25 February 2022) the bio-banding competition to ensure the conformation of the maturity bands. The assessment was performed by qualified personnel in Physical Activity and Sports Sciences (level 2) according to the International Standards for Anthropometric Assessment (ISAK) [26].

2.2.2. Biological Maturity Status — BMS

All anthropometric data were used to calculate the biological maturity status based on the predicted adult stature of the players using a regression formula validated in white Caucasian children [27]. Separate equations for boys and girls were used due to the specific developmental differences of each sex, assuming absolute average deviations of 2.2 cm in boys and 1.7 cm in girls between the current height and the height predicted at 18 years.

The estimated biological maturity status was expressed as a *Z*-score relative to the specific age-reference values for boys and girls, using the percentage of the predicted adult stature achieved at the time of measurement and the specific half-yearly means and standard deviations by age and sex included in the ''Berkeley Guidance'' study [28]. This type of maturity classification has shown a moderate correlation with other maturational classifications based on skeletal age in both males and females [29]. Thus, the *Z*-scores were used to classify the players into three groups: late ($z < -0.5$), on-time ($-0.5 < z < +0.5$) and early maturers ($z > +0.5$). This less conservative maturation criterion was employed with the aim of reducing the differences derived from growth factors with a direct impact on the biological maturity status [30].

2.2.3. Bio-banding competition

The participants competed separately on 28 February 2022 according to sex (i.e., boys and girls) in two different formats: (i) by age group; and (ii) by maturity status. In the first competition format, players were organized into the two official biennial categories corresponding to their age group (i.e., U-13/U-14 and U-15/U-16): The U-17 players ($n = 9$) were integrated into the U-15/U-16 category to allow for a minimum number of players. Three teams were formed in each category, with a total of six matches being played consecutively (three matches per category). After a 30-minute break to avoid any carryover effects, the bio-banding competition was held. Players were distributed into three maturational bands (i.e., late, on-time, and early maturers), forming two teams per band, with two matches per band and six matches in total.

The rules were the same in the age group competition for both boys and girls, except for the size of the ball (sizes 1 and 2) and the duration of the matches (30 and 25 minutes). However, the rules in the bio-banding competition (dimensions of the court, ball size, dimensions of the goal, and duration of the match) were adapted for each maturational level for both boys and girls (see Table 2).

2.2.4. Pre-competitive anxiety evaluation

The psychological assessment conducted was of the ''state'' type, as it examined the temporary psychological response of players to a specific event [31]. The instrument used to evaluate pre-competitive anxiety was the Spanish-validated version of the CSAI-2R (Revised Competitive State Anxiety Inventory-2) [32]. This instrument, originally developed by Cox et al. [33], assesses three constructs:

- cognitive anxiety (CA);
- somatic anxiety (SA);
- self-confidence (Sc).

Table 2 Game format and specific regulations by age group and biological maturity status.

GF	Specific regulations	AG		
		U-13/U-14		U-15/U-16
7 vs. 7	Pitch size (m.)	40 × 20		40 × 20
	Ball size	1		2
	Goal size (m.)	3 × 2		3 × 2
	Match duration/rests (min.)	25/5		30/5
GF	Specific regulations	BMS		
		LM	OM	EM
7 vs. 7	Pitch size (m.)	20 × 12	24 × 14	28 × 16
	Ball size	1	1	2
	Goal size (m.)	3 × 1.8	3 × 1.8	3 × 2
	Match duration/rests (min.)	12/5	15/5	18/5

GF: game format; AG: age group; U-13/U-16: under 13/under 16; BMS: biological maturity status; LM: late maturers; OM: on-time maturers; EM: early maturers.

The anxiety evaluation was conducted before the start of the competition, after all players had received information and understood the implications of both competition formats (age groups and bio-banding).

2.2.5. Competition perception evaluation

The competition perception questionnaire applied after the bio-banding tournament had been previously used in other studies [19,21]. The questionnaire consists of eight perception questions (PQ), which correspond to four areas of expression. Specifically, PQ1 and PQ2 are associated with the overall experience, PQ3 and PQ7 with the physical challenge, PQ4 and PQ6 with the psychosocial challenge, and PQ5 and PQ8 with the technical-tactical challenge. Although it is a form with eight double questions (quantitative and qualitative response), for this study, only the numerical information was considered, with each question being rated on a Likert scale (''1'': not at all; ''2'': a little; ''3'': some aspects; ''4'': most aspects; and, ''5'': completely). The questionnaires, via Google Forms, were completed simultaneously immediately after the end of the bio-banding competition (10—15 minutes) using a QR code scanned with their electronic devices. The names of the players were anonymized by assigning numbers from 1 to 87.

