



UNIVERSIDADE FEDERAL DE SANTA CATARINA
CENTRO DE DESPORTOS
PROGRAMA DE PÓS-GRADUAÇÃO EM EDUCAÇÃO FÍSICA

André Luiz de Almeida Soares

Beyond specialization in youth basketball: a multidimensional approach and scientific
mapping of developmental pathways and practical implications

Florianópolis

2025

André Luiz de Almeida Soares

Beyond specialization in youth basketball: a multidimensional approach and scientific mapping of developmental pathways and practical implications

Thesis submitted to the Graduate Program in Physical Education of the Federal University of Santa Catarina as a requirement for the doctoral degree.

Supervisor: Prof. Humberto Moreira Carvalho, Dr.

Florianópolis

2025

Soares, André Luiz de Almeida

Beyond specialization in youth basketball : a multidimensional approach and scientific mapping of developmental pathways and practical implications / André Luiz de Almeida Soares ; orientador, Humberto Moreira Carvalho, 2025.

188 p.

Tese (doutorado) - Universidade Federal de Santa Catarina, Centro de Desportos, Programa de Pós-Graduação em Educação Física, Florianópolis, 2025.

Inclui referências.

1. Educação Física. 2. Physical Education. 3. Youth Basketball. 4. Early Specialization. I. Carvalho, Humberto Moreira. II. Universidade Federal de Santa Catarina. Programa de Pós-Graduação em Educação Física. III. Título.

André Luiz de Almeida Soares

Beyond specialization in youth basketball: a multidimensional approach and scientific mapping of developmental pathways and practical implications

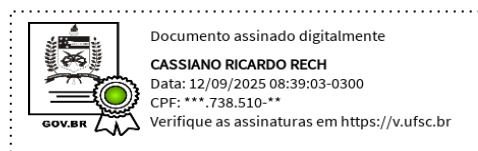
The present work at the doctoral level was evaluated and approved by an examining board composed of the following members:

Profª. Daniele Detânico, Dra.
Universidade Federal de Santa Catarina

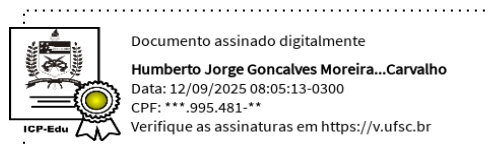
Prof. Thiago José Leonardi, Dr.
Universidade Federal do Rio Grande do Sul

Prof. Dilson Borges Ribeiro Júnior, Dr.
Universidade Federal de Juíz de Fora

We certify that this is the original and final version of the thesis deemed suitable for obtaining the Doctor degree in Physical Education.



Graduate Program Coordination



Prof. Humberto Moreira Carvalho, Dr.(a)
Supervisor

Florianópolis, 2025.

To everyone who made this study possible.

ACKNOWLEDGEMENTS

A todas as pessoas que, de alguma forma, contribuíram em minha trajetória até aqui.

À minha família José Luiz, Sandra e Andressa, que nunca deixou de me apoiar, e ofereceu condições para que sempre buscasse meus objetivos, não medindo esforços para permitir acesso a boa educação e convivência em ambientes que me fizeram crescer, pela influência na escolha profissional e do ambiente esportivo.

À minha companheira de vida, Nadine Oliveira, paciente e resiliente nos momentos de luta, noites mal dormidas e apreensões, mas também presente nos melhores momentos e memórias de todas as conquistas ao longo da trajetória.

Aos professores membros da banca, por suas preciosas contribuições e elevação do pensamento crítico na elaboração e desenvolvimento desse trabalho. Em especial, ao professor Dr. Humberto Carvalho, que oportunizou elevar os níveis de competências profissionais e pessoais, nos meios acadêmico, esportivo e social desde os primeiros momentos de convivência há mais de dez anos.

Ao Programa de Pós-Graduação em Educação Física (PPGEF) do Centro de Desportos (CDS) da Universidade Federal de Santa Catarina (UFSC) e todos os professores que o constituem e constituíram ao longo do tempo, pela estrutura e ambiente proporcionados para a formação na pós-graduação. À Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) pelo suporte oferecido em parte da constituição desse trabalho.

Aos clubes e associações que abriram suas portas para o desenvolvimento desse e muitos outros estudos que buscam compreender o esporte de jovens e suas dinâmicas. Também à Federação Catarinense de Basketball (FCB) que proporcionou condições de contato e apoio para o desenvolvimento desse trabalho.

Aos meus treinadores e treinadoras, que compartilharam de sua paixão pelo esporte, e pelas experiências em diferentes níveis de competição, envolvimento e significados.

Aos colegas acadêmicos, pelas trocas de ideias e experiências compartilhadas em todos os grupos de estudo, laboratórios, e outros momentos que nos ensinam muito mais do que em livros.

A todos colegas profissionais e gestores esportivos que compartilham as desventuras e desafios constantes da vida esportiva.

Atletas que tive a oportunidade de conviver e trabalhar, obrigado pela oportunidade de aprender, e por confiarem no processo de constante busca pela excelência dia após dia.

*“Se não posso fazer tudo o que devo.
Devo, ao menos, fazer tudo o que posso”*
- Amigos do Bem

ABSTRACT

This study uses a multidimensional and ecological approach to examine the developmental trajectories of young Brazilian basketball players, with a critical focus on early specialization. Drawing on a series of empirical studies and a comprehensive scoping review, the study explores how physical, psychological, and contextual factors interact to influence functional performance, motivation, and enjoyment across various stages of youth development. The thesis comprises four original studies: (1) a scoping review of the literature on youth basketball revealing gaps and methodological limitations, such as the underrepresentation of psychosocial and pedagogical variables and differences between sex and the lack of longitudinal studies compared with cross-sectional designs; (2) a longitudinal analysis compares the physical fitness development of early- and late-specialized athletes across the competitive season and shows no consistent advantage for early specialization. (3) a multilevel investigation examines motivational and (4) enjoyment variables among young female athletes and identifies contextual and relational factors as key to sustaining engagement in structured training over time. Methodologically, the thesis uses Bayesian hierarchical modeling to account for individual and contextual variations. It also classifies specialization timing based on biological maturation markers rather than arbitrary age cutoffs. The findings challenge the dominant narrative that early specialization brings advantages in functional fitness and is a predictor of dropping out. They offer evidence-based data for inclusive, developmentally appropriate practices in youth sports. This research contributes to theoretical advancements and applied practices in sports pedagogy by providing coaches, policymakers, and other stakeholders with tools to promote healthy, sustainable sports participation among youth.

Keywords: youth basketball; early specialization; athlete development; bioecological approach; Bayesian hierarchical modeling; enjoyment; dropout; motivation.

RESUMO EXPANDIDO

O presente estudo analisa as trajetórias de desenvolvimento de jovens atletas de basquete no Brasil, recorrendo a uma abordagem multidimensional e ecológica, com atenção crítica ao fenômeno da especialização esportiva. O trabalho parte do reconhecimento de que o sistema esportivo brasileiro está majoritariamente orientado para o alto rendimento desde tenra idade, frequentemente baseado na crença de que quanto mais cedo os jovens se envolverem em práticas específicas e intensas, maiores serão as suas chances de sucesso futuro. Ao mesmo tempo, as críticas constantes ao processo de especialização são apresentadas em diferentes modelos, mas carecem de evidências baseadas em dados, fazendo recomendações genéricas.

A tese está estruturada em capítulos temáticos, contendo estudos empíricos e revisões sistemáticas interligados por uma perspectiva multidimensional centrada no desenvolvimento de jovens atletas. Os capítulos 1 e 2 apresentam o campo de investigação e a temática que será abordada na tese, a partir de uma introdução geral, da apresentação da proposta da tese e dos principais objetivos, da abordagem conceitual e da definição dos principais termos e temas traduzidos durante o estudo. O capítulo 3 apresenta uma revisão de âmbito e um mapa de evidências, que iluminam a literatura científica sobre o basquetebol juvenil, identificando tendências, lacunas e limitações metodológicas. Com base em 719 artigos publicados entre 1964 e 2024, o estudo mostra que predominam investigações unidimensionais, focadas principalmente em variáveis antropométricas e fisiológicas, com uma representação reduzida de temas ligados à pedagogia, psicologia e participação esportiva feminina. Constatou-se ainda a escassez de estudos longitudinais, com perspectivas multidimensionais e amostras representativas de diferentes regiões e níveis de competição, revelando um desequilíbrio no conhecimento produzido sobre o desenvolvimento de jovens atletas.

O Capítulo 4 explicita as considerações metodológicas da tese, os testes utilizados e a abordagem analítica das principais variáveis consideradas, sobretudo nos estudos empíricos.

O Capítulo 5 investiga empiricamente a associação entre o tempo de especialização esportiva e o desenvolvimento da aptidão física em jovens jogadores de basquete. Com um delineamento longitudinal e classificando a especialização com base na idade biológica (a partir do pico de velocidade de crescimento, ou PHV), o estudo demonstrou que não houve vantagens claras no desenvolvimento físico dos atletas que se especializam mais cedo. Essa constatação não confirma os pressupostos amplamente difundidos na literatura e na prática esportiva de que a especialização prematura seria um caminho necessário para o desenvolvimento da excelência esportiva.

No Capítulo 6, foi adotada uma modelagem hierárquica bayesiana para investigar fatores individuais e contextuais associados à motivação para o desempenho e à competitividade entre atletas jovens. Os resultados indicam que essas variáveis não são moldadas apenas por traços individuais, mas principalmente por aspectos contextuais, como o ambiente de treino, a relação com treinadores e o clima motivacional predominante nos clubes. Essa abordagem permite compreender as diferenças de empenho e desempenho entre atletas a partir de suas realidades específicas, reforçando a importância de práticas pedagógicas mais sensíveis às necessidades individuais e contextuais.

O Capítulo 7 adota uma perspectiva ecológica para analisar as fontes de apreciação entre atletas femininas de basquete. Os resultados revelam que o prazer na prática esportiva é fortemente influenciado por relações interpessoais, percepção de competência e apoio social, e que essas variáveis são influenciadas pelo avanço da idade e pelas diferentes expectativas das atletas. A manutenção da motivação para a prática esportiva ao longo do tempo está mais relacionada à qualidade das experiências vividas no contexto esportivo do que à idade de início da especialização ou aos resultados imediatos obtidos. A análise sugere que políticas e práticas centradas no desenvolvimento humano, e não exclusivamente no desempenho competitivo,

podem ser mais eficazes para promover trajetórias esportivas saudáveis e sustentáveis. Ambos os estudos demonstram que a variação da motivação e do prazer na prática esportiva é mais influenciada pelo contexto do que pelo tempo de especialização.

Ao longo da tese, foram utilizados modelos estatísticos avançados, especialmente a modelagem hierárquica bayesiana, para lidar com os desafios metodológicos impostos por pequenas amostras e contextos diversos. A escolha do ponto de corte para a classificação da especialização precoce foi baseada em marcos biológicos de maturação, e não em idades cronológicas arbitrárias, como os 12 anos, frequentemente adotados na literatura canadense como exemplo, respeitando assim a diversidade cultural e o contexto específico do esporte brasileiro. Além disso, todos os dados utilizados nos estudos foram disponibilizados em repositórios de acesso aberto, promovendo a transparência científica e incentivando a reprodutibilidade e novas análises futuras.

Por fim, o Capítulo 8 apresenta uma discussão geral que integra os achados com implicações práticas para treinadores, gestores, educadores e formuladores de políticas públicas. Defende-se uma abordagem centrada no atleta, que priorize o desenvolvimento integral, o prazer pela prática e a permanência no esporte, em oposição a modelos exclusivos de seleção e especialização orientados unicamente para o rendimento esportivo. Nesse modelo, amplia-se a oferta de práticas com diferentes níveis e perspectivas, baseadas nas capacidades, orientação e expectativas dos atletas. A conclusão, apresentada no capítulo 9, reforça o compromisso da tese com a ciência aplicada e com a transformação do ambiente esportivo juvenil, de modo a promover práticas fundamentadas e adequadas ao sistema esportivo, destacando a necessidade de intervenções adequadas ao jovem atleta, assim como a promoção de uma sistema esportivo que amplie as possibilidades de participação de diferentes públicos.

Palavras-chave: basquete de jovens; especialização precoce; desenvolvimento de atletas; perspectiva bioecológica; modelação hierárquica bayesiana; fontes de apreciação; evasão esportiva; motivação.

PUBLICATIONS

The results presented in this thesis are published or were submitted in peer-reviewed journals, as follows:

1. SOARES, A. L. A.; CARVALHO, H. M. Burnout and dropout associated with talent development in youth sports. **Frontiers in Sports and Active Living**, Lausanne, v. 5, 2023. Available in: <https://doi.org/10.3389/fspor.2023.1190453>. Accessed: May 28th, 2025.
2. SOARES, A. L. A.; LIMA, A. B.; SARMENTO, H.; CLEMENTE, F. M.; GONÇALVES, C. E.; CARVALHO, H. M. Youth basketball research: a scoping review and evidence gap map of research trends and multidimensionality. Working manuscript.
3. SOARES, A. L. A.; LIMA, A. B.; MIGUEL, C. G.; GALVÃO, L. G.; LEONARDI, T. J.; PAES, R. R.; GONÇALVES, C. E.; CARVALHO, H. M. Does early specialization provide an advantage in physical fitness development in youth basketball? **Frontiers in Sports and Active Living**, Lausanne, v. 4, 2023. Available in: <https://doi.org/10.3389/fspor.2022.1042494>. Accessed: May 28th, 2025.
4. SOARES, A. L. A.; LIMA, A. B.; ALVES, A.C.; QUINAUD, R. T.; LEONARDI, T. J.; GONÇALVES, C.E.; CARVALHO, H.M. Achievement and competitiveness motivation in youth sport: A Bayesian hierarchical modeling of individual- and contextual-level determinants. Submitted.
5. SOARES, A. L. A.; LIMA, A. B.; POSSAMAI, K.; QUINAUD, R. T.; LEONARDI, T. J.; GONÇALVES, C.E.; CARVALHO, H.M. An ecological approach to sources of enjoyment in young female athletes. **Brazilian Journal Of Sport Psychology And Human Development**, v.1, n.1, 2025. Accessed: August 20th, 2025.

FIGURES

Figure 1. PRISMA flowchart diagram of the procedures used for the documents search and selection.....	43
Figure 2. (A) Cumulative papers on youth basketball topic through years from 2000 to 2024; and (B) Journal Impact Factor classification of youth basketball studies published between 2000 and 2024	44
Figure 3. Comparison among studies design from 2000 to 2024.....	45
Figure 4. Count of studies by participants' sex over the years, from 2000 to 2024.....	46
Figure 5. (A) Total distribution of age groups among published papers; and (B) distribution of age groups among different dimensions	47
Figure 6. Mapping concentration of published papers by knowledge dimension from 2000 to 2024	49
Figure 7. Total of published papers and number of dimensions accomplished through 2000 to 2024	50
Figure 8. Density of dimensions accomplished by published papers tendencies through years, from 2000 to 2024	52
Figure 9. Changes in countermovement jump performance for young females and male basketball players within a basketball season by the onset of specialization. The shaded area represents the 68% credible interval, similar to a standard deviation.	76
Figure 10. Changes in line-drill performance for young females and male basketball players within a basketball season by the onset of specialization. The shaded area represents the 68% credible interval, similar to a standard deviation.....	77
Figure 11. Changes in Yo-yo intermittent recovery test level 1 performance for young females and male basketball players within a basketball season by the onset of specialization. The shaded area represents the 68% credible interval, similar to a standard deviation.	77
Figure 12. Changes in overall basketball-specific physical fitness index for young females and male basketball players within a basketball season by the onset of specialization. The shaded area represents the 68% credible interval, similar to a standard deviation.....	78
Figure 13. Developmental changes in countermovement jump performance for young females and male basketball players by specialization onset. The shaded area represents the 68% credible interval, similar to a standard deviation.....	79

Figure 14. Developmental changes in line-drill performance for young females and male basketball players by specialization onset. The shaded area represents the 68% credible interval, similar to a standard deviation.	79
Figure 15. Developmental changes in Yo-yo intermittent recovery test level 1 performance for young females and male basketball players by specialization onset. The shaded area represents the 68% credible interval, similar to a standard deviation.	80
Figure 16. Developmental changes in overall basketball-specific physical fitness performance index for young females and male basketball players by specialization onset. The shaded area represents the 68% credible interval, similar to a standard deviation.	81
Figure 17. Posterior predictions of the probability of responses for the Work and family orientation questionnaire items in young Brazilian athletes. Uncertainty estimates represent the 68% credible intervals.	94
Figure 18. Posterior predictions of the probability of responses for Deliberate practice motivation questionnaire items in young Brazilian athletes. Uncertainty estimates represent the 68% credible intervals.	95
Figure 19. Posterior predictions of the probability of responses for Work and family orientation questionnaire items in young Brazilian athletes grouped by sex. Uncertainty estimates represent the 68% credible intervals.	96
Figure 20. Posterior predictions of the probability of responses for Deliberate practice motivation questionnaire items in young Brazilian athletes grouped by sex. Uncertainty estimates represent the 68% credible intervals.	97
Figure 21. Posterior predictions of the probability of responses for the Source of Enjoyment in youth sports questionnaire factors in young Brazilian athletes. Uncertainty estimates represent the 50% credible intervals.	115
Figure 22. Posterior predictions of the probability of longitudinal responses for Self-referenced competency aligned by chronological age (upper panel), distance to menarche (middle panel), and accumulated years of deliberate practice (lower panel) in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 50% credible intervals.	116
Figure 23. Posterior predictions of the probability of longitudinal responses for Other-referenced competency and recognition aligned by chronological age (upper panel), distance to menarche (middle panel), and accumulated years of deliberate practice (lower panel) in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 50% credible intervals.	117

Figure 24. Posterior predictions of the probability of longitudinal responses for Effort expenditure aligned by chronological age (upper panel), distance to menarche (middle panel), and accumulated years of deliberate practice (lower panel) in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 50% credible intervals.....118

Figure 25. Posterior predictions of the probability of longitudinal responses for competitive excitement aligned by chronological age (upper panel), distance to menarche (middle panel), and accumulated years of deliberate practice (lower panel) in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 50% credible intervals.....119

Figure 26. Posterior predictions of the probability of longitudinal responses for Affiliation with peers aligned by chronological age (upper panel), distance to menarche (middle panel), and accumulated years of deliberate practice (lower panel) in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 50% credible intervals.....120

Figure 27. Posterior predictions of the probability of longitudinal responses for Positive parental involvement aligned by chronological age (upper panel), distance to menarche (middle panel), and accumulated years of deliberate practice (lower panel) in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 50% credible intervals.....121

TABLES

Table 1. Summary of Discrete Variables and Their Levels	39
Table 2. Number of dimensions considered in studies by proportion in each category.....	50
Table 3. Descriptive statistics of the sample at pre-season by age group and sex	75
Table 4. Distribution of players by the onset of specialization within an age group and sex in the sample of young Brazilian players.	75