2.3. Statistical analysis

The statistical analysis was performed using SPSS software (version 26). Descriptive statistics were calculated for all variables, with results expressed as mean ± standard deviation (X ± SD). To evaluate the impact of biological maturity status and sex on the psychological variables and competition perceptions, a two-factor multivariate analysis of variance (MANOVA) was conducted. This method allowed for the examination of main effects and potential interactions between sex and biological maturity status across the dependent variables. Partial eta squared (ηp^2) was calculated to determine the effect size for each factor and interaction, following established thresholds: small ($\eta p^2 < 0.01$), medium ($\eta p^2 < 0.06$), and large ($\eta p^2 < 0.14$) [34]. To further explore relationships between the psychological constructs (cognitive anxiety, somatic anxiety, and self-confidence) and competition perception variables, Pearson correlation analyses were performed. The level of statistical significance was set at $P \leq 0.05$, with $\alpha = 0.05$. The choice of statistical methods, including MANOVA and Pearson correlations, aligns with the structure of the dataset and the study's experimental design. While alternative approaches could be considered, these analyses provide insights consistent with the objectives of the research and the nature of the data.

3. Results

According to biological maturity status, 34 late (39.08%), 26 on-time (29.89%), and 27 early maturers (31.03%) were identified. With regard to the psychological constructs associated with pre-competition anxiety, the descriptive statistics of the cognitive anxiety, somatic anxiety and self-confidence (X ± SD) in relation to sex and biological maturity status were showed in Table 3.

Table 4 shows the impact of BMS and the sex of the players on the psychological constructs of pre-competitive anxiety. With regard to the sex, significant effects were found on cognitive anxiety ($F = 6.55$; $P = 0.012$) and somatic anxiety ($F = 6.07$; $P = 0.016$) with moderate effect sizes ($\eta p^2 = 0.075$ and $\eta p^2 = 0.070$, respectively), while the impact of sex on self-confidence had a large effect size ($F = 15.38$; $P < 0.001$; $\eta p^2 = 0.160$). Specifically, girls reported higher levels of cognitive anxiety (12.29 ± 4.17) and somatic anxiety (14.41 ± 4.82) than boys (10.26 ± 3.05; 12.02 ± 3.83, respectively), while in relation to self-confidence, boys (16.30 ± 2.52) reported higher values than girls (15.13 ± 3.23). Conversely, no significant differences were found in any of the psychological constructs in relation to biological maturity status ($P > 0.05$). Regarding the interaction of sex and BMS, a significant effect was observed on cognitive anxiety ($F = 4.31$; $P = 0.017$; $\eta p^2 = 0.096$), iden-

Table 3 Descriptive statistics of the psychological variables of pre-competition anxiety (X ± SD) according to sex and biological maturity status.

Sex	BMS	CA			SA			Sc		
		X	SD	*n*	X	SD	*n*	X	SD	*n*
B	LM	9.78	2.63	18	11.50	2.60	18	16.50	2.07	18
	OM	11.27	2.25	15	13.07	4.06	15	16.33	2.38	15
	EM	9.77	4.17	13	11.54	4.91	13	16.00	3.32	13
	Total	10.26	3.05	46	12.02	3.83	46	16.30	2.52	46
G	LM	11.56	3.41	16	13.88	4.13	16	14.94	2.77	16
	OM	10.45	2.77	11	12.45	4.57	11	13.64	3.04	11
	EM	14.57	5.00	14	16.57	5.21	14	12.64	4.20	14
	Total	12.29	4.17	41	14.41	4.82	41	13.80	3.45	41
Total	LM	10.62	3.10	34	12.62	3.56	34	15.76	2.51	34
	OM	10.92	2.47	26	12.81	4.21	26	15.19	2.95	26
	EM	12.26	5.15	27	14.15	5.59	27	14.26	4.10	27
	Total	11.22	3.74	87	13.15	4.46	87	15.13	3.23	87

B: boys; G: girls; BMS: biological maturity status; LM: late maturers; OM: on-time maturers; EM: early maturers; CA: cognitive anxiety; SA: somatic anxiety; Sc: self-confidence.

Table 4 Differences between groups with regard to pre-competitive anxiety levels (cognitive anxiety, somatic anxiety and self-confidence) according to sex and biological maturity status.

Variables	F	*p*	ηp^2	Direction of effects
BMS				
Cognitive anxiety	1.58	0.213	0.037	—
Somatic anxiety	0.93	0.401	0.022	—
Self-confidence	1.66	0.196	0.039	—
Sex				
Cognitive anxiety	6.55	0.012	0.075	B < G
Somatic anxiety	6.07	0.016	0.070	B < G
Self-confidence	15.38	0.000	0.160	B > G
BMS × Sex				
Cognitive anxiety	4.31	0.017	0.096	EM (G) > OM (G)
Somatic anxiety	2.91	0.060	0.067	—
Self-confidence	0.71	0.495	0.017	—

BMS: biological maturity status; B: boys; G: girls; EM: early maturers; OM: on-time maturers; LM: late maturers.

tifying higher levels in early maturing girls (14.57 ± 5.00) compared to on-time maturing girls (10.45 ± 2.77).

A significant effect of biological maturity status on cognitive anxiety was found in girls (F = 3.91; $P = 0.029$), with a large effect size ($\eta p^2 = 0.170$). Specifically, early maturing female players (14.57 ± 5.00) reported significantly higher cognitive anxiety levels compared to those in the on-time maturity group (10.45 ± 2.77) (Fig. 1). No significant differences in the rest of the psychological variables for girls were found ($P > 0.05$). On the other hand, no effect of biological maturity status on the three psychological constructs in boys was observed ($P > 0.05$).

Regarding the competition perception questions about the game format by maturational level, Fig. 2(a—d) shows the scores obtained (X ± SD) through the questionnaire according to sex and BMS.

Table 5 shows the impact of biological maturity status and the sex of the players on each of the responses corresponding to the competition perception questions on bio-banding game format. With regard to sex, significant effects were found on the responses obtained from question 1 (F = 36.58; $P < 0.001$; $\eta p^2 = 0.314$) and question 2 (F = 6.58; $P = 0.012$; $\eta p^2 = 0.076$), both associated with the overall experience. Specifically, boys reported higher levels of understanding (4.17 ± 0.93) and enjoyment of the bio-banding tournament (4.39 ± 0.80) than girls (2.80 ± 1.11; 4.00 ± 0.88, respectively). Conversely, no significant differences were found in any of the eight competition perception questions in relation to BMS ($P > 0.05$). In relation to the interaction of sex and BMS, a significant effect was observed on the enjoyment of the bio-banding tournament (F = 4.87; $P = 0.010$; $\eta p^2 = 0.109$) with higher scores in late maturing girls (4.50 ± 0.63) than

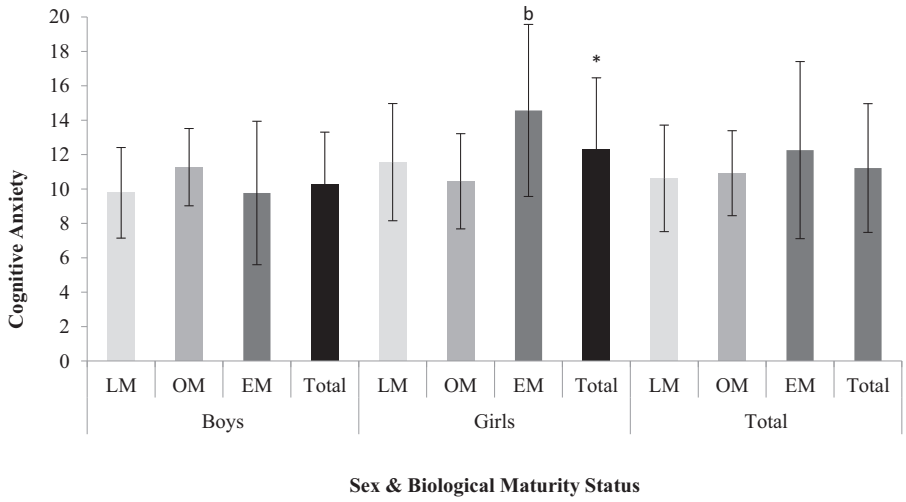

Figure 1 Cognitive anxiety levels according to sex and biological maturity status. Significance level is indicated by the number of symbols: one symbol (*) for $P < 0.05$, two (**) for $P < 0.01$, and three (***) for $P < 0.001$. ''a'': significant differences vs. late maturers (LM); ''b'': significant differences vs. on-time maturers (OM); ''c'': significant differences vs. early maturers (EM).

Table 5 Differences between groups with regard to competition perception questions (PQ1—PQ8) according to sex and biological maturity status.

Factor	PQ	F	p	ηp^2	Direction of effects
BMS	PQ1 — Understanding	0.80	0.452	0.020	—
	PQ2 — Enjoyment	1.62	0.204	0.039	—
	PQ3 — Injuries	0.36	0.702	0.009	—
	PQ4 — Leadership	0.16	0.851	0.004	—
	PQ5 — Participation	1.05	0.353	0.026	—
	PQ6 — Game influence	0.01	0.992	0.000	—
	PQ7 — Physical self-expression	0.16	0.855	0.004	—
	PQ8 — Technical self-expression	0.65	0.523	0.016	—
Sex	PQ1 — Understanding	36.58	0.000	0.314	B > G
	PQ2 — Enjoyment	6.58	0.012	0.076	B > G
	PQ3 — Injuries	1.65	0.203	0.020	—
	PQ4 — Leadership	1.20	0.277	0.015	—
	PQ5 — Participation	0.15	0.696	0.002	—
	PQ6 — Game influence	0.15	0.697	0.002	—
	PQ7 — Physical self-expression	0.01	0.974	0.000	—
	PQ8 — Technical self-expression	0.27	0.606	0.003	—
BMS × Sex	PQ1 — Understanding	0.07	0.933	0.002	—
	PQ2 — Enjoyment	4.87	0.010	0.109	LM(G) > OM(G); LM(G) > EM(G)
	PQ3 — Injuries	0.21	0.815	0.005	—
	PQ4 — Leadership	0.07	0.934	0.002	—
	PQ5 — Participation	0.28	0.755	0.007	—
	PQ6 — Game influence	1.58	0.212	0.038	—
	PQ7 — Physical self-expression	2.20	0.127	0.050	—
	PQ8 — Technical self-expression	1.02	0.364	0.025	—

PQ: competition perception questions; BMS: biological maturity status; B: boys; G: girls; EM: early maturers; OM: on-time maturers; LM: late maturers.

in on-time maturing (3.64 ± 0.92) and early maturing girls (3.69 ± 0.86).