CONTENTS

1. A CONCEPTUAL APPROACH TO YOUTH BASKETBALL SPECIALIZATION RESEARCH AND PRACTICAL IMPLICATIONS	17
1.1.YOUTH SPORTS PARTICIPATION	17
1.2.PERFORMANCE-ORIENTED SELECTION AND THE RISE OF SPECIALIZATION	
18	
1.3.SPORT SPECIALIZATION AND DELIBERATE PRACTICE.....	22
1.4.RESEARCH AND METHODOLOGICAL CHALLENGES IN SPORTS SPECIALIZATION	25
2. PURPOSE.....	28
2.1.DEFINING KEY TERMINOLOGIES.....	28
2.1.1.Sports selection	28
2.1.2.Deliberate practice.....	29
2.1.3.Dropout of sports participation.....	29
2.1.4.Early specialization.....	30
2.1.5.Multidimensional approach.....	30
2.1.6.Performance	30
2.1.7.Maturity offset	31
2.1.8.Athletes Development Programs.....	31
2.1.9.Bayesian hierarchical modeling	32
2.1.10.PPCT model	32
2.2.THESIS STRUCTURE	32
3. YOUTH BASKETBALL RESEARCH: A SCOPING REVIEW AND EVIDENCE GAP MAP OF RESEARCH TRENDS AND MULTIDIMENSIONALITY	35
3.1.INTRODUCTION	35
3.2.METHODS.....	37
3.2.1.Search strategy.....	37
3.2.2.Eligibility criteria.....	38
3.2.3.Data selection	38
3.2.4.Data categorization.....	38
3.3.RESULTS.....	42
3.3.1.Study selection and Characteristics	42

3.3.2.Publication Trends	43
3.3.3.Methodological Characteristics.....	44
3.3.4.Thematic Focus and Multidimensionality	47
3.4.DISCUSSION.....	51
3.5.LIMITATIONS	54
3.6.CONCLUSION	55
4. METHODOLOGICAL CONSIDERATIONS.....	56
4.1.ETHICAL CONSIDERATIONS	56
4.2.STUDY AND SURVEY APPROACH.....	57
4.3.MEASURES AND FIELD TESTS	58
4.3.1.Contextual and Developmental Variables.....	58
4.3.2.Anthropometry and Biological Maturation	59
4.3.3.Physical Fitness and Functional Capacity.....	60
4.3.4.Psychobehavioral and Motivational Variables	61
4.4.DATA ANALYSIS AND MODELLING STRATEGIES.....	62
5. DOES EARLY SPECIALIZATION PROVIDE AN ADVANTAGE IN PHYSICAL FITNESS DEVELOPMENT IN YOUTH BASKETBALL?	63
5.1.INTRODUCTION	63
5.2.MATERIALS AND METHODS	65
5.2.1.Participants and study design.....	65
5.2.2.Procedures.....	66
<i>5.2.2.1.Anthropometric measurements</i>	<i>67</i>
<i>5.2.2.2.Chronological age and maturity status</i>	<i>67</i>
<i>5.2.2.3.Onset of specialization in basketball.....</i>	<i>68</i>
<i>5.2.2.4.Physical fitness assessment</i>	<i>69</i>
5.2.3.Statistical models	69
<i>5.2.3.1.Modeling changes within a competitive season</i>	<i>69</i>
<i>5.2.3.2.Modeling developmental changes</i>	<i>70</i>
<i>5.2.3.3.Prior distributions</i>	<i>71</i>
<i>5.2.3.4.Statistical software, code repository, and reproducibility</i>	<i>71</i>
5.3.RESULTS.....	71
5.4.DISCUSSION.....	78
5.5.DATA AVAILABILITY STATEMENT.....	82
5.6.SUPPLEMENTARY MATERIAL	82

6. ACHIEVEMENT AND COMPETITIVENESS MOTIVATION IN YOUTH SPORT: A BAYESIAN HIERARCHICAL MODELING OF INDIVIDUAL- AND CONTEXTUAL-LEVEL DETERMINANTS	83
6.1.INTRODUCTION	83
6.2.METHODS	86
6.2.1.Sample.....	86
6.2.2.Procedures.....	87
6.2.3.Data analysis	88
6.3.RESULTS	90
6.3.1.Individual-level determinants.....	92
6.3.2.Contextual-level determinants.....	94
6.4.DISCUSSION.....	94
7. AN ECOLOGICAL APPROACH TO SOURCES OF ENJOYMENT IN YOUNG FEMALE ATHLETES.....	99
7.1.INTRODUCTION	99
7.2.MATERIALS AND METHODS	102
7.2.1.Study design and participants	102
7.2.2.Cross-sectional data.....	103
7.2.3.Repeated measures data.....	103
7.2.4.Measures.....	103
7.2.4.1.Outcomes variable.....	103
7.2.5.Person outcomes	104
7.2.5.1.Chronological age.....	105
7.2.5.2.Age at menarche and menarcheal status.....	105
7.2.6.Process outcomes	105
7.2.6.1.Sport-specific onset of specialization and accumulated deliberate practice	105
7.2.7.Context outcomes.....	106
7.2.7.1.Microsystem and mesosystem variables.....	106
7.2.7.2.Exosystem and macrosystem variables.....	106
7.2.8.Data analysis	107
7.2.8.1.Models specification.....	107
7.2.8.2.Prior distributions	109
7.2.8.3.Posterior predictive checks and computation	110
7.3.RESULTS.....	110

7.4.DISCUSSION.....	119
7.5.LIMITATIONS	123
7.6.ACKNOWLEDGEMENTS.....	124
7.7.FUNDING	124
7.8.DATA AVAILABILITY STATEMENT	124
7.9.CODE AVAILABILITY	124
8. GENERAL DISCUSSION	125
8.1.CONTRADICTIONS IN SELECTION PRACTICES AND TALENT IDENTIFICATION	
125	
8.2.CHALLENGING THE ASSUMPTIONS ON EARLY SPECIALIZATION	127
8.3.A MULTIDIMENSIONAL UNDERSTANDING OF YOUTH ATHLETE	
DEVELOPMENT.....	129
8.4.METHODOLOGICAL ADVANCES AND RESEARCH GAPS	130
8.5.LIMITATIONS	132
9. CONCLUSION	133
REFERENCES	135
APPENDIX A – SUPPLEMENTARY MATERIAL FOR THE MANUSCRIPT “DOES	
EARLY SPECIALIZATION PROVIDE AN ADVANTAGE IN PHYSICAL FITNESS	
DEVELOPMENT IN YOUTH BASKETBALL?”	153
APPENDIX B – SUPPLEMENTARY MATERIAL FOR THE MANUSCRIPT	
“ACHIEVEMENT AND COMPETITIVENESS MOTIVATION IN YOUTH SPORT: A	
BAYESIAN HIERARCHICAL MODELING OF INDIVIDUAL- AND CONTEXTUAL-	
LEVEL DETERMINANTS”	162
APPENDIX C – SUPPLEMENTARY MATERIAL FOR THE MANUSCRIPT “AN	
ECOLOGICAL APPROACH TO SOURCES OF ENJOYMENT IN YOUNG FEMALE	
ATHLETES”.....	175

1. A CONCEPTUAL APPROACH TO YOUTH BASKETBALL SPECIALIZATION RESEARCH AND PRACTICAL IMPLICATIONS¹

1.1. YOUTH SPORTS PARTICIPATION

Youth participation in sports has been widely acknowledged as a significant part of children's and adolescents' lives, contributing to many positive outcomes (BERGERON et al., 2015; LOGAN et al., 2019). Beyond recreational engagement, many organized youth sports programs strongly focus on performance development. To foster participants' competence and skills as they transition into adulthood as athletes, these programs adopt a competitive orientation. They cultivate efforts to drive athletes to excel and engage in the high-volume and high-intensity practice standards required for expert performance (CARVALHO et al., 2023; GONÇALVES et al., 2011; KALÉN et al., 2021; POSSAMAI et al., 2024).

The pursuit of developing elite athletes to achieve success in adulthood is a primary interest for talent identification and development programs in many countries. There is increasing interest in sports research to understand the effectiveness of policies and programs aimed at achieving elite sports success (DE BOSSCHER et al., 2006; DE BOSSCHER et al., 2009; DE BOSSCHER, 2015; KALÉN et al., 2021; MAZZEI et al., 2014). Sports organizations and federations invest substantial funds in promoting programs and pathways to develop talent at both club and national levels to remain competitive and attain excellence in sports performance (DE BOSSCHER et al., 2009; DE BOSSCHER, 2015; KALÉN et al., 2021; WILLIAMS and REILLY, 2000; WILLIAMS and REILLY, 2020). Programs are typically designed, structured, and financed by clubs and governmental bodies to provide adequate conditions for young athletes to achieve high performance levels, often as early as possible (GONÇALVES et al., 2012; OSTOJIC et al., 2014).

This increased interest in fostering elite athletes has led to the professionalization of programs through specific training interventions. These interventions include adequate and specialized coach supervision, multidisciplinary support for sports practice, and financial assistance to athletes, enabling them to dedicate time and effort to sports training and competitive performance, often from an early age (DE BOSSCHER, 2015; GONÇALVES et al., 2012; OSTOJIC et al., 2014). From a developmental perspective, the prevailing notion is

¹This chapter was partially published in: SOARES, A. L. A.; CARVALHO, H. M. Burnout and dropout associated with talent development in youth sports. **Frontiers in Sports and Active Living**, Lausanne, v. 5, 2023. Available in: <https://doi.org/10.3389/fspor.2023.1190453>. Accessed: May 28th, 2025.

that initiating involvement and accruing deliberate practice under the guidance of specialized coaches, coupled with exposure to higher levels of competition during adolescence, will enhance skill progression beyond the impacts of typical growth and development. This is considered necessary for excelling in high-level competitions in senior years (BAKER and YOUNG, 2014; DE BRUIN et al., 2008; ERICSSON et al., 1993; GONÇALVES et al., 2011; GÜLLICH, 2018). Consequently, the concept of early specialization during the pre-adolescent years holds appeal for numerous national governing bodies, clubs, coaches, parents, and aspiring young athletes who aim to achieve excellence and ascend to an elite level in sports. In basketball, for example, club programs may encourage commitment and engagement in deliberate practice from as early as 5 years old (WABC, 2016). Furthermore, young athletes engaged in youth sports academies demonstrate an increased likelihood of achieving professional status by age 16 in English football, or being chosen for the Finnish national under-15 youth teams in football (FORD et al., 2009), as well as in basketball and ice hockey (FORSMAN et al., 2016).

In Brazil, youth sports are primarily organized by national confederations. For instance, in basketball, the *Confederação Brasileira de Basketball* (CBB) is the national body responsible for promoting and supervising international and national level competitions and developmental programs. At the state level, competitions are supervised by local state federations. Most youth development programs are promoted by clubs, associations, and schools, often supported by public bodies and policies or private sponsorship initiatives. These characteristics may create an environment that stimulates athletes' commitment to the specialization process, encouraging them to invest time, effort, and resources to achieve high performance levels and professionalization (MAZZEI et al., 2014; POSSAMAI et al., 2024).

1.2.PERFORMANCE-ORIENTED SELECTION AND THE RISE OF SPECIALIZATION

The paths of sports specialization are intricately woven within contextual and cultural influences. For instance, individuals who enroll in youth sports academies at a tender age, a practice termed early specialization, seem to exhibit a heightened likelihood of ascending to international competitive levels during their late adolescence or achieving professional recognition in disciplines like football (FORD et al., 2009), basketball, and ice hockey (FORSMAN et al., 2016). The prevalence of early sport specialization has surged (JAYANTHI et al., 2015; WIERSMA, 2000), particularly within youth sports programs focused on

cultivating athletes identified as talented (BRYLINSKY, 2010; HOWE et al., 1998). It is assumed that the sooner individuals engage in focused practice, the greater their advantage compared to others (BAKER et al., 2009; BAKER et al., 2017; BARREIROS et al., 2014; ERICSSON et al., 1993). Identifying potentially talented athletes at an early age should ensure that players receive specialized coaching and training to accelerate the talent development process through accumulated exposure to specialized training and supervised coaching (ERICSSON et al., 1993; WILLIAMS and REILLY, 2000). Consequently, early specialization has emerged as the prevailing strategy for talent identification and development across various sports. This emphasis on early specialization may accentuate the exclusive and selective nature of sports within organized youth programs (LIMA et al., 2020; SOARES et al., 2019; SOARES et al., 2020; WILLIAMS and REILLY, 2000;).

In the pursuit of potential future adult performers, selection processes in youth sports often occur based on subjective and intuitive decisions made by coaches and scouts (BAKER and WATTIE, 2018; BERGERON et al., 2015; ROGERS et al., 2022). Recent studies have found that more accumulated experience leads to higher chances for athletes' career progression (FIGUEIREDO et al., 2009; SOARES et al., 2020), and the performance in youth ages could influence professional level achievement (CARVALHO et al., 2023). Even with increased discussions about talent identification and development, there are still no reliable and sensitive tools capable of fully predicting future high-level performers in youth sports due to the complex interaction of multiple factors that may influence talent prediction (MENDES et al., 2021; SOARES et al., 2016; SOARES et al., 2019; SOARES et al., 2020; WILLIAMS and REILLY, 2000; WILLIAMS and REILLY, 2020).

Past studies examining both individual and team sports have indicated that national team programs do not follow a pattern of initial selection followed by a nurturing long-term development process for talented athletes. Instead, they involve a fluid dynamic process of selection, re-selection, and even de-selection, suggesting a survival system (CARVALHO and GONÇALVES, 2023; BARTH et al., 2018; GÜLLICH, 2013; JONES et al., 2018;), influenced by organizational and strategic aspects, and long-term performance in youth competitions (CARVALHO et al., 2023; KALÉN et al., 2021). In general, players appear to be selected into youth national team programs at varying ages, either remaining in the program by being re-selected year to year or dropping out by being de-selected at some later stage (KALÉN et al., 2021). Even so, later initial selection in national programs has been linked to increased chances of reaching the senior national team (SCHROEPF and LAMES, 2018). Recent findings support the argument that strategic and organizational factors influence talent development programs

and long-term sporting success (DE BOSSCHER, 2015; DE BOSSCHER and DE RYCKE, 2017; KALÉN et al., 2021a; KALÉN et al., 2021b). These patterns may be present in both national and club-level sports programs, given their boundaries, as sports policies are based on national guidelines and integrate all sports systems.

Despite limited research, previous studies have highlighted the presence of the relative age effect in the initial selection stage and in some professional leagues from different countries (ARRIETA et al., 2016; DELORME et al., 2013; DE SUBIJANA and LORENZO, 2018; GARCÍA et al., 2014; GIL et al., 2021; RIAZA et al., 2020; RIBEIRO et al., 2020; RIBEIRO et al., 2021). However, other studies have found an inverse relative age effect in older ages through youth sports progression (KALÉN et al., 2021; MCCARTHY et al., 2016; STEINGRÖVER et al., 2016). These controversial findings suggest the need for coaches and other stakeholders to consider biological age in the selection process to avoid the initial bias of favoring physically advantaged athletes who are chronologically and biologically older (BAKER et al., 2017; CARVALHO and GONÇALVES, 2023; CUMMING et al., 2017; SOARES et al., 2020). Even with limitations in estimating maturity status due to errors in estimation equations, especially for boys, following up athletes over time may provide useful insights for understanding growth and maturational timing and tempo of development. On the other hand, girls have a biological marker (i.e., menarche) that precisely specifies the timing of maturational development, providing useful information for researching growth and maturation.

In numerous sports, particularly in basketball, factors such as body dimensions and specific physical attributes like vertical jumps, directional sprints, and intermittent endurance play a pivotal role in determining performance at elevated competitive tiers (DRINKWATER et al., 2008). These measures have been predominantly used in talent selection assessment and/or classification due to the objectivity and reliability of field tests (BAKER and WATTIE, 2018; BRYLINSKY, 2010). Consequently, choices related to selection and progression in youth basketball are heavily influenced by players' physical fitness and stature (SOARES et al., 2019). Conversely, it is essential to disentangle the contribution of maturity-related changes in body size and physiological functions to accurately interpret the performance of young players (CARVALHO et al., 2018; CARVALHO et al., 2019; CARVALHO and GONÇALVES, 2023; SOARES et al., 2016). While professional settings may provide adequate human resources, facilities, and support to develop promising athletes, coaches and scouts should still avoid making decisions biased by maturational variance. Such interpretations may potentially exclude talented late-maturing athletes who will not experience high-quality coaching, and unduly favor

early-maturing athletes who may not attain higher levels of performance at older ages (BAKER et al., 2017; CARVALHO and GONÇALVES, 2023; GÜLLICH, 2013; WILLIAMS and REILLY, 2000; WILLIAMS and REILLY, 2020). Data in youth football highlights that talent identification and development is often biased by maturation-related differences in young athletes, frequently resulting in an overrepresentation of early maturers in youth football (BIDAURAZAGA-LETONA et al., 2015; BIDAURAZAGA-LETONA et al., 2019; FIGUEIREDO et al., 2009; OSTOJIC et al., 2014).

Furthermore, psychological and behavioral characteristics and skills are subjectively assumed to be influential throughout athletes' developmental processes, facilitating learning, training, and competitive performance (WILLIAMS and REILLY, 2000). Moreover, motivation and enjoyment may be determinant for long-term deliberate engagement in such highly demanding practices, focusing on improving weaknesses and optimizing specific performance (GONÇALVES et al., 2011; LIMA et al., 2020; SOARES et al., 2020; SOARES et al., 2020). However, scarce longitudinal data is available to better understand the development of these psychological and behavioral aspects from childhood and adolescence to adulthood, due to the difficulty in establishing sensitive and reliable tools to assess developmental changes (DOWNING et al., 2023; WILLIAMS and REILLY, 2000; WILLIAMS and REILLY, 2020).

According to the Achievement Goal Theory, individuals define success and interpret their competence in achievement settings. In sports, two primary orientations have been identified: task orientation, which is focused on self-improvement and learning, and ego orientation, which is focused on outperforming others (DUDA and NICHOLLS, 1992). According to Duda and Nicholls (1992), these orientations are influenced by social environments, particularly coaching climates. Task-oriented environments tend to promote intrinsic motivation and persistence, whereas ego-oriented contexts may lead to anxiety, avoidance, and dropping out, especially among less skilled athletes.

On the other hand, according to Self-Determination Theory (RYAN and DECI, 2000) enjoyment in youth sports is strongly tied to the satisfaction of three basic psychological needs: autonomy, competence, and relatedness. Athletes are more likely to experience intrinsic motivation and long-term engagement when these needs are fulfilled through meaningful challenges, supportive relationships, and opportunities for self-expression. Scanlan et al. (1993) also identify enjoyment as a key factor in sports commitment. Conversely, environments that are overly controlling, stressful, or misaligned with athletes' personal goals can undermine enjoyment and lead to dropping out.