Table 6 presents the correlation levels between the psychological constructs of pre-competitive anxiety and the boys' perception of the bio-banding tournament. A positive correlation was observed between the enjoyment of the bio-banding tournament (PQ2) and self-confidence levels ($r = 0.278$, $P < 0.01$), with no further associations found between the psychological constructs and the rest competition perception levels in boys ($P > 0.05$).

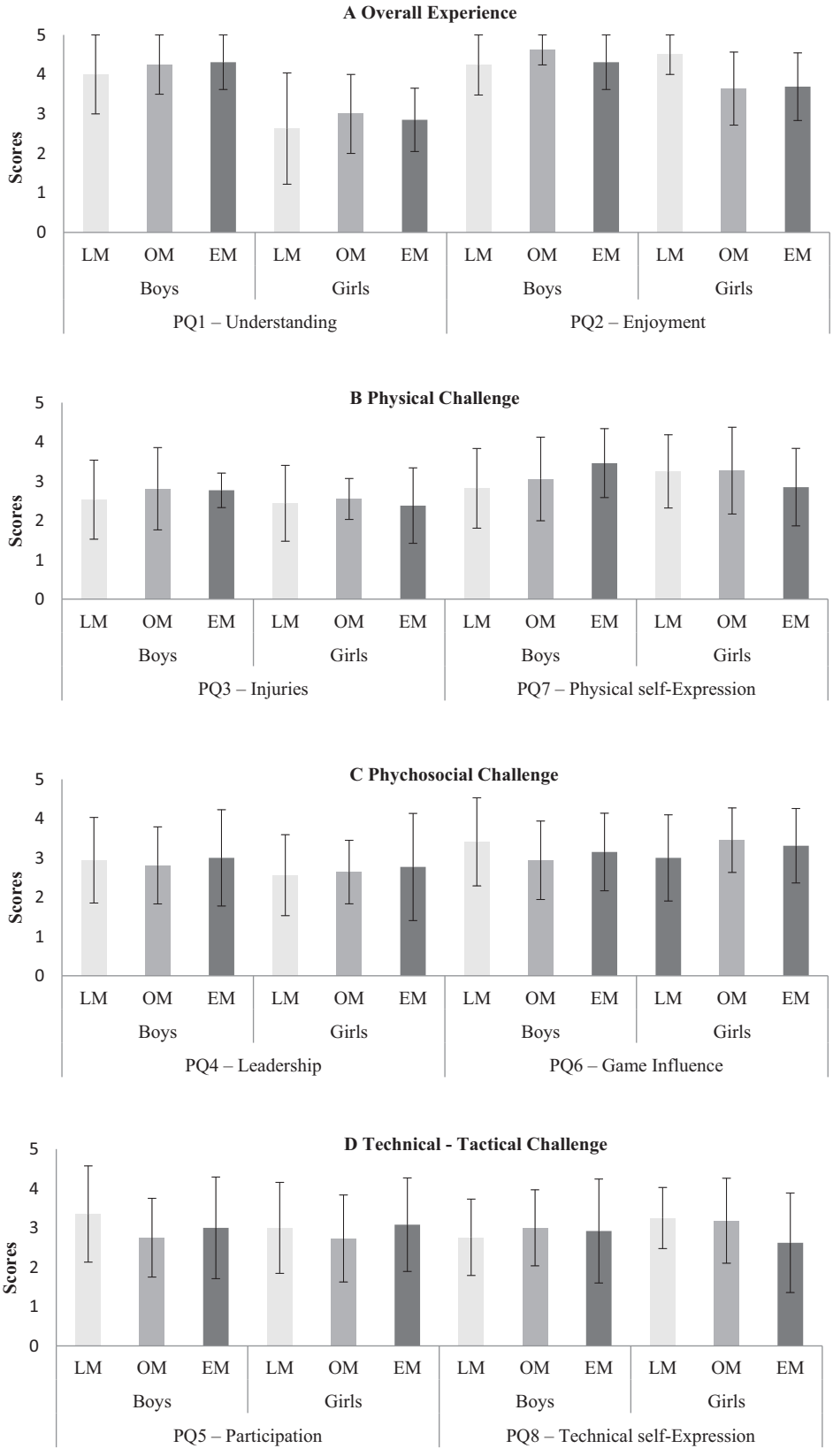

Figure 2 a–d: perception question scores in relation to the areas of expression according to sex and biological maturity status.