Coaches, researchers, and practitioners should exercise caution in interpreting current and potential future performance when making decisions about selecting or excluding players in sports participation, especially at younger ages. Their decisions may be determinant for young athletes' career progression by offering or limiting opportunities for children and adolescents to access adequate training facilities, coaching orientations, and support for their development (WILLIAMS and REILLY, 2020).

1.3.SPORT SPECIALIZATION AND DELIBERATE PRACTICE

Most youth sports development programs are based on the belief that young athletes should be exposed to specific training in a single "signature" sport (BRYLINSKY, 2010), with appropriate specialized supervision. This is reasoned by deliberate practice theory applied in sports, which posits that specialized supervision is a prerequisite for expertise attainment (ARMSTRONG, 2018; CÔTÉ and JENNIFER, 2012; DE BRUIN et al., 2008; ERICSSON et al., 1993; GÜLLICH, 2018). The premise is that accumulated exposure to deliberate practice will provide advantages for players in adult performance and expertise attainment in later stages of life (BAKER, 2003; BAKER et al., 2009; BAKER and YOUNG, 2014; BAKER et al., 2017; JOHNSTON et al., 2018; KALÉN et al., 2017; KALÉN et al., 2021a; KALÉN et al., 2021b). Consequently, early engagement and commitment to sport-specific deliberate practice may strongly resonate with coaches, parents, and aspiring young athletes aiming for sports expertise and elite recognition (GONÇALVES et al., 2011). This conceptual commitment to sport-specific deliberate practice is often termed sport specialization (BAKER et al., 2009; BRENNER, 2016; COAKLEY, 2010; DISANTI and ERICKSON, 2019). However, consensus on its exact definition remains nebulous (BERGERON et al., 2015; LIMA et al., 2020; MOSHER et al., 2020; SOARES et al., 2023). It is generally assumed that exclusive year-round engagement in a single sport, limited involvement in alternative sports, and a purposeful emphasis on training and development in the chosen sport, all geared towards attaining elite status, are integral prerequisites for success and expertise acquisition (BAKER et al., 2009; DISANTI and ERICKSON, 2019; HILL and SIMONS, 1989; WIERSMA, 2000). A recent conceptualization has detailed specialization in a single sport as a three-step process: expectations, engagement, and experiences (DISANTI and ERICKSON, 2021). The authors suggested that every athlete adopts pathways directed toward certain expectations; based on these, they engage in a set of behaviors along their participation pathway; then, they observe their choices unfold over time through their multifaceted accumulated experiences.

The dialogue encompassing the advantages and potential pitfalls of specialization within youth sports has experienced a recent resurgence in scholarly attention (DISANTI and ERICKSON, 2019; HERMAN et al., 2022; MOSHER et al., 2020; MOSHER et al., 2022; PASULKA et al., 2017; WALDRON et al., 2020). Specialization, at its core, can be conceptualized as the year-round engagement in a singular "signature" sport, accompanied by limited participation in alternate sports, all while placing deliberate emphasis on training and development with the goal of achieving elite status (BAKER et al., 2009; COAKLEY, 2010; DISANTI and ERICKSON, 2019; LIMA et al., 2020). While the involvement in youth sports and the concept of specialization can be envisioned as a continuous spectrum, a clear demarcation between early and late specialization remains elusive (LIMA et al., 2020; MOSHER et al., 2020). A crucial caveat arises due to the lack of unanimity in defining early specialization (MOSHER et al., 2020). We argue that specialization can be precisely outlined and interpreted in conjunction with the progress of pubertal growth (ARMSTRONG, 2018; LIMA et al., 2020). Specifically, the onset of specialization can be aligned with critical milestones in biological maturation that delineate the phase of pubertal growth, encompassing the inception of the pubertal growth spurt and the age of peak height velocity (PHV) (LARSON et al., 2019; LIMA et al., 2020).

Embedded within this deliberate practice systematic model, the endeavor to prognosticate potentially talented athletes may commence at younger ages, leading to specialization in a solitary sport as a consequential strategy in practical settings. The premise here is that the earlier individuals immerse themselves in focused practice, they will have the opportunity to accumulate many more hours of sport experience, capacities, and skills development, providing a greater comparative advantage over their peers over time. From a developmental perspective, there exists a widespread consensus that sports expertise shows a positive correlation with substantial exposure to sport-specific deliberate practice as the preferred path for sport development in most sports. Consequently, the idea of early specialization during pre-adolescent years might hold allure for various stakeholders, including national governing bodies, clubs, coaches, parents, and aspiring young athletes who aim to achieve sports mastery and ascend to an elite level (BAKER et al., 2009; BARREIROS et al., 2014; BAKER et al., 2017; DE BRUIN et al., 2008; ERICSSON et al., 1993; GÜLLICH, 2018).

A foundational assumption of the deliberate practice theory as applied to sports suggests that engaging in highly targeted training under suitable guidance during the formative years will enhance the performance of the body's primary organ systems beyond the attainments possible through regular growth, typical development, or engagement in a broader spectrum of

physical activities (BAKER and YOUNG, 2014; ERICSSON et al., 1993; KALETH and MIKESKY, 2010;). Regrettably, compelling empirical evidence is markedly lacking to ascertain whether an early specialization approach confers physiological advantages.

The primary counterargument to this approach is embodied by the *Developmental Model of Sports Participation* (CÔTÉ et al., 2009; CÔTÉ and VIERIMAA, 2014), which advocates for engagement in a variety of sports primarily for enjoyment and recreation, rather than focusing on singular dedication and skill acquisition in a specific sport. This model posits that early specialization might underlie various adverse issues within the sports environment, including an escalated injury risk, diminished enjoyment, negative psychosocial impacts, and the likelihood of burnout or attrition (BAKER, 2003; CÔTÉ and VIERIMAA, 2014; FRASER-THOMAS et al., 2008; DIFIORI et al., 2014). The potential negative consequences associated with early specialization, encompassing its effects on physical, psychological, and social development, have been intensively discussed (BAKER et al., 2009; BELL et al., 2018; BRENNER, 2016; DISANTI and ERICKSON, 2019; FABRICANT et al., 2016; JAYANTHI et al., 2019; MOSEID et al., 2019; MYER et al., 2015; POST et al., 2020; SMITH et al., 2017). Concretely, the practice of early specialization has been associated with unfavorable psychosocial consequences that heighten the susceptibility to burnout or attrition from sports engagement (FRASER-THOMAS et al., 2008; LARSON et al., 2019). However, the available empirical data on this matter demonstrate inconsistency and constraint (DISANTI and ERICKSON, 2019).

Commitment and engagement in highly demanding tasks, such as deliberate practice, require athletes to be highly motivated, and such accomplishment may determine athletes' achievement in higher or lower levels of youth sports participation, or even lead to dropping out (GONÇALVES et al., 2011). Several studies have suggested that early specialization in a single sport has been hypothesized to lead athletes to a lack of enjoyment in sports practice due to the high monotony of routines and the extensive time spent in specific training (BOYD and YIN, 1996; FRASER-THOMAS et al., 2008; LARSON et al., 2019), ultimately leading to youth sports dropout and further evasion of practice (BAKER, 2003; BERGERON et al., 2015; JAYANTHI et al., 2015; LAPRADE et al., 2016). On the other hand, recent reviews focused on the reasons for dropout in different contexts of youth sports suggested that influential factors leading to dropout were mostly related to psychological issues originating from athletes' personal lives and social relationships, with no evidence indicating that early specialization was a predictor for burnout and dropout (BACK et al., 2022; MOULDS et al., 2022).

In general, current consensus statements assume that early specialization and intensive training in youth sports are related to high rates of injury (BERGERON et al., 2015; JAYANTHI et al., 2015). However, interpretations are based on data with varying levels of youth sports exposure and participation, limiting their scope. Only recently, prospective data considering a heterogeneous sample of young athletes engaged in talent development contexts noted the contrasting high impacts on injuries and illnesses (MOSEID et al., 2018). The same research group noted that early specialization did not increase the risk of injury among young athletes in talent development programs (MOSEID et al., 2019). This data contrasts with general observations arguing for the occurrence of injury in specialized athletes when compared to peers with contrasting youth sports levels (JAYANTHI et al., 2015). In summary, the available data considering the links between psychological characteristics and dropout is based on varying contexts of youth sports but is scarce when considering structured and high-performance-oriented settings.

In contemplating the ecologies of sport specialization and talent development settings, it becomes imperative to consider confounding individual variables (such as age, body size, sex, or age of specialization) (SMITH et al., 2017) and contextual attributes (including sports context, competition level, socio-economic environment, or geographic factors) (DISANTI and ERICKSON, 2019). Framed within an ecological standpoint (BRONFENBRENNER, 1977; BRONFENBRENNER, 1979), these sources of confounding elements should be considered integrated within adequate analytical approaches, allowing for the different simultaneous interactions between person and context.

1.4. RESEARCH AND METHODOLOGICAL CHALLENGES IN SPORTS SPECIALIZATION

As a consequence of the pressure to identify and nurture talented athletes with limited resources available in clubs and national programs has led sports organizations to invest significant efforts in identifying markers of talent at increasingly younger ages (GONÇALVES et al., 2012; PEARSON et al., 2006). In the attempt to predict talented athletes, sports scientists have a role to play in working together with sports organizations to underline key elements for talent identification and development processes (ABBOTT et al., 2005; BAKER et al., 2017; WILLIAMS and REILLY, 2000).

Coaches commonly perceive the maintenance or enhancement of fitness as essential throughout a competitive season and the course of adolescence (MONTGOMERY et al., 2008).

Hence, comprehending developmental trends during both a competitive season and adolescence can offer invaluable insights to coaches and stakeholders, thereby elevating the efficacy of their training interventions and decision-making, particularly in the early stages. Regrettably, there is a dearth of data investigating the variations in physical fitness responses among young basketball players across a competitive season and during adolescence (CARVALHO et al., 2019; DRINKWATER et al., 2005; MONTGOMERY et al., 2008).

Despite the persistent demand for longitudinal designs (BACK et al., 2022; FIGUEIREDO et al., 2009; MOULDS et al., 2022; SOARES et al., 2020), much of the information garnered from youth sports, specially youth basketball, remains rooted mostly in cross-sectional surveys (AREDE et al., 2019; CARVALHO et al., 2018; LIMA et al., 2020; RAMOS et al., 2021; TORRES-UNDA et al., 2016). Data tracking developmental changes in young athletes considering the influence of growth, maturation and training exposure is still scarce and merits further studies for better comprehension (CARVALHO and GONÇALVES, 2023; WILLIAMS and REILLY, 2000). Moreover, the intricate role of sexual dimorphism and pubertal growth may add complexity to the interpretations concerning the influence of specialization on the physical fitness development of youth athletes. Noteworthy sexual discrepancies in the timing and tempo of pubertal growth and maturation merit consideration when examining the physical fitness trajectory of adolescent athletes (CARVALHO and GONÇALVES, 2023; MALINA et al., 1988).

Given the highly selective population of youth athletes who aim to achieve professional levels and the boundaries to investigate them longitudinally, many studies have considered small populations and generalized their interpretations – a concern for replication in sports and exercise science (MESQUIDA et al., 2022). Data collection may occur by convenience in specific clubs or programs, considering small samples of athletes who may or may not achieve higher levels of competition. Another challenge in Brazil is that youth sports studies have the demand to accomplish with the country's continental size territory. The differences between regions, states and cities may have potential influences in many dimensions of sports structures, consequently affecting athletes development, as reported before (CÔTÉ et al., 2006; LEITE et al., 2021; MAAYAN et al., 2022). Another issue may be related to the efforts, resources, and support need to conduct longitudinal research in different contexts with reliable and adequate methodological approaches, considering the complex interactions between the multidimensional phenomenal of athletes' development (DE BOSSCHER et al., 2006; WILLIAMS and REILLY, 2000).

Acknowledging methodology as the bridge between theory and data, we embrace the notion that methods encompass more than just an assortment of analytical techniques, they encompass choices that traverse the spectrum from data collection to result interpretation. When studying the influence of person, process, and context characteristics on physical, physiological, and psychological aspects among young athletes within a multidimensional framework, a judicious analytical approach is paramount. The interplay between theoretical paradigms and empirical data often entails crossed or nested levels, where effects are liable to vary across distinct subgroups (JUDD et al., 2017). Consequently, conventional single-level analyses, such as analysis of variance, are frequently unsuitable, yet persistently employed (DIEZ-ROUX, 1998). Therefore, adopting hierarchical/multilevel modeling strategy can accomplish with such specific characteristics (GELMAN and HILL, 2007; GELMAN et al. 2012). Bayesian hierarchical regression models facilitate the incorporation of constructs of interest, individual characteristics, and contextual covariates within the realm of youth sports. Moreover, these models yield aggregated estimates for the target population, markedly improving estimations for data originating from small and limited groups (GELMAN and HILL, 2007; GELMAN et al., 2013).

Limitations and uniqueness of data setting in talent development settings should be assumed and discussed more often. Even considering retrospective findings about high-level athletes' background convergences, there are limits to drawing causal interpretations for expertise attainment. Prospective design studies, considering the data, context limitations, and multiple sources of information, with clear conceptual and theoretical frameworks, and combined with available advanced modeling approaches, may provide a path to advance the understanding of young athletes within talent development settings and its impacts on young athletes' development.

The present study examines the effects of early specialization on developmental trajectories in youth basketball athletes. It aims to contribute to the ongoing debate on young basketball players' development, embracing a multidimensional approach, considering the complexity of different aspects that may influence performance and progression into players' progression into sports careers.

2. PURPOSE

The main objective of this study was to improve our understanding of developmental trends among Brazilian youth basketball athletes engaged in specialized training programs aimed at advancing them to higher performance levels, using a multidimensional perspective.

Specifically, we aimed to:

- Conceptualize the current body of knowledge on youth basketball across multiple thematic and disciplinary dimensions;
- Identify gaps in the existing evidence base in different thematic dimensions;
- Empirically examine how the onset of specialization affects the magnitude and patterns of changes in basketball-specific physical fitness over a competitive season and across age groups, using biological maturity status as a classification criterion;
- Investigate potential negative consequences of early specialization, such as sport dropout, by examining how sustained engagement in specialized training environments impacts achievement motivation, competitiveness, and enjoyment of sports participation;
- Incorporate both individual and contextual variables in a multidimensional analytical framework for developmental patterns analysis.

2.1.DEFINING KEY TERMINOLOGIES

Following Grainger et al. (2025) we bring the definitions of the main concepts and aspects we brought into this study, to clarify the interpretations and allow a better understanding about thesis findings and discussions.

2.1.1.Sports selection

The process of selecting athletes for teams, programs, or competitive pathways is called sport selection. It is often based on early indicators of talent or performance. According to Larkin and Reeves (2018), selection is influenced by subjective judgments and systemic biases, such as maturity and socioeconomic background. Bailey and Collins (2013) critique the "standard model" of selection for being exclusionary and misaligned with developmental principles. A pedagogically sound approach to selection prioritizes potential and learning capacity while avoiding biases that can lead to mistakes (CARVALHO et al., 2023; GARCIA-RUBIO et al., 2022).

From a pedagogical standpoint, sport selection carries both opportunities and risks. It can provide access to high-quality training and competitive environments but may also lead to exclusion, early dropout, psychological pressure, or premature specialization. In youth sports contexts, especially in formative and educational settings, selection processes should be critically evaluated to ensure they are developmentally appropriate and aligned with long-term athlete development models (KALÉN et al., 2017; KALÉN et al., 2020; KALÉN et al., 2021).

2.1.2.Deliberate practice

Deliberate practice is defined as structured, purposeful, and cognitively engaging activity that aims to improve performance through repetition, feedback, and the effortful execution of specific designed tasks. According to Ericsson et al. (1993), deliberate practice differs from play or mere participation because it is not inherently enjoyable and requires sustained attention and focus. In sports, deliberate practice is considered a key driver of acquiring expert skills, though its intensity and volume must be carefully managed with young athletes to avoid negative developmental consequences (BAKER and YOUNG, 2014).

2.1.3.Dropout of sports participation

It refers to the voluntary or involuntary discontinuation of organized sports participation by an athlete, which typically occurs during childhood or adolescence. This multifactorial phenomenon is influenced by personal, social, contextual, and organizational factors. Common reasons for dropping out include a lack of enjoyment, excessive pressure, conflicts with coaches, limited playing time, an overemphasis on competition, competing academic and social demands, and a lack of financial resources (CRANE and TEMPLE, 2014; FRASER-THOMAS et al., 2008).

In youth sports, dropout is often associated with overly competitive environments that prioritize short-term performance over long-term development. Such environments may undermine athletes' sense of autonomy, competence, and relatedness — key psychological needs outlined by self-determination theory (RYAN and DECI, 2000). High dropout rates may therefore reflect systemic shortcomings in the design of youth sports programs, particularly when opportunities for meaningful engagement and personal growth are lacking.

From a pedagogical and developmental standpoint, understanding dropout requires an ecological perspective that considers the athlete's individual motivations, the surrounding sports climate, coaching style, and institutional values (BALISH and CÔTÉ, 2014).

2.1.4. Early specialization

Early specialization is a sports development pathway in which young athletes engage intensely and exclusively in one sport from an early age, often before puberty begins (BAKER, 2003; BAKER et al., 2009; MOSHER et al., 2020). This pathway is characterized by year-round training and competition with limited or no participation in other sports. Although some proponents claim that early specialization accelerates skill acquisition, particularly in sports with early peak performance, an increasing amount of research warns about its connection to overuse injuries, burnout, and dropping out (CÔTÉ et al., 2009; JAYANTHI et al., 2015).

2.1.5. Multidimensional approach

A multidimensional approach to youth athlete development integrates multiple factors in research and practice. Unlike unidimensional models that focus exclusively on a single field or perspective, recognizing that development occurs through the interaction of multiple individual (nature) and procedural (nurture) domains is crucial for understanding youth development in sports (BAILEY et al., 2010; CARVALHO et al., 2018; CARVALHO and GONÇALVES, 2023; WILLIAMS and REILLY, 2000). The emergent need for multidimensional perspectives on youth athletes' development has been recognized in last past decades (WILLIAMS and REILLY, 2020). This approach demands adequate analytical approaches, allowing for the different simultaneous interactions between multiple personal- and environmental-characteristics that may influence into developmental processes.

2.1.6. Performance

In youth sports, performance refers to the execution of objectively measurable physical, technical, tactical, or perceptual-motor skills and capacities in training or competitive contexts. It has traditionally been quantified using indicators such as speed, strength, accuracy, and in-game statistics (MCGARRY et al., 2013). The performance of youth basketball players is

shaped by multiple factors, including biological maturation, training exposure, motivational climate, and coaching strategies. Therefore, performance should not be reduced to immediate results, as tests and measures occur in a single moment. Rather, performance should be considered a dynamic and evolving construct embedded in the athlete's long-term learning and development process (DAVIDS et al., 2008). In this study we considered specific basketball performance similar to the terms functional and physical fitness in different periods of childhood and adolescence in a long-term perspective.