Table 6 Correlations between the psychological constructs of pre-competition anxiety and the competition perception questions.

Variables	PQ1	PQ2	PQ3	PQ4	PQ5	PQ6	PQ7	PQ8
CA	−0.151	−0.158	−0.116	0.047	0.063	0.007	−0.003	−0.112
SA	−0.200	−0.206	0.112	−0.093	0.016	0.001	−0.050	0.006
Sc	0.204	**0.278****	0.056	0.186	0.038	−0.102	0.098	0.040

PQ1—PQ8: competition perception questions from 1 to 8; CA: cognitive anxiety; SA: somatic anxiety; Sc: self-confidence. *$P < 0.05$. **$P < 0.01$.

4. Discussion

The current study focused on assessing the impact of biological maturity status on three psychological constructs associated with pre-competitive anxiety. On the other hand, the competition perception of young male and female handball players about the bio-banding competition format was examined. The findings highlighted a significant influence of sex on cognitive anxiety, somatic anxiety, and self-confidence, with girls (vs. boys) exhibiting higher cognitive anxiety and somatic anxiety levels, while boys (vs. girls) displayed greater self-confidence levels. Concerning biological maturity status and sex, early maturing girls showed higher cognitive anxiety levels in comparison to on-time maturing girls. In terms of competition perception about bio-banding, boys reported greater understanding and enjoyment. In contrast, among girls, late maturers experienced more enjoyment compared to on-time and early maturers. Additionally, a positive correlation was observed between greater enjoyment and increased Sc.

This sex differentiation aligns our findings with previous studies, such as Brown et al. [35], which noted that sex differences during adolescence could significantly influence sports participation and psychosocial behaviour. Furthermore, prior research has shown that the psychological variables, such as cognitive anxiety, somatic anxiety, and self-confidence, are often significant performance predictors, with consistent differences between sexes [34]. According to an evolutionary perspective, such differences might be linked to the varying considerations by sex with respect to adaptive challenges, such as competition in handball [36]. Conversely, biological perspectives explore elements like the role of sex hormones and their impact on specific cognitive functions, proposing that these could be key to understanding the disparate approaches to competition based on sex [37]. On the other hand, some theories suggest that certain sex differences may stem from sex biases embedded in the sociohistorical construction of psychological categories [38].

Additionally, the present study demonstrated that biological maturity status significantly interacts with sex in relation to cognitive anxiety. Specifically, early maturing girls experienced higher levels of cognitive anxiety than on-time maturing girls, with no other effects found in the rest of the psychological variables or in boys. This finding aligns with studies by Drenowatz et al. [30] and Towlson et al. [14], which emphasized the importance of considering the maturity in assessing development and psychological adaptation in young players. However, these results contrast with the findings of Smart et al. (2012), who indicated an inverse relationship between maturity and physical self-perception, thus affecting quality of life and physical activity. Factors such as performance expectations, self-concept, or the experience of negative events during puberty could be some of the reasons why players with a more advanced maturational level experienced higher cognitive anxiety levels [39]. Considering that puberty is a period of constant and fast physical growth and development characterised by the appearance of sexual and physiological differences (e.g., hormone concentration) [40], it is possible that psychological constructs, such as cognitive anxiety, may be more influenced in girls than in boys, as this process tends to occur earlier in young female players.

To mitigate such differences, various grouping strategies have been developed, one of the most well-known and applied in different sports contexts being bio-banding [4]. According to Hill et al. [41], bio-banding could reduce these differences, especially at a psychological level, allowing for more equitable and adjusted development at both ends of the biological maturation spectrum. Additionally, due to the great variability in maturity during adolescence, this strategy could have long-term effects [42]. In our study, although no direct effect of biological maturity status on the psychological constructs (cognitive anxiety, somatic anxiety and self-confidence) was observed, the significant interaction with sex (early maturing girls showed higher cognitive anxiety levels than on-time maturing girls) suggests that bio-banding could reduce or eliminate disadvantages or differences among children, especially in young female players.

On the other hand, regarding the players' competition perception, boys understood and enjoyed the bio-banding format more than girls. However, among girls, greater enjoyment was identified in late maturers compared to early and on-time maturers. This inverse trend of the girls' maturity in relation to the concept of ''bio-banding'' contrasts with the results obtained in boys, where early maturers tend to enjoy bio-banding competition more [19—21]. An earlier maturational offset already cushioned in the adolescent age with smaller maturational differences among girls could mean a lesser impact of the bio-banding concept on girls' enjoyment levels. This reality, coupled with greater experience of playing-up in female chronological age competition, could signify a blurred effect of bio-banding in girls [43]. Additionally, self-confidence might enhance these results as it is positively correlated with the experienced enjoyment, observing higher levels in boys and in late maturing girls. In this latter case, and thanks to the equalization of deter-

mining game performance factors through bio-banding (i.e., physical demands), self-confidence could play a crucial role in girls with a less advanced maturational level to perceive bio-band competition as more attractive [14,41]. Therefore, it may be worth considering the need to reassess strategies and actions related to the application of the ''bio-banding'' concept in women's sports, as the maturational criteria established for boys do not appear to yield similar outcomes for girls, particularly in terms of satisfaction.

This study has certain limitations that should be acknowledged. First, the participants were selected based on accessibility criteria, as they were the only individuals available from the handball academy who met the study's age and activity requirements. Consequently, the sample size may be considered relatively small, and the findings should be interpreted with caution, as the sample may not fully represent the broader population of youth handball players. Second, the distribution of handball players across age groups and maturity bands was uneven. Third, parental heights used for the % PAH-based maturity estimation method were self-reported rather than directly measured, with adjustments made for potential overestimation. Fourth, the menstrual cycle was not included as a criterion for the inclusion or exclusion of young female players. Fifth, the timing of the psychological assessment should be noted as a limitation. Future research could benefit from incorporating repeated measures conducted under different conditions over time (e.g., chronological age competition vs. bio-banding competition) to provide a more comprehensive understanding of the psychological effects. Finally, the application of the bio-banding strategy is specific to a particular socio-cultural context (Spanish youth handball) and may not be directly transferable to other sport systems or cultural settings with different organisational structures (e.g., Norwegian youth sports).

5. Conclusions

The present study, pioneering in exploring the interplay between bio-banding, psychological constructs, and player competition perceptions, identified significant effects of sex and biological maturity status on psychological variables. Specifically, girls exhibited higher levels of cognitive and somatic anxiety, while boys displayed higher self-confidence. Boys also demonstrated greater understanding and enjoyment of the competition, suggesting bio-banding may currently be more suitable for male contexts. Additionally, early maturing girls experienced greater cognitive anxiety, whereas late maturing girls reported higher enjoyment levels.

These findings offer valuable insights for coaches and talent developers aiming to optimize talent selection and player development processes. Practical applications include:

- differentiating competitive experiences by maturity status: coaches can leverage strategies such as ''playing up'' or ''playing down'' to match athletes' maturity levels with appropriate challenges, creating a fairer and more developmentally aligned environment;
- managing anxiety in female athletes: special attention should be given to the psychological responses of female athletes, especially in early maturing girls with regard to anxiety levels. Tailored interventions, such as mental skills training or fostering supportive team environments, can help reduce anxiety and improve their competition experiences;
- designing safe development spaces: by creating contexts based on maturity status, coaches can reduce subjective performance pressures, which are particularly relevant for female athletes, who may face greater social and psychological challenges. Bio-banding provides a framework to design safer developmental pathways that consider individual differences in personality and character;
- maximizing enjoyment and understanding: efforts to increase enjoyment and understanding of bio-banding among all players, particularly females, could enhance its applicability and acceptance. Structured educational sessions for players and stakeholders about the benefits of bio-banding may aid in this process.

These practical strategies underscore the importance of integrating bio-banding as a flexible and adaptable tool within talent development systems, particularly in handball. By addressing psychological and maturity-related differences, bio-banding offers the potential to support more equitable and effective athlete development.

Credit authorship contribution statement

Alfonso de la Rubia: conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; software; supervision; validation; visualization; roles/writing — original draft; and writing — review and editing. Carlos García Sánchez: supervision; validation; visualization; roles/writing — original draft; and writing — review and editing. Moisés Marquina: data curation; supervision; validation; visualization; roles/writing — original draft; and writing — review and editing. Adrián Martín Castellanos: data curation; roles/writing — original draft; and writing — review and editing. Ángel Lino Samaniego: data curation; roles/writing — original draft; and writing — review and editing. Kyran Tannion: data curation; formal analysis; investigation; project administration; resources; software; supervision; validation; visualization; roles/writing — original draft; and Writing — review and editing.

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Disclosure of interest

The authors declare that they have no competing interest.

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Références

[1] Matthys SPJ, Vaeyens R, Vandendriessche J, Vandorpe B, Coutts AJ, Lenoir M, et al. A multidisciplinary identification model for youth handball. Eur J Sport Sci 2011;11:355—63, http://dx.doi.org/10.1080/17461391.2010.523850.

[2] Sweeney L, Horan D, MacNamara Á. Premature professionalisation or early engagement? Examining practise in football player pathways. Front Sports Act Living 2021;3:1—9, http://dx.doi.org/10.3389/fspor.2021.660167.

[3] Massa M, Moreira A, Costa RA, Lima MR, Thiengo CR, Marquez WQ, et al. Biological maturation influences selection process in youth elite soccer players. Biol Sport 2022;39:435—41, http://dx.doi.org/10.5114/biolsport.2022.106152.

[4] Cumming SP, Lloyd RS, Oliver JL, Eisenmann JC, Malina RM. Bio-banding in sport: applications to competition, talent identification, and strength and conditioning of youth athletes. Strength Cond J 2017;39:34—47, http://dx.doi.org/10.5152/tjsm.2019.126.