2.1.7.Maturity offset

Maturity offset refers to the estimation of the time before or after an individual reaches peak height velocity (PHV) and serves as an indirect indicator of biological maturation. The method proposed by Mirwald et al. (2002) is widely used in sports science due to its practicality and noninvasiveness. However, it has notable limitations, particularly in cases of early or late maturation, and should be interpreted with caution (MALINA et al., 2015). An accurate understanding of maturation is essential in youth sports for fair assessment, grouping, talent identification, and selection processes in youth sports.

2.1.8.Athletes Development Programs

Sports programs are mostly structured with the purpose to develop and promote high-level athletes for performing on a professional level in adulthood. It refers to the systematic processes of detecting, selecting, and nurturing athletes with the potential to perform at a high-level during adulthood. Traditional sports programs models rely on performance benchmarks and early specialization strategies, assuming that talent is a fixed capacity, the exposure to adequate coach instructions, training facilities and competitive environments are essential for athletes' development, and the accumulated time may provide advantages on capacities and skills development. However, these models have been criticized for overlooking contextual, psychosocial, and maturational factors (ABBOTT et al., 2005; VAEYENS et al., 2008). Due to limited resources, practitioners and researchers face the challenge of improving methods to accurately select and nurture potential athletes. More recent approaches advocate for holistic talent development environments that support long-term participation and engagement, a positive and motivational atmosphere conducive to learning and developing sports skills and

capacities, and personal growth (BAKER and YOUNG, 2014; BAKER et al., 2017; CARVALHO et al., 2019; GONÇALVES et al., 2011).

2.1.9. Bayesian hierarchical modeling

Bayesian hierarchical modeling is a statistical approach that accounts for data structured in nested levels such as athletes within teams or clubs. This approach allows for the incorporation of prior knowledge and procedures probabilistic estimates of various levels of analysis. Gelman and Hill (2007) emphasize its usefulness in complex systems, such as youth sports, where individual performance is influenced by contextual variables. This method aligns with multidimensional and ecological perspectives, supporting the modeling of complex sports systems with multiple interactive variables in applied settings (CARVALHO and GONÇALVES, 2023; GARCIA-MAS et al., 2015; KRUSCHKE, 2010).

2.1.10. PPCT model

The Bioecological Model of Human Development (BRONFENBRENNER and CECI, 1994; BRONFENBRENNER and MORRIS, 2007) explains development as the result of interactions between the individual and the environment, while also accounting for biological aspects. It is organized through the PPCT framework – person, process, context, and time. The *person* dimension includes characteristics such as sex, age, biological maturation, social relations, and psychological factors like motivation and enjoyment. *Process* refers to dynamic interactions with the environment, observable in relationships with peers and coaches, with deliberate practice often serving as a proxy for these interactions in sport. *Context* encompasses four interrelated systems: the microsystem (immediate environment, such as teammates and coach), the mesosystem (relations between microsystems, such as teams at different levels), the exosystem (indirectly influential contexts), and the macrosystem (broader sociocultural structures, like sport federations). Finally, *time* highlights the temporal dimension of development, acknowledging that growth, performance, and behavior unfold across chronological and biological stages in nonlinear trajectories.

2.2. THESIS STRUCTURE

The thesis begins in Chapter 1 with a general introduction of the main topics related to youth basketball players' development and participation in formal training structures. It contextualizes the main tensions shaping current youth sport environments – particularly the contradictions between talent-based sport systems and pedagogical commitments to long-term development. This chapter outlines the conceptual and practical motivations behind the research and highlights the need for integrative models that account for the complexity of youth athletes' experiences over time.

Chapter 2 details the methodological considerations that support the thesis, including data quality criteria, participant sampling, ethical approval, and analytical strategies. Special attention is given to the use of Bayesian hierarchical modeling and the measures taken to ensure transparency and replicability across studies.

Chapter 3 presents a scoping review and evidence mapping of the international literature on youth basketball. This systematic synthesis identifies prevailing trends, evidence gaps, and methodological limitations in the field, notably the dominance of unidimensional approaches, a lack of evidence-based findings, and the underrepresentation of psychosocial and pedagogical themes.

Chapter 4 outlines the general and specific objectives of the research, situating the thesis within a multidimensional perspective that emphasizes the interplay between physical, psychological, and contextual variables in youth sport development.

Chapters 5, 6, and 7 constitute the empirical core of the thesis. Chapter 5 investigates whether early specialization confers advantages in physical fitness development among adolescent basketball players. Contrary to widespread assumptions, the findings suggest that early specialization does not lead to superior physical outcomes. While early specialization is often promoted as advantageous, the results align with previous findings that challenge this notion. Chapter 6 examines achievement and competitiveness motivation using Bayesian hierarchical modeling, demonstrating that motivational orientations are shaped not only by individual traits but also by the social and structural contexts in which athletes are embedded. Chapter 7 adopts an ecological perspective to explore sources of enjoyment among young female basketball players. It highlights the importance of relational and environmental factors – such as peer support, coaching style, and perceived competence – in sustaining long-term sport engagement.

Chapter 8 presents the general discussion and practical applications. It integrates the empirical findings with the theoretical frameworks explored throughout the thesis, offering critical reflections on their implications for pedagogical practices and sport development policy.

The discussion reinforces the importance of athlete-centered approaches, contextual sensitivity, and long-term thinking in youth sport systems. It also translates the findings into actionable recommendations for coaches, educators, and sport program coordinators committed to fostering inclusive and developmentally appropriate environments.

Finally, Chapter 9 provides concluding reflections, summarizing the thesis's contributions to scientific knowledge, methodological innovation, and pedagogical advancement. It advocates for a rethinking of how youth sport is conceptualized and practiced – emphasizing development over performance, process over outcomes, and the holistic growth of young people over narrow definitions of success.

All studies are presented in formats that are either fully or partially aligned with the submission or accepted versions prepared for peer-reviewed journals, in accordance with the publication stage of each manuscript.

3. YOUTH BASKETBALL RESEARCH: A SCOPING REVIEW AND EVIDENCE GAP MAP OF RESEARCH TRENDS AND MULTIDIMENSIONALITY ²

ABSTRACT

Youth basketball development is a growing field in sport sciences, marked by its multifactorial nature and long-term implications for athletes' career progression. This scoping review, following PRISMA and PRISMA-ScR guidelines, aimed to map the current scientific evidence on youth basketball, identifying thematic trends, research gaps, and methodological limitations. A systematic search across Web of Science, Scopus, and PubMed yielded 719 eligible articles published from 1964 to 2024, demonstrating exponential growth since 2010. Studies were analyzed by publication characteristics, methodological approaches, and alignment with nine thematic dimensions (e.g., anthropometry, physiology, psychology, pedagogy, nutrition, biomechanics). Findings reveal a predominance of cross-sectional and unidimensional studies, with limited use of longitudinal and integrative methodologies. While a trend toward multidimensional approaches is emerging, the literature remains heavily concentrated in anthropometry, physiology, and biomechanics, while pedagogy, psychology, and nutrition are significantly underrepresented. Most research focuses on male athletes aged 14–18 years, with scarce investigation into female players or earlier developmental stages (U10 and U12). Additionally, over half of the studies failed to report competitive level, indicating a lack of contextual clarity. In conclusion, this review underscores the critical need for more comprehensive, interdisciplinary, and ecologically valid research in youth basketball. Greater transparency in participant characterization and broader inclusion of neglected dimensions are essential to advance both theoretical and applied knowledge. **Keywords:** Youth sports, Athlete development, Talent, Coaching & pedagogy, Adolescent, Young athlete

3.1.INTRODUCTION

Basketball stands as one of the most widely played sports globally, engaging individuals of diverse cultures and ages across various settings, including clubs, training centers, and public courts. Recent evidence highlights the potential health and developmental benefits of participation. However, many basketball programs are predominantly designed to develop

² SOARES, A. L. A.; LIMA, A. B.; SARMENTO, H.; CLEMENTE, F. M.; GONÇALVES, C. E.; CARVALHO, H. M. Youth basketball research: a scoping review and evidence gap map of research trends and multidimensionality. Woking manuscript.

high-performance adult players, with a singular focus on achieving excellence (WILLIAMS and REILLY, 2000). These talent development programs typically hinge on identifying and recruiting "talented" youth—often around puberty and the onset of the growth spurt. They then provide specialized training and coaching within highly selective environments, aiming to accelerate performance development (BAKER et al., 2017; CARVALHO and GONÇALVES, 2023; GÜLLICH and BARTH, 2024; WILLIAMS and REILLY, 2000; WILLIAMS and REILLY, 2020). As a long-term process, the development of talented basketball players remains a critical concern for basketball federations and researchers. Their goal is to establish appropriate structures and policies that enable children and adolescents to reach higher performance levels in line with their potential, expectations, and commitment throughout their sports careers (DE BOSSCHER, 2015; DE BOSSCHER and DE RYCKE, 2017; GONÇALVES et al. 2011; GÜLLICH and BARTH, 2024).

From a more comprehensive perspective, youth athlete development presents a multifactorial dynamic, shaped by numerous contextual influences and individual aspects. The interactive processes to which youth are subjected, and the contexts with which they interact directly and indirectly throughout their developmental years, can significantly determine their achievements and career progression (CARVALHO and GONÇALVES, 2023; DE BOSSCHER and DE RYCKE, 2017). As Williams and Reilly (2000) underscored, a multidisciplinary approach is paramount to providing robust evidence for the theoretical development of youth sport, considering both individual (nature) and contextual (nurture) differences.

The challenging and complex task of developing potentially talented athletes to professional levels with limited resources, such as financial support and time, has led researchers to discuss various theoretical development models. However, previous studies in sport science have highlighted a lack of empirical evidence supporting the efficacy of these models for young athletes (ABBOTT et al., 2005; BAKER et al., 2017). This raises potential concerns for sport sciences, as some models may have been adopted for convenience without providing high-quality, reliable, and evidence-based empirical data.

Scoping reviews and evidence and gap mapping reviews are categorized within the "Big Picture family" of reviews. Their common aim is to describe a topic of interest by providing an overview of a broader research area and addressing wide-ranging research questions, rather than narrowly focused intervention effectiveness questions. These reviews serve various purposes, including guiding research priorities and decision-making by describing, categorizing, and cataloging key findings in the existing body of knowledge, ultimately

identifying the nature and extent of research evidence (ATO et al., 2013; CAMPBELL et al., 2023).

The purpose of this review is to provide an overview of the existing body of knowledge in the scientific literature on youth basketball. Specifically, we aimed to identify the trends, gaps, and limitations of the scientific field in youth basketball from a multidimensional perspective. Additionally, we map the body of knowledge that describes the developmental pathways of basketball athletes through childhood, adolescence, and early adulthood from multiple perspectives.

3.2.METHODS

This study comprises a scoping review combined with an Evidence Gap Map. We conducted it through a systematic process of data retrieval and study selection, reporting all procedures in accordance with the PRISMA Extension for Scoping Reviews (PRISMA-ScR) guidelines (TRICCO et al., 2018). This approach aimed to identify the main characteristics of published articles on youth basketball, summarize their key findings, and map the principal thematic dimensions explored in the current literature to date (ATO et al., 2013; CAMPBELL et al., 2023).

3.2.1.Search strategy

To ensure comprehensive coverage and methodological rigor, a systematic electronic search was performed across three major scientific databases: Web of Science (Core Collection, 1945–present), SCOPUS (Elsevier), and MEDLINE (via PubMed, 1946–present). The initial search ran up to February 2023, with an update to include publications through November 2024. All retrieved records were exported for subsequent screening and eligibility assessment.

The search strategy was designed to identify articles focused on youth basketball athletes, combining controlled vocabulary and free-text terms for each database. An example of the search query for the SCOPUS database is as follows: *TITLE-ABS-KEY (young OR youth OR adolescent OR teen OR teenagers OR children OR adolescents) AND TITLE-ABS-KEY(players OR athletes) AND TITLE-ABS-KEY(basketball)*. The Boolean operator "**AND**" was used to maximize specificity and ensure that all documents addressed the key conceptual components of the review, while the Boolean operator "**OR**" was applied within each term

group to broaden the search and include synonyms. No additional filters or restrictions were applied.

3.2.2. Eligibility criteria

The *inclusion* criteria for article selection were: (i) studies written in English, Spanish, or Portuguese; (ii) samples composed of basketball players; (iii) participants (boys and/or girls) aged up to 19 years; studies including both youth and adult participants were also considered eligible; (iv) original research articles published in peer-reviewed journals.

The *exclusion* criteria were: (i) articles that did not report specific data for youth basketball players; (ii) studies conducted exclusively with adult-level samples; (iii) research involving injured players or those with clinical conditions; (iv) articles published without peer review; (v) abstracts from conference proceedings; (vi) opinion pieces and theoretical essays; (vii) review articles.

3.2.3. Data selection

Two independent reviewers conducted the search, screening, and eligibility processes, following the predefined strategy. Titles and abstracts were initially reviewed for relevance, and potentially eligible articles were retrieved for full-text evaluation. In cases of uncertainty regarding a study's eligibility, both reviewers jointly assessed the full text to reach a consensus. Any disagreements were resolved by consulting a third reviewer, who made the final decision regarding study inclusion.

3.2.4. Data categorization

Following data collection and assessment, a total of 719 studies that met the eligibility criteria were selected. The characteristics of the included articles were extracted and categorized into variables related to publication features and main findings.

Data extracted from the included studies were organized into a structured database. Descriptive analysis was performed to summarize the characteristics of the studies, including year of publication, journal quality, methodological approach, study design, participant characteristics (age, gender, competitive level), and thematic dimensions addressed.

Frequencies and percentages were calculated for categorical variables (e.g., participants' sex, competitive level, study design) to provide an overview of trends within the existing literature. Continuous variables, such as sample size and mean age, were reported as means and standard deviations when available.

Table 1. Summary of Discrete Variables and Their Levels

Variable	Description	Levels
Journal Index	Presence of a Journal Impact Factor (JIF) from Journal Citation Reports (JCR)	0 = Not indexed in JCR; 1 = Indexed in JCR
Methodological Approach	Nature of the study design	Qualitative; Quantitative; Mixed Methods
Study Design	Data collection and analysis procedures	Cross-sectional; Repeated Measures; Cross-sectional with Repeated Measures; Retrospective; Narrative
Thematic Dimension	Primary topic(s) addressed by the study	Anthropometry; Game-related Performance Analysis; Social Sciences and Humanities; Sports and Exercise Medicine; Sports Biomechanics; Sports Coaching and Pedagogy; Sports Nutrition; Sports Physiology & Performance; Sports Psychology
Number of Dimensions	Cumulative count of thematic dimensions addressed by a study	Unidimensional (1); Multidimensional (>1)
Participant Sex	Sex of study participants	Female (only female); Male (only male); Both (mixed samples); Unknown
Age Group	Age classification of participants	U10; U12; U14; U16; U18; U20
Competitive Level	Highest reported competitive level of participants	International; National; Local; Regional; Domestic; Semi-elite; Amateur; Professional; Unknown

Considering the characteristics of the studies and the journals in which they were published, as well as their approaches and reported data, we categorized the studies based on several variables described on Table 1. **Journal index** was determined by the presence of a Journal Impact Factor (JIF) classified by the Journal Citation Reports (JCR) (CLARIVATE) for the year of publication. Studies were coded as “1” if the journal was indexed in the JCR, and “0” if it was not. **Methodological approach** was categorized as qualitative, quantitative, or mixed methods, according to the nature of the study design. Based on data collection and analysis procedures, **study design** was classified into five categories: cross-sectional, repeated measures, cross-sectional with repeated measures, retrospective, or narrative.

To provide an overview of the knowledge landscape and map evidence gaps, each study was classified into one or more of nine previously purposed **thematic dimensions**, similar to Carvalho and Gonçalves (2021), according to the topics addressed and the data presented:

- (i) *Anthropometry* – Studies reporting body dimensions, body mass index (BMI), growth spurts, and/or biological maturation estimated by peak height velocity (PHV).
- (ii) *Game-related Performance Analysis* – Studies analyzing technical actions during official matches, small-sided games, or simulated games; including use of performance indexes (e.g., Performance Index Rating - PIR) or other tools for technical and tactical assessment.
- (iii) *Social Sciences and Humanities* – Presents data related to discussions about athletes and sport developmental models, practice in a single signature sport or multisport participation, sport specialization and selection processes at different levels of club, national and professional levels, and their influences—discussions about talent, early specialization, relative age effect (RAE), constituent year effect (CYE), birthplace effect, geographical and economical differences in basketball program facilities and resources; parental perceptions and involvement in players' development; contextual differences in male and female youth basketball programs; official competitions and training programs for youth development.
- (iv) *Sports and Exercise Medicine* – Research focused on epidemiology, hormonal and immunological responses to training, injury incidence and prevention, recovery protocols, drug and alcohol use, sleep quality, and other clinical conditions.
- (v) *Sports Biomechanics* – Presents data of kinetics and kinematics; functional movement screening (FMS), range of movement degrees, limb asymmetries, and quantification of physical actions in game analyses—distance covered, acceleration/deceleration relation, speed limits, changes of direction, number of sprints, peak of force-velocity.
- (vi) *Sports Coaching and Pedagogy* – Presents data on coaches' behavioral instruction and feedback provided, coaching educational programs, and coaches' perceptions, coaching interventions and aspects of teaching-learning-training environments, development of declarative and procedural tactical knowledge, purposes of small-sided games (SSG), simulated games and task-constraints manipulation on different responses and actions during players' activities, scaling equipment for younger

players to improve drills effectiveness and players' actions—ball size and basket heights manipulation.

- (vii) *Sports Nutrition* – presented nutritional aspects related to hydration or nutritive ingestion, and education intervention effects – vitamins, dietary ingestion, eating disorders, doping, supplements demands and use.
- (viii) *Sports Physiology and Performance* – Research assessing physical and technical capacities through field tests, such as lower-limb power, speed, agility, motor coordination, cognitive reaction time, and training effects (e.g., weightlifting, HIIT, plyometrics, small-sided games) on performance and physiological adaptations, including internal and external training loads and monitoring.
- (ix) *Sports Psychology* – Presents aspects related to motivation, eating disorders, stress, self-regulation, attention level, collective and self-perceptions, personal characteristics of behavior.

Each study was coded as “1” when it presented data related to the dimension and “0” when it did not, for subsequent analysis. The cumulative number of dimensions identified per study was used to determine whether an article addressed one or multiple dimensions.

Regarding the study samples, the number of participants was recorded for each study. Participants' **sex** was classified as *female* (only female participants), *male* (only male participants), or *both* (mixed samples). When sex was not explicitly reported, it was categorized as *unknown*.

Participants' ages were considered based on **age groups** or reported **mean ages**, to accurately reflect the scientific production related to youth basketball across different developmental stages. If specific age groups were not provided, categorization was based on the reported mean age and standard deviation. Following typical youth basketball competition categories, age groups were classified into two-year bands: *u10*, *u12*, *u14*, *u16*, *u18*, *u20*.

The **competitive level** was also considered when studies explicitly described competition level athletes were engaged. Competitive level was categorized based on the highest level reported for participants, classified as *international*, *national*, *local*, *regional*, *domestic*, *semi-elite*, *amateur*, *professional*. Studies that did not specify the competitive level were categorized as "unknown" in the database.

In addition, cross-tabulations were performed to explore relationships between variables such as study design and thematic dimension, number of dimensions addressed, and age groups of participants. Graphical representations (e.g., bar graphs, frequency distributions) were

developed to facilitate the visualization of key findings and evidence gaps within existing literature.

3.3.RESULTS

3.3.1.Study selection and Characteristics

Figure 1 summarizes the systematic literature search and study selection process, adhering to PRISMA guidelines for scoping reviews (HADDAWAY et al., 2022). Initially, 8,733 records were identified. After managing references and removing 5,169 duplicates, 3,564 unique articles remained. These were screened for relevance based on title, keywords, and abstracts using the Rayyan platform (OUZZANI et al., 2016). This initial screening yielded 998 potentially eligible articles, which were then retrieved for full-text evaluation. Of these, 41 articles were unavailable; despite attempts to contact authors directly, no responses were received. Following an in-depth full-text review, a final total of 719 documents were included in the review and categorized according to the predefined procedures. The primary reasons for exclusion were: *Wrong population*, *Wrong publication type*, *Not focused on basketball*, or *Language not eligible*.

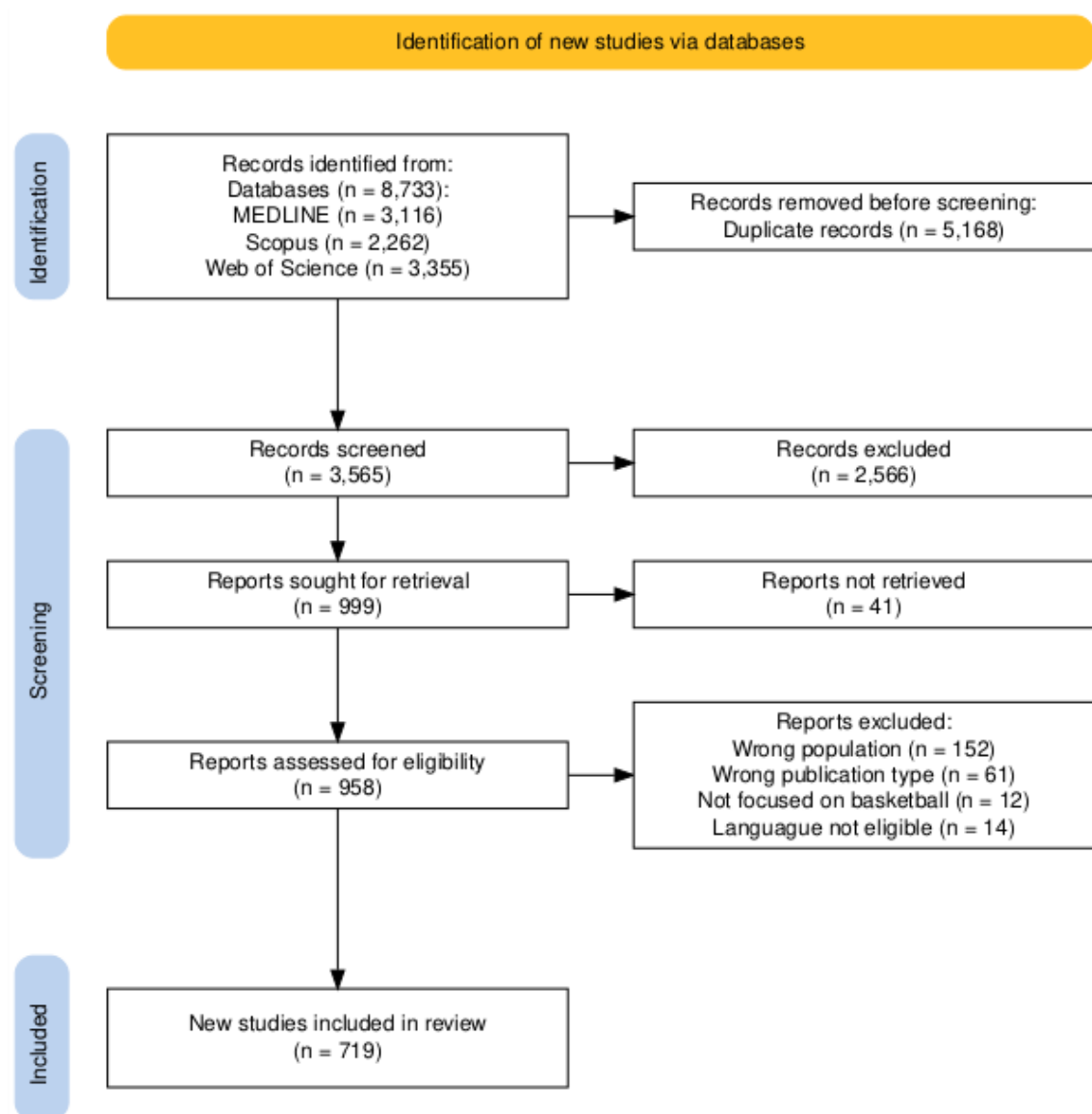


Figure 2. PRISMA flowchart diagram of the procedures used for the documents search and selection

3.3.2.Publication Trends

Figure 2A illustrates the cumulative number of papers on youth basketball published between 2000 and 2024. A notable increase in research output is evident, with only 80 papers published until 2010, compared to 639 papers from 2011 onwards. The year 2023 alone saw the publication of 90 papers, marking a significant milestone. Figure 2B details the annual publication count by Journal Citation Reports (JCR) index status. Of the included papers, 402 were published in JCR-indexed journals, while 302 were not. An additional 15 papers published before 2000 could not be classified for JCR indexing.

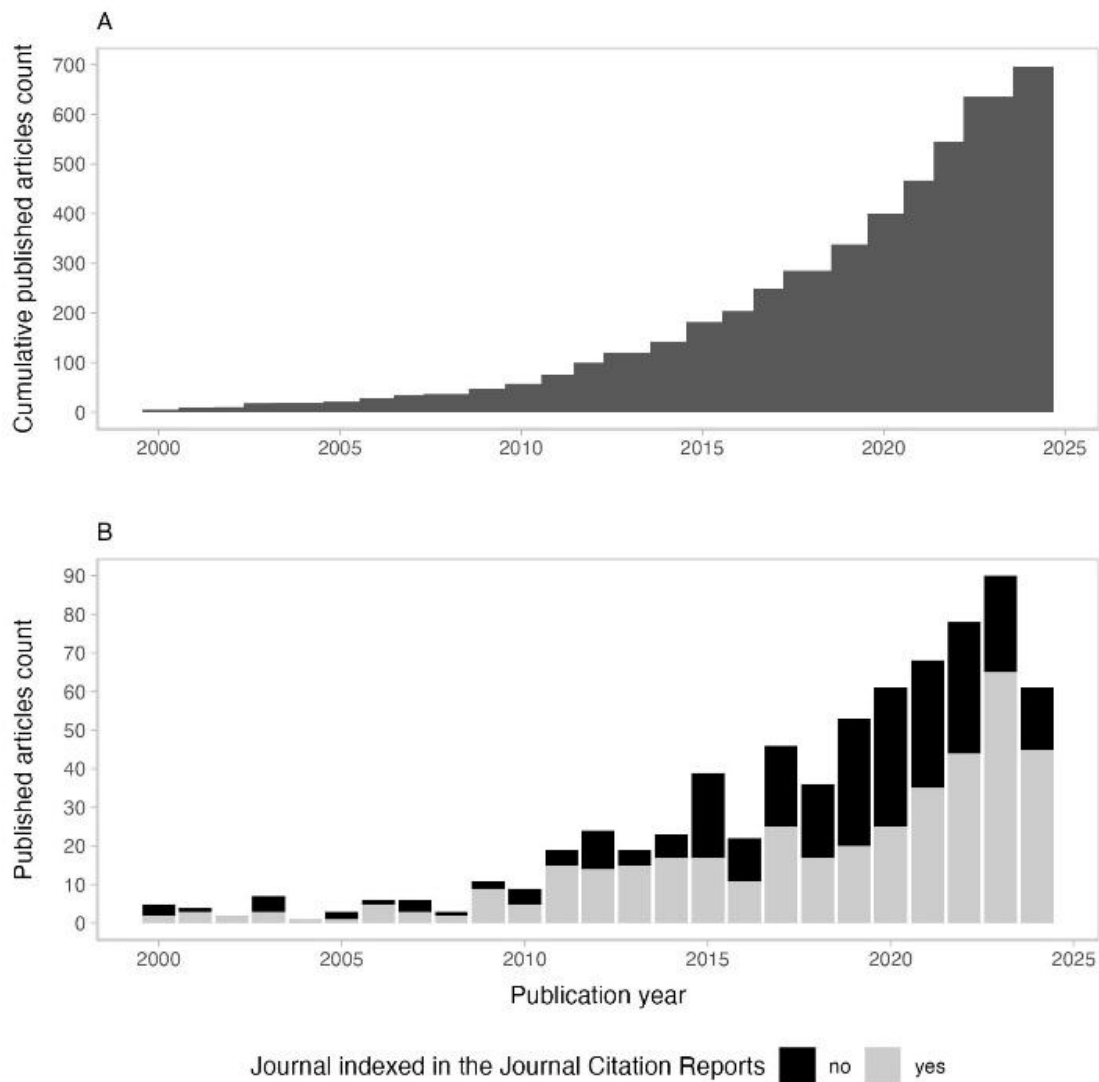


Figure 3. (A) Cumulative papers on youth basketball topic through years from 2000 to 2024; and (B) Journal Impact Factor classification of youth basketball studies published between 2000 and 2024

3.3.3. Methodological Characteristics

Figure 3 presents the distribution of study designs from 2000 to 2024, encompassing both quantitative and qualitative approaches. The majority of selected papers (61.89%) employed a cross-sectional design. A substantial portion (191 studies) represented experimental, quasi-experimental, and validation studies that utilized repeated measures for specific interventions. Only 10.15% of studies featured longitudinal and mixed-longitudinal designs. Regarding methodological approach, 680 studies presented quantitative data, 26 exclusively qualitative data, and only 13 studies (1.8%) adopted a mixed-methods approach.

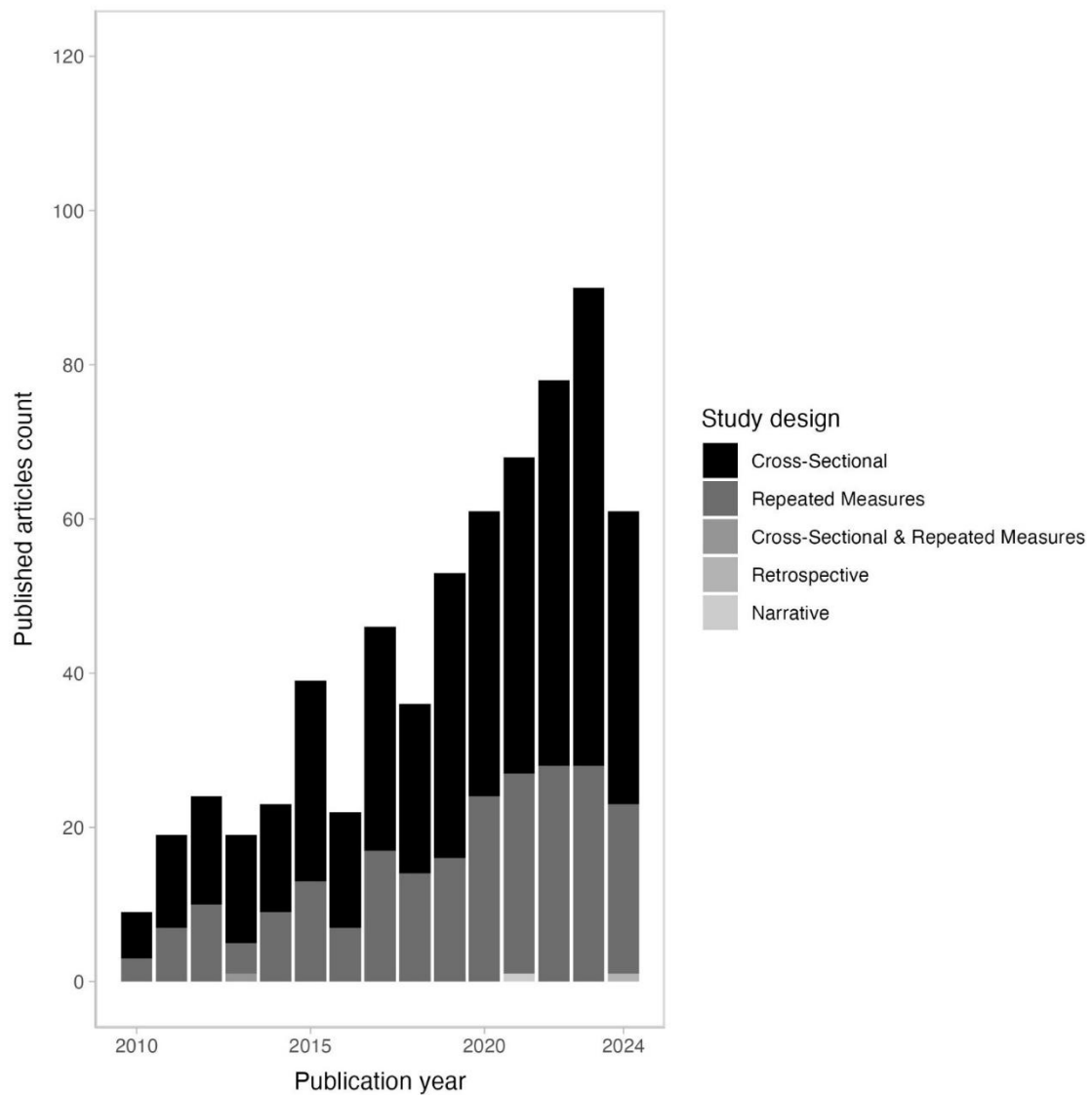


Figure 4. Comparison among studies design from 2000 to 2024

Participant Demographics

Figure 4 illustrates the proportion of studies based on participants' sex composition. In terms of sample demographics, 96 studies (13.35%) did not explicitly report participant sex, while 168 studies (23.37%) included both male and female participants. Only 100 papers (13.91%) exclusively featured female participants, contrasting with 355 papers (49.37%) that focused solely on male participants.

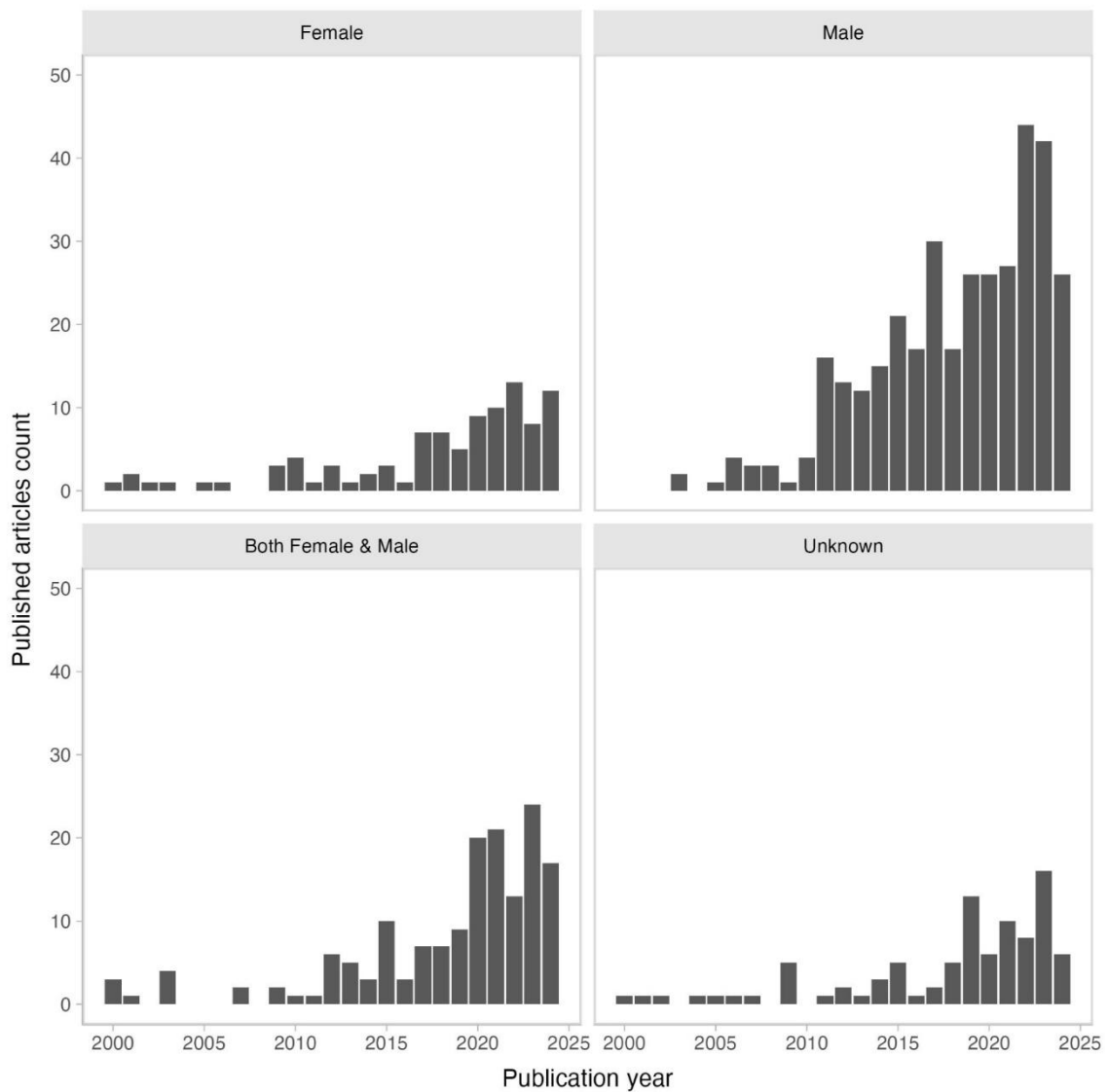


Figure 5. Count of studies by participants' sex over the years, from 2000 to 2024

Regarding age bands, studies predominantly featured participants aged between 14 and 18 years. Figure 5A shows the overall distribution of participants' ages across studies, while Figure 5B presents the age group distribution within each thematic dimension. Of the 719 included studies, 91 did not explicitly declare participants' mean age or age bands. For the 628 studies that did describe participant age, 67 studies included players in the U10 age group, 158 included U12 players, 295 included U14 players, 399 included U16 players, 300 included U18 players, and 110 included U20 players. The mean age of participants across all studies in our database ranged from 6.17 to 21.7 years, with an overall mean age of 15.19 ± 0.06 years.