[5] Malina RM, Cumming SP, Rogol AD, Coelho-e-Silva MJ, Figueiredo AJ, Konarski JM, et al. Bio-banding in youth sports: background, concept, and application. Sport Med 2019;49:1671—85, http://dx.doi.org/10.1007/s40279-019-01166-x.

[6] Malina RM, Bouchard C, Bar-Or O. Growth, maturation, and physical activity. Human Kinetics; 2004.

[7] Malina RM, Rogol AD, Cumming SP, Coelho e Silva MJ, Figueiredo AJ. Biological maturation of youth athletes: assessment and implications. Br J Sports Med 2015;49:852—9, http://dx.doi.org/10.1136/bjsports-2015-094623.

[8] Johnson A. Monitoring the immature athlete. Aspetar Sport Med J 2015;4:114—8.

[9] Baxter-Jones ADG, Eisenmann JC, Sherar LB. Controlling for maturation in pediatric exercise science. Pediatr Exerc Sci 2005;17:18—30, http://dx.doi.org/10.1123/pes.17.1.18.

[10] Thomas C, Oliver J, Kelly AL. Bio-banding in youth soccer: considerations for researchers and practitioners. Birth advantages and relative age effects in sport. Routledge; 2021, p. 107—24.

[11] Johnson A, Farooq A, Whiteley R. Skeletal maturation status is more strongly associated with academy selection than birth quarter. Sci Med Footb 2017;1:157—63, http://dx.doi.org/10.1080/24733938.2017.1283434.

[12] MacMaster C, Portas M, Parkin G, Cumming SP, Wilcox C, Towlson C. The effect of bio-banding on the anthropometric, physical fitness and functional movement characteristics of academy soccer players. PLoS One 2021;16:1—16, http://dx.doi.org/10.1371/journal.pone.0260136.

[13] Lüdin D, Donath L, Cobley S, Romann M. Effect of bio-banding on physiological and technical-tactical key performance indicators in youth elite soccer. Eur J Sport Sci 2022;22:1659—67, http://dx.doi.org/10.1080/17461391.2021.1974100.

[14] Towlson C, MacMaster C, Gonçalves B, Sampaio J, Toner J, MacFarlane N, et al. The effect of bio-banding on physical and psychological indicators of talent identification in academy soccer players. Sci Med Footb 2021;00:1—13, http://dx.doi.org/10.1080/24733938.2020.1862419.

[15] Arede J, Cumming S, Johnson D, Leite N. The effects of maturity matched and un-matched opposition on physical performance and spatial exploration behavior during youth basketball matches. PLoS One 2021;16:e0249739, http://dx.doi.org/10.1371/journal.pone.0249739.

[16] de la Rubia A, Kelly AL, García-González J, Lorenzo J, Mon-López D, Maroto-Izquierdo S. Biological maturity vs. relative age: independent impact on physical performance in male and female youth handball players. Biol Sport 2024;41:3—13, http://dx.doi.org/10.5114/biolsport.2024.132999.

[17] PoVoas SCA, Seabra AFT, Ascensao ANAMR, MagalhaEs J, Soares JMC, Rebelo ANNC. Physical and physiological demands of elite team handball. J Strength Cond Res 2012;26:3365—75, http://dx.doi.org/10.1519/JSC.0b013e318248aeee.

[18] Figueiredo AJ, Gonçalves CE, Coelho e Silva MJ, Malina RM. Characteristics of youth soccer players who drop out, persist or move up. J Sports Sci 2009;27:883—91, http://dx.doi.org/10.1080/02640410902946469.

[19] Bradley B, Johnson D, Hill M, McGee D, Kana-ah A, Sharpin C, et al. Bio-banding in academy football: player's perceptions of a maturity matched tournament. Ann Hum Biol 2019;46:400—8, http://dx.doi.org/10.1080/03014460.2019.1640284.

[20] Cumming SP, Brown DJ, Mitchell SB, Bunce J, Hunt D, Hedges C, et al. Premier League academy soccer players' experiences of competing in a tournament bio-banded for biological maturation. J Sports Sci 2018;36:757—65, http://dx.doi.org/10.1080/02640414.2017.1340656.

[21] de la Rubia A, Lorenzo-Calvo J, Rojas-Valverde D, Mon-López D, Radnor J, Kelly AL. Bio-banding in handball: academy players' perceptions based on maturity status and gender. Int J Sports Med 2023;44:871—81, http://dx.doi.org/10.1055/a-2145-6454.

[22] Gómez-López M, Chicau Borrego C, Marques da Silva C, Granero-Gallegos A, González-Hernández J. Effects of motivational climate on fear of failure and anxiety in teen handball players. Int J Environ Res Public Health 2020;17:592, http://dx.doi.org/10.3390/ijerph17020592.