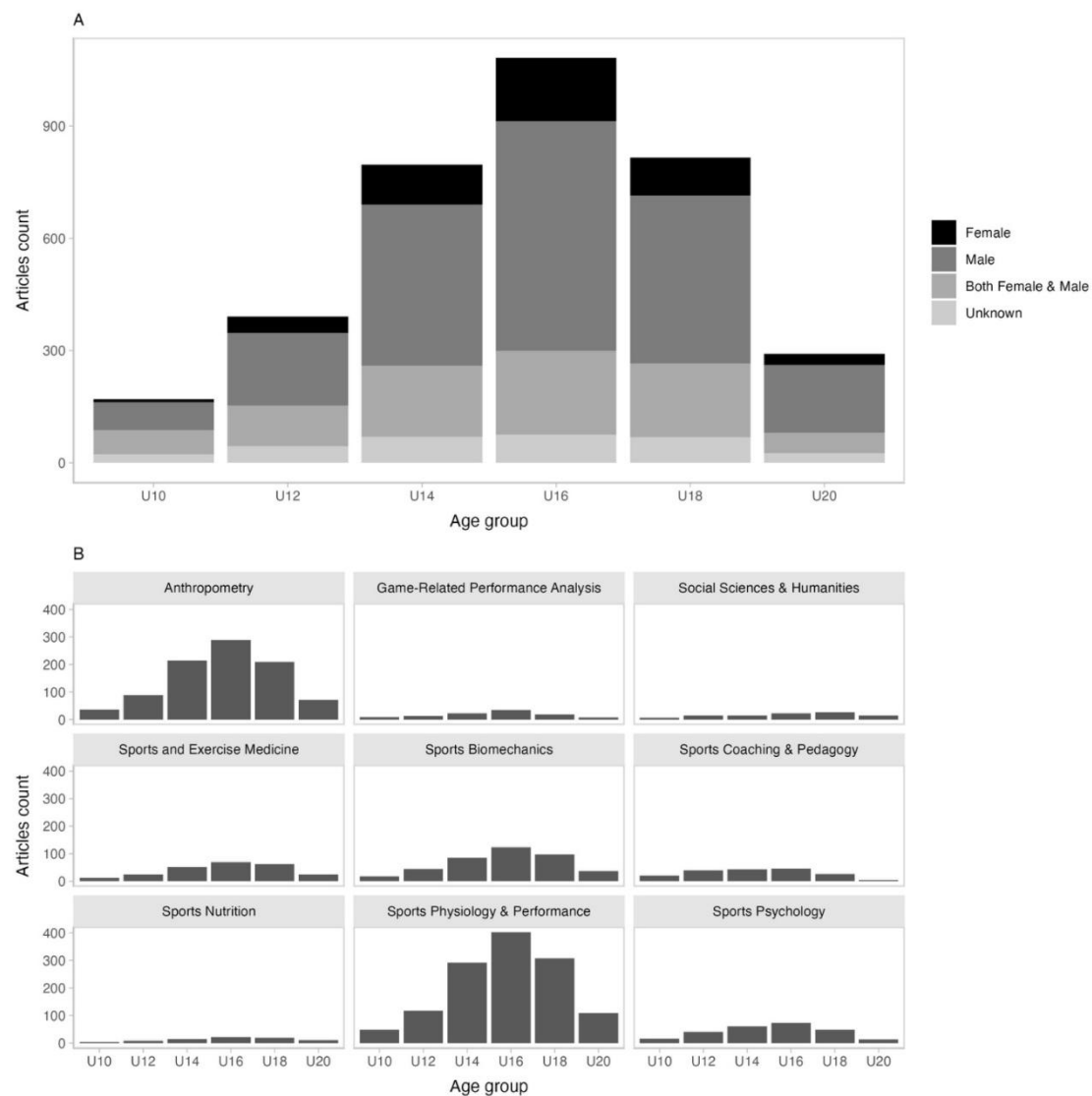


Figure 6. (A) Total distribution of age groups among published papers; and (B) distribution of age groups among different dimensions

The competitive level of participants was specified in 302 studies (42.0%), with 417 papers (58.0%) not reporting this information. Among the 302 papers that reported competitive level, 60 studies involved international players, 126 involved national-level players, 33 involved state-level players, 6 described participants as elite or sub-elite youth, 14 considered mini-basketball samples. Other papers presented amateur, non-official competition, scholar, and college levels.

3.3.4. Thematic Focus and Multidimensionality

Figure 6 illustrates the proportion of studies categorized within each of the nine thematic dimensions. Based on the content presented, the 719 included studies generated 1,697 thematic

registers, Anthropometry was presented in 476 studies (28.05%), Game-Related Performance Analysis in 72 studies (4.24%), Social Sciences & Humanities in 52 studies (3.06%), Sports and Exercise Medicine in 112 studies (6.60%), Sports Biomechanics in 216 studies (12.73%), Sports Coaching & Pedagogy in 105 studies (6.19%), Sports Nutrition in 35 studies (2.06%), Sports Physiology & Performance in 503 studies (29.64%), and Sports Psychology in 126 studies (7.42%)

Beyond the sheer number of studies per dimension, Figure 6 also highlights the distribution of study designs within each thematic area, noting a high proportion of longitudinal designs in the Anthropometry and Sports Physiology & Performance dimensions, particularly after 2015.

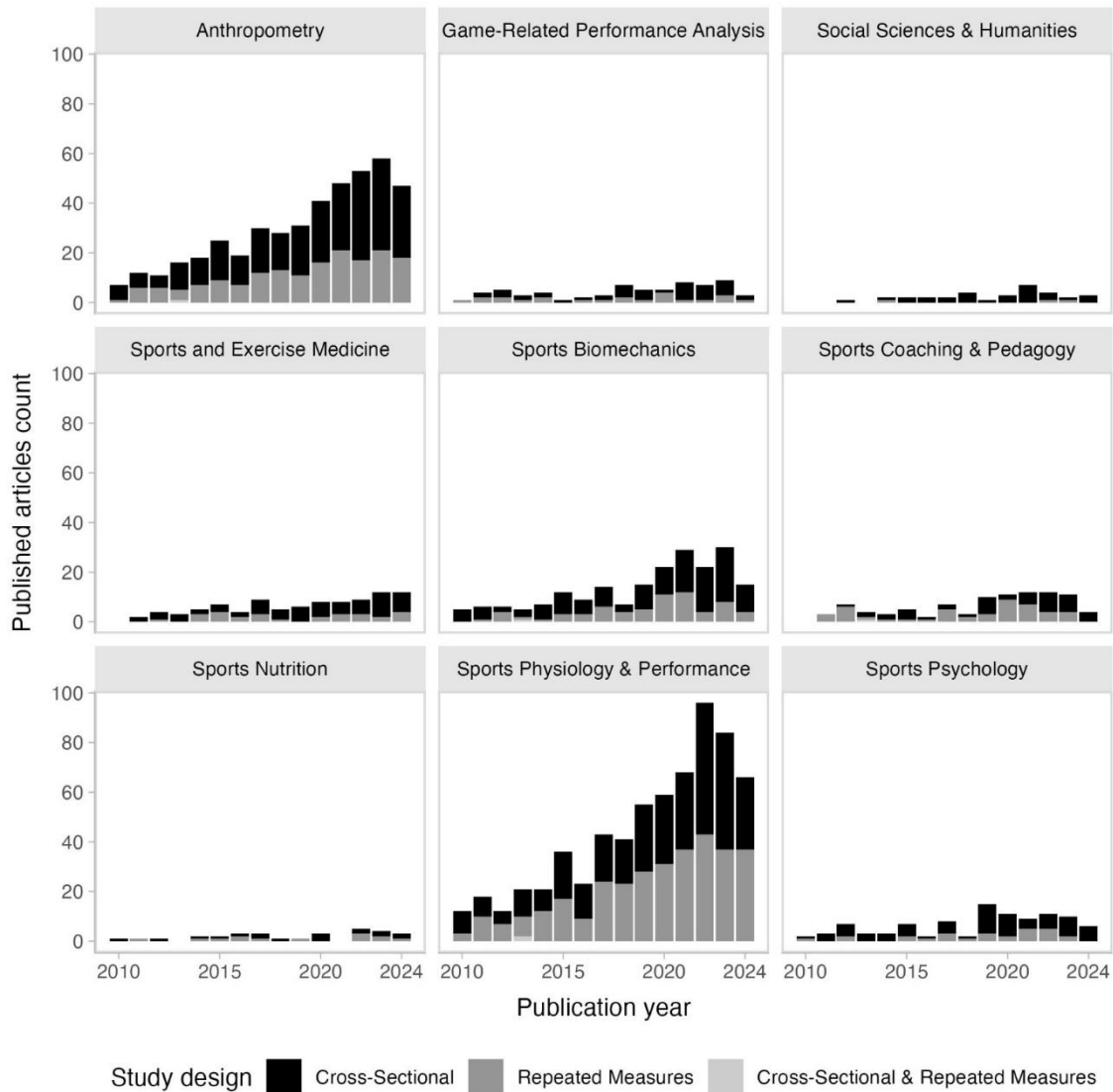


Figure 7. Mapping concentration of published papers by knowledge dimension from 2000 to 2024

Figure 7 displays the proportion of published studies from 2000 to 2024 categorized by the number of thematic dimensions addressed (from 1 to 5). As noted, the 719 studies generated 1,697 total dimension entries. The distribution of studies by the number of dimensions found were: 115 studies (6.78%) with One dimension, 630 studies (37.12%) with Two dimensions, 651 studies (38.36%) with Three dimensions, 236 studies (13.91%) with Four dimensions, and 65 studies (3.83%) counted Five dimensions. Overall, 75.79% of studies considered data across two or three dimensions.

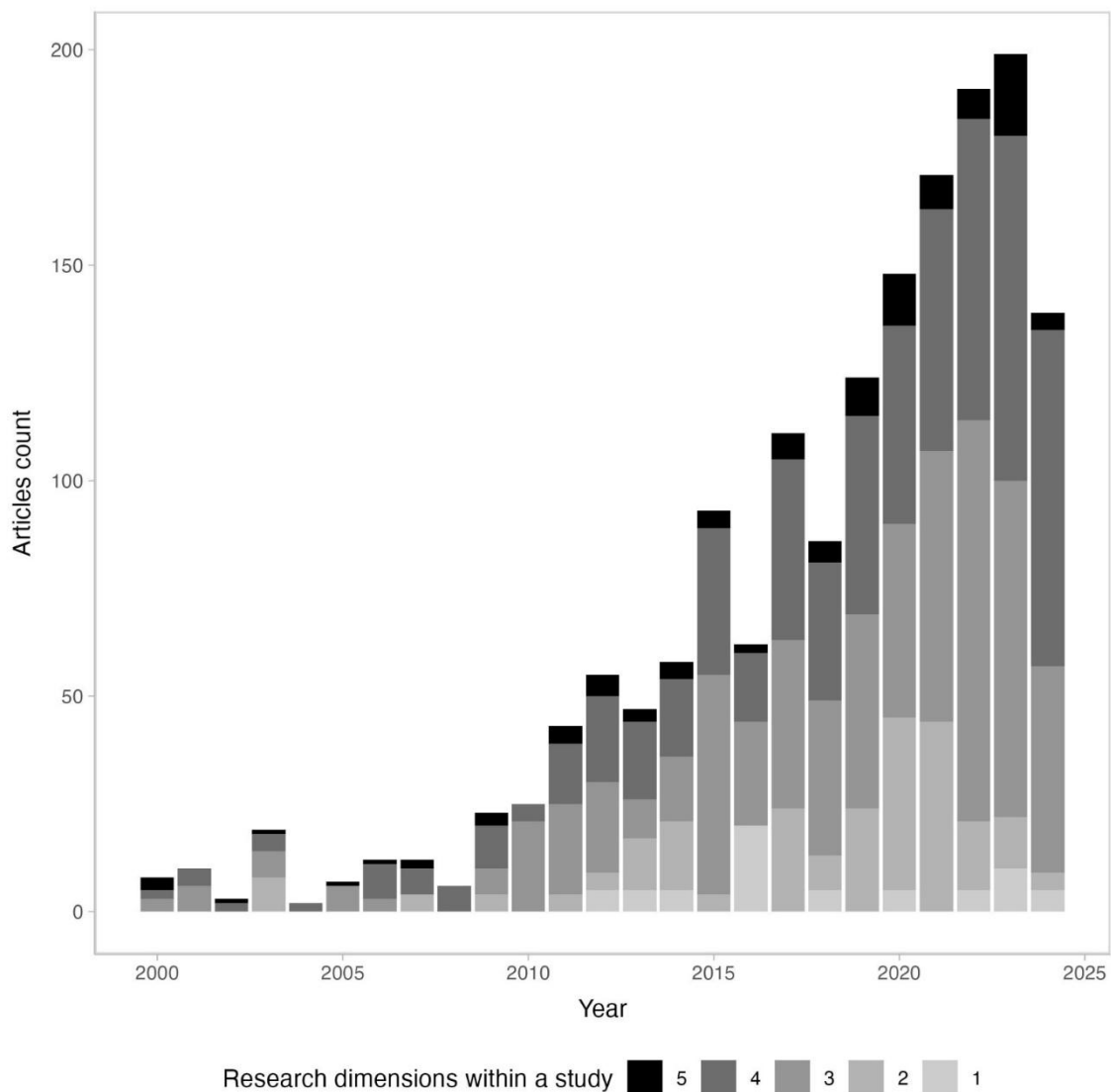


Figure 8. Total of published papers and number of dimensions accomplished through 2000 to 2024

Table 2 provides a detailed breakdown of the number of papers categorized within each dimension, further cross-tabulated by the number of dimensions addressed by the studies. For studies categorized in two dimensions, 33.81% included Anthropometry data and 35.24% included Sports Physiology & Performance data. Among three-dimension studies, 27.80%

encompassed Anthropometry, 19.20% Sports Biomechanics, and 29.49% Sports Physiology & Performance. Notably, one or both of these dimensions (Anthropometry and Sports Physiology & Performance) were considered in 75.49% of all studies.

Table 2. Number of dimensions considered in studies by proportion in each category

	<i>Number of dimensions considered</i>					
	1	2	3	4	5	All
<i>Categories</i>						
Anthropometry	16	213	181	53	13	476
Game-Related Performance Analysis	4	15	24	21	8	72
Social Sciences & Humanities	0	23	25	3	1	52
Sports and Exercise Medicine	18	36	32	20	6	112
Sports Biomechanics	7	43	125	34	7	216
Sports Coaching & Pedagogy	10	32	28	26	9	105
Sports Nutrition	1	8	15	8	3	35
Sports Physiology & Performance	17	222	192	59	13	503
Sports Psychology	42	38	29	12	5	126
All	115	630	651	236	65	1697

Figure 8 illustrates the density of dimensions addressed by published papers over time, from 2000 to 2024. A positive trend of increasing multidimensionality in studies is apparent, particularly from 2015 onwards. While the prevalence of studies considering more than one dimension has increased in recent years, the lack of studies addressing four or five dimensions remains notable, even with their comparatively higher representation in recent years compared to earlier periods.

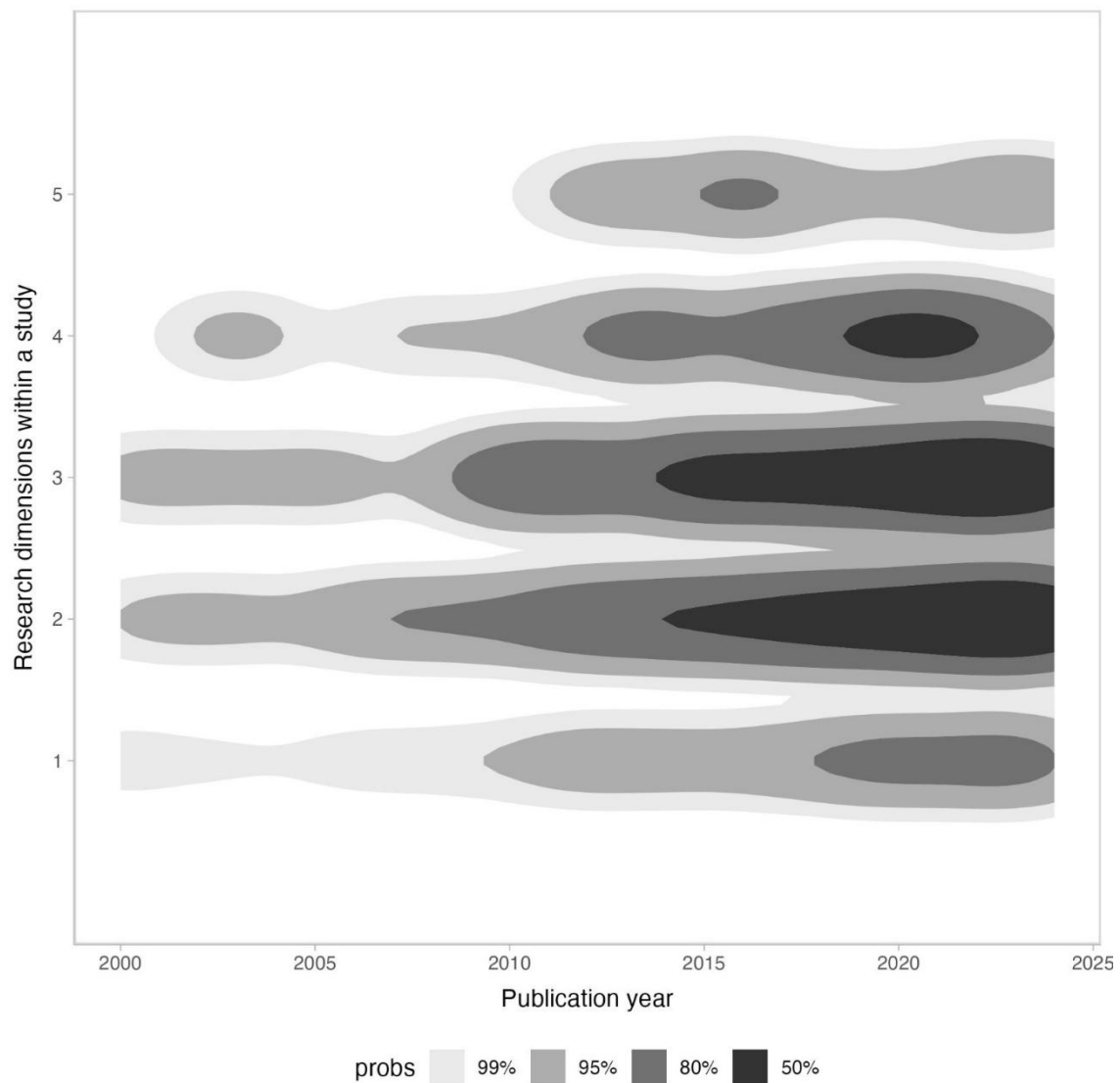


Figure 9. Density of dimensions accomplished by published papers tendencies through years, from 2000 to 2024

3.4.DISCUSSION

The analysis of articles included in this scoping and mapping review on youth basketball revealed important trends in scientific production within the field. A progressive increase in publications over the years is evident (Figure 2), particularly after 2010, with a notable peak around 2023. Prior to 2000, only 15 articles (approximately 2.08% of the total) were included, spanning from 1964 to 1998. This growth reflects the increasing interest of the scientific community in understanding the multifaceted aspects of young basketball athletes' development within structured programs. Furthermore, the rising proportion of papers indexed in JCR-indexed journals suggests an overall improvement in the quality of studies published in recent years.