[23] Dutil C, Tremblay MS, Longmuir PE, Barnes JD, Belanger K, Chaput J-P. Influence of the relative age effect on children's scores obtained from the Canadian assessment of physical literacy. BMC Public Health 2018;18:1040, http://dx.doi.org/10.1186/s12889-018-5895-6.

[24] Ford J, Ildefonso K, Jones M, Arvinen-Barrow M. Sport-related anxiety: current insights. Open Access J Sport Med 2017;8:205—12, http://dx.doi.org/10.2147/OAJSM.S125845.

[25] Epstein LH, Valoski AM, Kalarchian MA, McCurley J. Do children lose and maintain weight easier than adults: a comparison of child and parent weight changes from six months to ten years. Obes Res 1995;3:411—7, http://dx.doi.org/10.1002/j.1550-8528.1995.tb00170.x.

[26] Stewart A, Marfell-Jones M, Olds T, De Ridder H. International society for the advancement of kinanthropometry: international standards for anthropometric assessment. Int Soc Adv Kinanthropometry 2011:115.

[27] Khamis HJ, Roche AF. Predicting adult stature without using skeletal age-the Khamis-Roche Method. Pediatrics 1994;94:504, http://dx.doi.org/10.1542/peds.94.4.504.

[28] Bayer LM, Bayley N. Growth diagnosis: selected methods for interpreting and predicting physical development from one year to maturity. Oxford, England: University of Chicago Press; 1959.

[29] Malina RM, Dompier TP, Powell JW, Barron MJ, Moore MT. Validation of a noninvasive maturity estimate relative to skeletal age in youth football players. Clin J Sport Med 2007;17:362—8, http://dx.doi.org/10.1097/JSM.0b013e31815400f4.

[30] Drenowatz C, Wartha O, Klenk J, Brandstetter S, Wabitsch M, Steinacker J. Differences in health behavior, physical fitness, and cardiovascular risk in early, average, and late mature children. Pediatr Exerc Sci 2013;25:69—83, http://dx.doi.org/10.1123/pes.25.1.69.

[31] Fridhandler BM. Conceptual note on state, trait, and the state—trait distinction. J Pers Soc Psychol 1986;50:169—74, http://dx.doi.org/10.1037/0022-3514.50.1.169.

[32] Fernández A, Elena M, Lois Río G, Arce Fernández C. Propiedades psicométricas de la versión española del inventario de ansiedad competitiva CSAI-2R en deportistas. Psicothema 2007;19:150—5.

[33] Cox RH, Martens MP, Russell WD. Measuring anxiety in athletics: the revised competitive state anxiety inventory—2. J Sport Exerc Psychol 2003;25:519—33, http://dx.doi.org/10.1123/jsep.25.4.519.

[34] Taylor J. Predicting athletic performance with self- confidence and somatic and cognitive anxiety as a function of motor and physiological requirements in six sports. J Pers 1987;55:139—53, http://dx.doi.org/10.1111/j.1467-6494.1987.tb00432.x.

[35] Brown KA, Patel DR, Darmawan D. Participation in sports in relation to adolescent growth and development. Transl Pediatr 2017;6:150—9, http://dx.doi.org/10.21037/tp.2017.04.03.

[36] Eriksen IM. Teens' dreams of becoming professional athletes: the gender gap in youths' sports ambitions. Sport Soc 2022;25:1909—23, http://dx.doi.org/10.1080/17430437.2021.1891044.

[37] Buss DM. Psychological sex differences. Origins through sexual selection. Am Psychol 1995;50:164—8, http://dx.doi.org/10.1037/10756-019 [Hoboken: John Wiley & Sons Inc.].

[38] Rutherford A. Psychology at the intersections of gender, feminism, history, and culture. Cambridge: Cambridge University Press; 2021.

[39] Smart JEH, Cumming SP, Sherar LB, Standage M, Neville H, Malina RM. Maturity associated variance in physical activity and health-related quality of life in adolescent females: a mediated effects model. J Phys Act Heal 2012;9:86—95, http://dx.doi.org/10.1123/jpah.9.1.86.

[40] Handelsman DJ, Hirschberg AL, Bermon S. Circulating testosterone as the hormonal basis of sex differences in athletic performance. Endocr Rev 2018;39:803—29, http://dx.doi.org/10.1210/er.2018-00020.

[41] Hill M, Spencer A, McGee D, Scott S, Frame M, Cumming SP. The psychology of bio-banding: a Vygotskian perspective. Ann Hum Biol 2020;47:328—35, http://dx.doi.org/10.1080/03014460.2020.1797163.

[42] Romann M, Lüdin D, Born DP. Bio-banding in junior soccer players: a pilot study. BMC Res Notes 2020;13:1—5, http://dx.doi.org/10.1186/s13104-020-05083-5.

[43] Kelly AL, Wilson M, Jackson DT, Goldman D, Turnnidge J, Côté J, et al. A multidisciplinary investigation into ''playing-up'' in academy football according to age phase. J Sports Sci 2021;39:854—64, http://dx.doi.org/10.1080/02640414.2020.1848117.