Descriptive and cross-sectional observational studies largely predominate in study design, representing the majority of the scientific output. Studies employing repeated measures, including longitudinal and interventional designs, appeared less frequently. This indicates a significant gap in research that assesses the long-term effects of programs and strategies applied to youth basketball contexts. While cross-sectional studies can provide valuable insights into characteristics and comparisons among young athletes, their findings are limited in generalizability (CARVALHO et al., 2019; LEONARDI et al., 2018). The scarcity of longitudinal studies remains a critical issue, highlighting the need for more robust methodological approaches. Despite the inherent logistical and ethical challenges of long-term research following young athletes (KEMPER, 2007), longitudinal designs are paramount for a comprehensive understanding of changes in youth basketball players over time, especially considering the influence of growth and maturation on other aspects of players' development and career progression (LLOYD et al., 2016; MALINA et al., 2015).

Another significant finding regarding study design is the low number of qualitative studies, and even fewer studies integrating both quantitative and qualitative methodological approaches. This oversight limits the depth of insight, particularly when considering the multifactorial and complex nature of athlete development programs. There is a clear need to advance towards more ecological methodological designs in future research to better capture the rich, intricate dynamics of youth athlete development.

The detailed quantitative distribution of studies by thematic dimension provided a general overview of highly researched areas and those lacking sufficient evidence. Most articles addressed a single dimension, indicating a predominant unidimensional approach in youth basketball scientific production. However, a notable number of studies did encompass two or more thematic dimensions simultaneously, suggesting an emerging trend toward greater integration and multidimensional approaches within the field. The limited interdisciplinary integration across themes hinders a holistic understanding of young athletes' needs and points to a disconnect between current research practices and widely accepted models of athlete development, which advocate for a comprehensive perspective encompassing physical, psychological, social, and pedagogical factors.

Although the number of studies addressing multiple dimensions has gradually increased, most still focus on one or two areas, with a high prevalence of "laboratory" testing and measurements within the *Anthropometry*, *Sports Physiology and Performance*, and *Sports Biomechanics* thematic dimensions. In contrast, *Social Sciences and Humanities*, *Coaching and*

Pedagogy, and *Sports Nutrition* remain significantly underrepresented and often appear in studies with little or no integration with other themes. To advance the field, future research should embrace multidimensional collaborations and prioritize designs that reflect the complexity and interdisciplinary aspects of youth sport. Broader inclusion of nutritional, pedagogical, and psychosocial aspects would better align scientific inquiry with the realities of youth basketball development and provide stronger support for evidence-based practices, particularly during adolescence when growth and maturation profoundly influence development (CUMMING et al., 2017; MIGUEL et al, 2025; WILLIAMS and REILLY, 2000).

The higher prevalence of studies on male players, to the detriment of female samples, likely reflects the disproportionate number of girls participating in structured basketball programs (POSSAMAI et al., 2024). Despite well-established knowledge that boys and girls exhibit different growth and biological maturation patterns across physical, physiological, cognitive, social, personal, and psychological characteristics (ARMSTRONG, 2018; LIMA et al., 2024), studies exclusively featuring female participants remain scarce. Therefore, there is a clear opportunity for the scientific community to address this gap and provide valuable evidence-based information for practitioners and decision-makers. This would enable the development of tailored interventions and policies for female players, rather than relying on generalized data predominantly based on male populations (MIGUEL et al, 2025; SEDEAUD et al., 2025).

Regarding participant age groups, studies most commonly featured participants aged between U14, U16, and U18, indicating an overrepresentation of research on junior-level athletes, typically after peak height velocity (PHV). Some of these studies did consider different biological maturation stages and changes across developmental phases. Measures of biological maturation were mostly based on the *maturity offset* protocol, despite the scientific community having reported its limitations in predicting adult height (MIRWALD et al., 2002; MOORE et al., 2015). This strong focus on these age bands may stem from the ongoing challenge for researchers and practitioners to predict determinants of high-level performance in youth basketball (CARVALHO et al., 2019; KEMPER, 2007; SEDEAUD et al., 2025; WILLIAMS and REILLY, 2000). Clubs, academies, and governing bodies often invest limited resources in structured programs focused on talent selection and development, aiming to promote high-level performers to professional and international competition. In contrast, studies involving U12 and U10 aged athletes were considerably underrepresented, highlighting a significant gap in understanding the initial stages of basketball participation.

Finally, the *competitive level* of participants was not explicitly described in 417 (57.92%) of the studies. While some studies stated the name of the club, academy, or training center, they often omitted explicit details about the competitive level at which the athletes were engaged. Although 302 papers provided information on competitive level, there is still limited information regarding the characteristics of the competition and sport programs themselves. Such details could offer valuable insights into the contextual aspects of dynamic relationships and the training and competition loads athletes experience. For instance, Zarić et al. (2021) discussed mental toughness in competitive female basketball players, highlighting the participation of national team selected players within the same competition as other study participants. Establishing comparisons across many leagues, countries, and regions is inherently difficult due to variations in competitive playing levels, styles of play (MADARAME, 2018a; MADARAME, 2018b), coaching interventions, and available facilities and resources across different study contexts. Nevertheless, our results suggest that much research has been conducted within highly structured training programs primarily focused on developing high-level performance players.

Even though six studies described their participants as elite and sub-elite youth, there remains a critical need for clear conceptual definitions. As Grainger et al. (2025) recently discussed, the consistent use of key terms and conceptual definitions by both practitioners and researchers is essential to minimize misinterpretations and misunderstandings. Inconsistent terminology can lead to the misuse of scarce resources, such as time, funding, and facilities, ultimately hindering strategic goals in both scientific and practical fields. McAuley et al. (2022) and Baker et al. (2019) emphasized the importance of transparency in sport science studies, advocating for the categorization of relevant participant characteristics, including age, competition level, league status, sex, international ranking, nationality, province/state, sport, and success/achievements.

3.5.LIMITATIONS

We were unable to access 41 papers selected for full-text screening (4.1% of the total). We believe that the limited number of inaccessible papers likely has a minimal impact on the overall discussion of this scoping review, as its primary purpose is to provide a broad overview of youth basketball research. However, we acknowledge that future research and systematic reviews targeting specific questions might need to consider these papers to provide different findings. While this review offers a comprehensive overview of the youth basketball research

topic, we recognize the inherent limitations of interpreting scoping reviews and evidence gap mapping.

3.6.CONCLUSION

Despite a growing body of research, our scoping review reveals that youth basketball studies often adopt a narrow methodological and thematic scope, frequently relying on isolated variables and compartmentalized perspectives. This overlooks the complex, dynamic nature of athletic development. There's a critical need for longitudinal designs that can capture developmental processes over time, moving beyond descriptive snapshots.

The empirical scientific knowledge in youth basketball remains scarce and urgently requires a multidisciplinary approach, particularly given how growth and maturation influence various developmental aspects. Researchers must embrace ecological methodological designs to address the high complexity of factors involved in young athletes' development.

To foster a deeper understanding and build robust theoretical frameworks, authors must provide more explicit information on player characteristics, including sex, competitive level, maturational status, and sports experience. Clear conceptual distinctions are vital to avoid misinterpretations and ensure efficient financial and time-demanding resources allocation in both research and practice.

This review highlights how much remains unknown and unconsolidated in youth basketball development, underscoring the scientific literature's need for more interactive and integrative perspectives. We must be cautious about accepting current developmental model assumptions without robust, evidence-based data.

Ultimately, future research has a crucial opportunity to advance by adopting interdisciplinary frameworks, integrating neglected themes, and applying longitudinal and mixed-longitudinal designs to fully capture the complex developmental pathways of youth basketball players.

4. METHODOLOGICAL CONSIDERATIONS

The methodological choices made throughout this thesis are grounded in the need to ensure transparency, consistency, and scientific rigor in the study of youth athlete development. Given the complexity of interactions among biological, psychological, pedagogical, and contextual variables, it is essential that research procedures be explicitly described and theoretically justified. Detailed documentation of participant characteristics, instruments, measurement protocols, and analytical strategies is crucial not only for the validity and confiability of results, but also for enabling future replications and comparisons across studies. This section presents the key methodological aspects that underpin the empirical and theoretical contributions of the thesis, including sampling procedures, data quality control, measurement tools, and analytical approaches.

4.1. ETHICAL CONSIDERATIONS

All of the empirical studies included in this thesis were conducted in accordance with national and international ethical standards for research involving human participants. The Research Ethics Committee of the Federal University of Santa Catarina (UFSC) approved the research protocol under Certificate of Presentation for Ethical Consideration (CAAE) number 71260117.2.0000.0121, and University of Campinas, CAAE number 49143515.3.0000.5404, ensuring compliance with Brazilian Resolution No. 510/2016 of the National Health Council and the principles outlined in the Declaration of Helsinki.

Prior to data collection, participants and their legal guardians were provided with detailed information about the research objectives and procedures, as well as the potential risks. They were also informed that their participation was voluntary and that they had the right to withdraw at any time without penalty. Written informed consent was obtained from all guardians and adolescent participants. All procedures were carried out in sports environments familiar to the athletes, such as training centers and facilities, to minimize discomfort and ensure ecological validity.

Data confidentiality and participant anonymity were maintained throughout the research process. All datasets were coded and stored in encrypted digital formats accessible only to the research team. No invasive procedures were conducted, and all physical and psychological assessments were administered by trained professionals following standardized protocols.

These measures ensured that participant welfare was prioritized and that the research adhered to the highest standards of scientific and ethical integrity.

4.2.STUDY AND SURVEY APPROACH

The empirical studies included in this thesis were conducted with adolescent players actively engaged in organized training programs. Even the focus of this study is youth basketball, we have considered some data about other sports modalities, due to the differences between different contexts cultures, relations, and dynamics. Participants were recruited from competitive youth teams affiliated with clubs or regional federations, representing both male and female teams and encompassing a range of developmental stages.

The sampling strategy was intentional and stratified, aiming to capture variation across biological maturation, sex, training experience, and competitive level. Athletes were included if they met the following criteria: (i) regular participation in organized basketball training (minimum of three sessions per week); (ii) engagement in competition at the regional, state, or national level; and (iii) availability of consent from parents or legal guardians, in accordance with ethical guidelines. Athletes were excluded if they were (i) injured or under physical therapy treatment during the data collection period, or (ii) involved in fewer than six months of continuous basketball participation.

The studies considered data collected during the period from 2015 to 2023. Data collection occurred in familiar environments to the athletes, and measurement sessions were scheduled to avoid overload, injury risk, or interference with competitions. Three different periods of the season were considered, according to the official schedule of competitions promoted and supervised by local federations and national confederation: pre-season (February/March), mid-season (July/August), and end-season (November/December). In longitudinal studies, only players with repeated measures were considered into the analysis.

The studies took place primarily in southern Brazil, involving athletes from cities with structured youth sport programs, although the selection was not geographically limited to a single region. This approach ensured ecological validity while balancing logistical feasibility and ethical considerations.

Importantly, each study considered stratification by sex, age group, and maturity status, allowing for developmental comparisons and subgroup analyses. Samples included players from under-11 (U11), under-13 (U13), under-15 (U15), and under-17 (U17) categories, reflecting the typical structure of Brazilian youth basketball competitions. In one study, the age

of menarche was used as an additional indicator of biological maturity (i.e. menarche age) in female participants.

Although the sample does not represent the full national landscape of youth basketball, it reflects key characteristics of competitive sport development contexts in Brazil and offers insights relevant to club-based programs. The sampling approach prioritized ecological representativeness, while maintaining analytic control through subgroup classifications and standardized procedures across studies. Clubs and associations were contacted by the author, who had access due professional network, and their collaboration was essential for data collection procedures. By convenience and accomplishment for papers objectives, data of different sport contexts and modalities is contained in some papers included in this thesis. More details are presented about samples and procedures in each chapter.

4.3.MEASURES AND FIELD TESTS

To ensure methodological rigor and analytical coherence, the empirical studies comprising this thesis employed standardized procedures for data collection, variable classification, and participant characterization. Trained researchers collected all data using validated instruments, and quality control was ensured through calibration protocols, familiarization trials, and internal consistency verification.

The variables used in the analyses were organized into four main domains, as outlined below.

4.3.1.Contextual and Developmental Variables

To contextualize findings and enable ecological interpretation, several background and structural variables were collected:

Chronological age was calculated to the nearest 0.1 year by subtracting birth date from date of testing. Age grouping followed the typical youth basketball competitive categories (e.g., U11, U13, U15, U17).

Sex was recorded for all participants. Studies were conducted with male-only, female-only, and mixed-sex samples depending on the research objective and conditions for participation accounting.

Years of structured basketball training and **age of deliberate practice onset in basketball** were obtained by the self-reported age when athletes began formal training and

competition exclusively in basketball, under the supervision of a coach within a basketball program affiliated to the local basketball federation. This procedure was based on previous study methods (LIMA et al., 2020). We considered two biologic maturation milestones, the age of onset of the pubertal growth spurt and the age at PHV to interpret age starting basketball deliberate practice, based on previous longitudinal growth studies (Malina, Bouchard et al. 1988). The reference age of the pubertal growth spurt onset was 9.4 (95% Credible Interval, CI 9.0 to 9.8) years and 11.1 (95% CI 10.8 to 11.5) years for girls and boys, respectively. The reference age at PHV was 11.9 (95% CI 11.8 to 12.0) years and 13.9 (95% CI 13.8 to 14.0) years for girls and boys, respectively. We classified players by the onset of deliberate basketball practice as follows: *pre-puberty* deliberate basketball practice onset, the players who started practice before the reference age of pubertal growth spurt onset; *mid-puberty* deliberate basketball practice onset, the players starting practice between the reference ages of pubertal growth spurt onset age and at PHV; *late-puberty* deliberate basketball practice onset, the players starting practice after the reference age at PHV.

Competitive level was determined based on athletes' participation in local, regional, state, or national tournaments. In some cases, the level was inferred based on club affiliation and coaching records when not explicitly reported.

These variables were used to stratify analyses, compare subgroups, and assess the interaction between physical, psychological, and contextual factors across developmental stages.

4.3.2. Anthropometry and Biological Maturation

Anthropometric measurements were conducted according to the Level 1 protocol of the *International Society for the Advancement of Kinanthropometry* (ISAK). **Stature** was measured using a portable stadiometer (Seca model 206, Hanover, MD, USA) to the nearest 0.1 cm. **Body mass** was obtained with a calibrated portable balance (Seca model 770, Hanover, MD, USA) to the nearest 0.1 kg. The precision of the measurements was ensured by calculating the technical error of measurement (TEM), which was 0.27 cm for stature and 0.47 kg for body mass, which were well within the range of intra- and interobserver errors in several surveys in the U.S.A. and a variety of field studies of young athletes.

Biological maturation was assessed via *maturity offset*, estimated using regression equations developed by Moore et al. (2015). This method calculates the time (in years) before or after peak height velocity (PHV), which serves as a proxy for biological age. Age at peak height velocity (PHV) was estimated with the maturity offset protocol (MIRWALD et al.,

2002). Based on maturity offset, the participants, ranging from -2.96 to $+2.45$ years from/to PHV, were grouped into three maturity status categories for analysis: early ($\text{PHV} \leq -1.00$ year), on-time ($-1.00 < \text{PHV} < +1.00$ year), and late ($\text{PHV} \geq +1.00$) maturers. The range of distance to PHV to classify players by maturity status in the present study was larger and conservative than previous studies using age at PHV (THOMIS et al., 2005), assuming limitations of the offset equation estimations (CARVALHO et al., 2018; MALINA et al., 2006; MOORE et al., 2015). This classification enabled maturity-adjusted analyses and subgroup comparisons. In the study with female athletes sample, age at menarche was used as an additional maturation indicator.

4.3.3. Physical Fitness and Functional Capacity

Physical fitness was assessed using a battery of standardized field-based tests, chosen for their validity in adolescent basketball populations and alignment with sport-specific demands. All physical tests were preceded by a standardized warm-up, and instructions were delivered by experienced evaluators. Measurements were usually taken in training facilities environments, and data were collected at two or more time points (pre/post-season), allowing for repeated measures modeling. Verbal encouragement for an all-out effort was given throughout the test.

Countermovement Jump (CMJ) (BOSCO et al., 1983; MARKOVIC et al., 2004) was used to assess lower limb explosive power. Athletes performed three maximal vertical jumps with hands on hips, and flight time was recorded via Optojump photocell system® (Microgate, Bolzano, Italy) (GLATTHORN et al., 2011). The highest jump between three trials was retained for analysis. CMJ is a widely used indicator of neuromuscular performance and responsiveness to training stimuli.

The **Line Drill Test**, a basketball-specific intermittent sprint task, was used to evaluate anaerobic capacity and agility. Athletes sprinted back and forth repeatedly between court landmarks (baseline, free-throw line, half-court), 5.8m, 14.0m, 22.2m, and 28.0m distances, with sharp directional changes. The total time to complete the 140m protocol reflected anaerobic endurance under fatigue. The test is known for its strong ecological validity and relevance to in-game movement patterns (CARVALHO et al., 2017; SEMENICK, 1990; SOARES et al., 2016). Athletes began the test one meter behind the baseline of the basketball court, where a pair of Optojump photocell system® (Microgate, Bolzano, Italy) was positioned, with a video recorder (recording rate of 120 fps) aligned with the baseline (Sony, Tokyo, Japan)

used as reference for the beginning and end of the test. Time was obtained by the photocells and validated by video analysis of players crossing the reference baseline with available video analysis software Kinovea – 0.8.15 (<http://www.kinovea.org>). Reliability of video recording for time measurement was completed by comparison with photoelectric cells in previous study where video analysis for time recording in the Line Drill test was assumed as accurate and reliable (CARVALHO et al., 2018).

The **Yo-Yo Intermittent Recovery Test Level 1 (YYIR1)** was administered to measure aerobic capacity. Athletes ran repeated 2 x 20 m runs back and forth between the lines marked on the floor at a progressively increased speed controlled by audio bleeps from a tape recorder, with short recovery intervals until exhaustion. Based on replicate measures separated by one week in 18 players, reliability estimates were reported before (CARVALHO et al., 2018): coefficient of variation, 6.4 (95% CI 4.8 to 9.7); retest correlation, 0.97 (95% CI 0.93 to 0.99). Total distance covered was recorded in meters and used as an indicator of intermittent aerobic fitness, which is critical for game endurance in basketball (BANGSBO et al., 2008; KRUSTRUP et al., 2003).

4.3.4. Psychobehavioral and Motivational Variables

Psychological and motivational variables were assessed using validated self-report instruments appropriate for adolescent athletes. Data were collected in group settings before or after training, with researcher supervision to clarify doubts and ensure data integrity.

The **Work and Family Orientation Questionnaire (WOFO)** (HELMREICH et al., 1978) was employed to assess achievement and competitiveness motivation. The instrument comprises 19 items and assesses four dimensions of achievement: personal unconcern, work, mastery, and competitiveness. Each item rated on a 5-point Likert scale (1 = completely disagree to 5 = completely agree). In the present study, only the last three subscales were used, consistent with previous observations with similar samples of youth basketball (CARVALHO et al., 2018; GONÇALVES et al., 2011). The utility of the three subscales was noted in youth sports contexts before (CARVALHO et al., 2018; DE BRUIN et al., 2007; FARMER, 1985).

The **Deliberate Practice Motivation Questionnaire (DPMQ)** (DE BRUIN et al., 2007; DE BRUIN et al., 2008; GONÇALVES et al., 2011) was used to measure athletes' motivational orientation toward structured practice engagement. It contains 18 items (rated in a 5-point Likert scale) grouped into two dimensions: will to compete and will to excel, providing a nuanced picture of intrinsic and extrinsic drivers of sport commitment. The

Portuguese version of the questionnaire showed good reliability in previous data in youth basketball (GONÇALVES et al., 2011).

The **Sources of Enjoyment in Youth Sport Questionnaire (SEYSQ)** (SCANLAN and LEWTHWAITE, 1986; SCANLAN et al., 1993; WIERSMA, 2001) was partially administered to capture affective and relational factors associated with sport participation. Subscales included self-referenced competence, peer affiliation, and parental involvement, among others. Responses were given on a 5-point scale.

All scales were subjected to internal consistency analysis (Cronbach's $\alpha \geq 0.70$). Results were modeled using Bayesian hierarchical analysis, accounting for nested data structures (athletes within teams, teams within clubs).

4.4.DATA ANALYSIS AND MODELLING STRATEGIES

Data analysis across the empirical studies employed a combination of descriptive, inferential, and Bayesian hierarchical modeling techniques. Given the nested nature of the data (e.g., athletes within teams), as well as the presence of repeated measures and multilevel covariates (e.g., age, sex, maturity status), Bayesian multilevel models were used to produce more robust, flexible, and interpretable estimates.

Analyses were conducted using the R programming language (v.4.x), primarily utilizing the “brms” and “rstanarm” packages, which implement Bayesian models using Stan. These tools allowed for full posterior distribution estimation via Markov Chain Monte Carlo (MCMC) methods, providing credible intervals, probability densities, and shrinkage estimates that enhance interpretability over traditional frequentist outputs.

Multilevel structures were used to estimate individual-level effects (Level 1), such as maturity status or motivation scores, and group- or context-level effects (Level 2), such as team or competitive category. When applicable, repeated-measures designs accounted for within-subject variability over time.

Descriptive statistics were reported for all key variables (means, standard deviations, minimum and maximum values), and missing data were handled using complete case analysis or multiple imputation under a Bayesian framework, depending on the specific model.

This analytical strategy ensured coherence between the theoretical framework, the empirical structure of the data, and the interpretive logic of the thesis, supporting nuanced and developmentally informed conclusions.

5. DOES EARLY SPECIALIZATION PROVIDE AN ADVANTAGE IN PHYSICAL FITNESS DEVELOPMENT IN YOUTH BASKETBALL? ³

ABSTRACT

The present study examined the influence of the specialization onset on the magnitude and patterns of changes in basketball-specific physical fitness within a competitive season and developmental fitness trends between 11 and 17 years in young basketball players. Repeated measures of 181 young basketball players (female, n = 40; male, n = 141) were examined. Anthropometry, age, estimated maturity status, and basketball-specific physical fitness (assessed with the countermovement jump, line drill, and yo-yo intermittent recovery level-1 and fitness score) were considered. Players were grouped by the onset of specialization as related to biological maturation milestones (pre-puberty, mid-puberty, and late-puberty specialization). The within-season and developmental changes in physical fitness were fitted using multilevel modeling in a fully Bayesian framework. The fitness outcomes were similar between-player and within-player changes when grouped by specialization across a season. Fitness improvements across a season were apparent for female players, while male players maintained their performance levels. There was no variation in the patterns of physical fitness development between 11 and 17 years associated with the onset of specialization. Conditional on our data and models, the assumption that early sport specialization provides a physical fitness advantage for future athletic success does not hold.

Keywords: youth sports, Bayesian methods, statistics, young athletes, biological maturation, selection

5.1.INTRODUCTION

The notion that early sport specialization is essential for performance development and attainment of expertise is deeply entrenched in youth sports (BRYLINSKY, 2010). The notion has been based on the deliberate practice theory (ERICSSON et al., 1993) applied to sports (ARMSTRONG, 2018; BAKER and YOUNG, 2014; CÔTÉ and JENNIFER, 2012). An underlying premise of the theory applied to sports is that highly specific training with

³ SOARES, A. L. A.; LIMA, A. B.; MIGUEL, C. G.; GALVÃO, L. G.; LEONARDI, T. J.; PAES, R. R.; GONÇALVES, C. E.; CARVALHO, H. M. Does early specialization provide an advantage in physical fitness development in youth basketball? *Frontiers in Sports and Active Living*, Lausanne, v. 4, 2023. Available in: <https://doi.org/10.3389/fspor.2022.1042494>. Accessed: August 28th, 2025.

appropriate supervision at an early age will improve the functioning of the body's main organ systems beyond what normal growth and development or more diversified physical activities can achieve (KALETH and MIKESKY, 2010). Unfortunately, clear evidence is virtually nonexistent to address whether there is a physiological advantage of early specialization.

The debate about the merits and risks of specialization in youth sports has recently increased (DISANTI and ERICKSON, 2019; HERMAN et al., 2022; MOSHER et al., 2020; MOSHER et al., 2022; PASULKA et al., 2017; WALDRON et al., 2020). Specialization, in general, can be conceptualized as year-round participation in a single “signature” sport, with limited involvement in potential sport alternatives, with a deliberate focus on training and development in the pursuit of elite status (BAKER et al., 2009; COAKLEY, 2010; DISANTI and ERICKSON, 2019; LIMA et al., 2020). Youth sports participation and specialization can be conceptualized as a continuum, but there are no clear references for early or late specialization (LIMA et al., 2020; MOSHER et al., 2020). An important caveat remains, given the lack of consensus about the definition of early specialization (MOSHER et al., 2020). We argue that specialization can be defined and interpreted relative to pubertal growth (ARMSTRONG 2018; LIMA et al., 2020). Specifically, we can consider the onset of specialization as related to biological maturation milestones that describe the pubertal growth period, i.e., the age of initiation of the pubertal growth spurt and the age at peak height velocity (PHV). Based on growth studies data (MALINA et al., 1988), the biological maturation milestones can be defined using meta-analysis (LIMA et al., 2020). Players can be labeled as follows: pre-puberty specialization, when specialization occurs before the onset of pubertal growth (i.e., early specialization); mid-puberty, when specialization occurs between the onset of pubertal growth and the age of PHV (i.e., during pubertal growth); late-puberty specialization, when specialization occurs after pubertal growth (i.e., after the age of PHV).

In this study, we focus on youth basketball. Coaches and youth basketball programs generally promote engagement and commitment to basketball practice in supervised training contexts as early as five years of age (WABC, 2016). In basketball, body dimensions and specific physical fitness, including vertical jumps, sprints with direction changes, and intermittent endurance, are important determinants of performance at high competitive levels (DRINKWATER et al., 2008). Consequently, decisions of selection/promotion in youth basketball are substantially influenced by players' physical fitness and size. On the other hand, the partition of maturity-associated variation in body size and physiological functions is warranted to interpret appropriately young players' performance (CARVALHO et al., 2018; CARVALHO et al., 2019). However, the increased observations in youth basketball continue

to be mostly based on cross-sectional surveys (AREDE et al., 2019; CARVALHO et al. 2018, LIMA et al., 2020, RAMOS et al., 2021; TORRES-UNDA et al. 2016), despite the persistent call for longitudinal designs.

Coaches generally interpret fitness to be maintained or improved during a season and across adolescence (MONTGOMERY et al., 2008). Therefore, understanding the development patterns across a competitive season and adolescence may provide valuable information to coaches and stakeholders to elevate the quality of their training interventions and decision-making, especially at early ages. Unfortunately, data analyzing physical fitness responses across a competitive season and adolescence among young basketball players is limited (CARVALHO et al., 2019; DRINKWATER et al., 2005; MONTGOMERY et al., 2008). Furthermore, sexual dimorphism with pubertal growth may complicate the interpretations of the influence of specialization on physical fitness development in youth basketball. Sex differences in timing and tempo of pubertal growth and maturation are substantial (MALINA et al., 1988) and merit consideration when examining the physical fitness development of adolescent basketball players.

We examine the validity of the assumption supporting early specialization, stating that there are basketball-specific physical fitness advantages of early specialization in young players (BRYLINSKY, 2010; KALETH and MIKESKY, 2010). Hence, we examined the influence of the specialization onset on the magnitude and patterns of changes in basketball-specific physical fitness within a competitive season and the developmental trends of fitness from 11 to 17 years in young basketball players. To allow a comprehensive interpretation, we illustrate the use of multilevel modeling in a fully Bayesian framework to estimate the variation in the outcomes accounting for repeated measures and cross-classified nesting, i.e., within players' variation across the season and between player variation in the physical fitness changes responses by the onset of specialization, sex, competitive age group, and estimated maturity status.

5.2.MATERIALS AND METHODS

5.2.1.Participants and study design

This study considered data from surveys with repeated measures collected from competitive seasons from 2015 to 2019 in youth basketball. The sample included 181 youth basketball players (female players, $n = 40$; male players, $n = 141$) aged between 11.7 to 17.0

years at pre-season. Specifically, in this study, we considered repeated measures across a competitive season of players from under-13, under-15, and under-17 teams at pre-season (February/March), mid-season (July/August), and end-season (November/December). The players were measured and tested within a week in each observation period. From the total sample, 53, 105, and 53 under-13 players completed observations at pre-, mid-, and end-season, respectively; 67, 102, and 43 under-15 players completed observations at pre-, mid-, and end-season, respectively; 31, 32, and 23 under-17 players completed observations at pre-, mid-, and end-season, respectively.

Hence a total of 509 measurements were considered. In addition, data from consecutive seasons were grouped by season to adjust for variation between seasons in the outcomes of interest.

Players were engaged in formal youth basketball training programs and competed in the state-level competition supervised by the local federation. All players trained at least three times a week (1.5–2.5 h/training day) and played a match most of the weekends over a 9-month competitive season. No players reported moderate or more severe injuries during 6-months before the testing. We grouped players into five age categories (under-13, under-15, and under-17) according to birth date and the date of assessment (for example, a player who would complete 13 years was classified as under 13, while a player who would complete 14 years in the same season was classified as under 15). The state basketball federations supervise youth basketball competitions in Brazil. In the present sample, players were engaged in official competitions in São Paulo and Santa Catarina, promoted by the *Federação Paulista de Basketball* and *Federação Catarinense de Basketball*, respectively. Clubs' programs run traditionally from February to July and August to November, completing nine months each season. Data were collected at each basketball club facility.

Players and their parents or legal guardians were informed of the nature of the study, the participation was voluntary, and they could withdraw from the study at any time. The study was approved by the Research Ethics Committee of the Federal University of Santa Catarina and by the Research Ethics Committee of the University of Campinas. Both athletes and their legal guardians provided written informed consent.

5.2.2.Procedures

5.2.2.1. Anthropometric measurements

We considered anthropometry measurements taken by a single experienced observer following standardized procedures (LOHMAN et al., 1991), including stature and body mass. Intra-observer technical measurement errors were 0.25 cm for stature and 0.42 kg for body mass (SOARES et al., 2020).

5.2.2.2. Chronological age and maturity status

Chronological age was considered to the nearest 0.1 years by subtracting a birth date from the testing date. The sex-specific maturity offset equations were used to estimate age at peak height velocity (PHV) based on the age and stature prediction model (MOORE et al., 2015). The prediction model calculates the distance from PHV by subtracting the estimation from chronological age, i.e., the offset. With the offset estimation, we can derive each player's age at PHV. Often overlooked, the offset equations estimate timing (i.e., the age at which a given pubertal milestone is reached). However, the interest in interpreting young athletes' performance and development lies in tempo information, i.e., the rate of within-person progression through maturation stages (GONÇALVES and CARVALHO, 2020). To interpret variation in maturity status between individuals, we compared the estimates of timing obtained with the sex-specific offset equations against the population references based on meta-analysis estimations (LIMA et al., 2020). Hence, we compared the players' estimated age at PHV against a sex-specific reference age at PHV derived from a meta-analysis of longitudinal growth studies (MALINA et al., 1988). Details of our procedure are available elsewhere (LIMA et al., 2020). Then we classified the young basketball players as follows: early maturers ($n = 90$), when the estimated age at PHV was lower than the reference age at PHV by more than six months; average maturers ($n = 52$) when players' estimated age at PHV was within plus/minus six months of the reference age at PHV; late maturers ($n = 5$), when estimated age at PHV was higher than the reference age at PHV by more than six months.

Nevertheless, the limitations of the maturity offset protocol are assumed in our analysis (CARVALHO et al., 2018), particularly at the extremes of the observed age range where bias is likely to be significant (KOZIEL and MALINA, 2018). Therefore, we considered the maturity status of players from the under-13 for female players and under-13 and under-15 age groups for male players. Female under-15 and female and male under-17 players were categorized as not classified ($n = 35$). We assume our interpretations about the influence of

maturity status on players across the ages that the offset protocol is less limited, i.e., the ages around the PHV (KOZIEL and MALINA, 2018).

5.2.2.3. Onset of specialization in basketball

The age of specialization in basketball was considered as the self-reported age when athletes started formal year-round participation in a single “signature” sport (basketball), including training and competition in basketball, under the supervision of a coach within a youth basketball program registered in the state basketball federation, and with no participation in practice and competition in other organized sport (LIMA et al., 2020). Hence, we follow a conceptual approach to specialization as year-round participation in a single “signature” sport, limited involvement in potential sport alternatives, and deliberate focus on training and development to pursue elite status (BAKER et al., 2009; COAKLEY, 2010; DISANTI and ERICKSON, 2019; LIMA et al., 2020). The onset of specialization in basketball was defined by considering two biological maturation milestones, the age of initiation of the pubertal growth spurt and the age at PHV (LIMA et al. 2020). Based on available longitudinal data from growth studies in the general population (MALINA et al., 1988), the sex-specific reference age of the biological milestones was estimated using a meta-analysis fitted with multilevel models. The reference age of initiation of the pubertal growth spurt and age at PHV was 9.4 [95% Credible Interval (CI) 9.0 to 9.8] years and 11.1 (95% CI 10.8 to 11.5) years for females and males, respectively. The reference age at PHV was 11.9 (95% CI 11.8 to 12.0) years and 13.9 (95% CI 13.8 to 14.0) years for females and males, respectively. Hence, the onset of specialization in basketball for young basketball players was classified as follows: pre-puberty specialization (i.e., early specialization), when players start their specialization in basketball before the reference age of onset of pubertal growth ($n = 84$); mid-puberty, when players began basketball specialization between the references for the onset of pubertal growth and the age of PHV, i.e., during pubertal growth ($n = 60$); late-puberty, when the start of specialization in basketball occurred after the reference age at pubertal growth ($n = 13$). For cases where it was impossible to retain the onset of specialization, we classified players as unknown ($n = 25$).

The present study did not consider deliberate play (CÔTÉ and JENNIFER, 2012) and informal participation in other sports before or after the specialization onset age in basketball. Therefore, similarly to our earlier observations with cross-sectional data (LIMA et al., 2020), it was assumed that the limits of our data to describe the continuum of sport participation of the sample and caution is advised in interpreting the data.

5.2.2.4. Physical fitness assessment

To describe players' basketball-specific physical fitness levels, we used the vertical jump with the countermovement jump (BOSCO et al., 1983), a short-term maximal running protocol with changes of direction, the line drill test (CARVALHO et al., 2017), and intermittent endurance test, the yo-yo intermittent recovery level 1 test (yo-yo IR1) (BANGSBO et al., 2008). Details about the present research project's physical fitness assessments and reliability estimates are available elsewhere (CARVALHO et al., 2017; CARVALHO et al., 2018; SOARES et al., 2020). The height of the best countermovement jump was retained to the nearest centimeter. Each time performance in the line drill test was recorded in seconds. The covered distance in the yo-yo IR1 was measured in meters. Based on the sum of the z-scores of each physiological measurement, we estimated a score of overall physical fitness, i.e., physical fitness score (lower-limb explosive strength, agility and anaerobic power, and intermittent endurance) (CARVALHO et al., 2019; MALINA et al., 2007). Given that lower times indicate better performance, the z-scores were reversed for the line drill test performance.

5.2.3. Statistical models

The repeated observations of each player across a season and multiple seasons present an example of a complex hierarchical structure. A multilevel modeling approach in a fully Bayesian framework (GELMAN et al., 2013; MCELREATH, 2020) was used to cope with a complex data structure with an imbalanced sample size and heterogeneity among and between players. Readers unfamiliar with Bayesian methods may be surprised that we do not report significance tests in our results. In its place, we will use a direct probabilistic interpretation of the models' parameters to simulate predictions and assess the quality of model fit to data (MCELREATH and KOSTER, 2014).

We used two model structures to examine changes within a competitive season and developmental changes during adolescence.

5.2.3.1. Modeling changes within a competitive season

Varying intercept and varying slope models were fitted to the repeated measures data, allowing for the possibility of varying intercepts (i.e., pre-season values) and slope (changes in players' outcomes across mid- and end-season) by players. In addition, sex was included as a population-level (also referred to as fixed effect) due to the difficulty of estimating the between-group variation when the number of groups is small (GELMAN and HILL, 2007). Furthermore, within- and between-group variation was incorporated in the model on the players' physical fitness changes across the competitive season. To capture variation in physiological responses by sex, we included an interaction term between sex and changes in players' outcomes across mid- and end-season. Also, to capture differences in physical fitness by sex, we allow players by sex to vary by the onset of specialization and age group. The group-level effect terms (also called random effects) and data-level terms (also called level-1 residuals) were drawn from normal distributions with variances to be estimated from the data. Note that some of these variables include “Unknown” or “Not classified” values and keep these values as separate levels in the model. We partially pool within each group to allow the model to pick up trends in cases with insufficient data or missing information to project the estimates onto the imbalanced repeated measures data.

When modeling the yo-yo IR1 and the overall physical fitness score responses, we included body mass (standardized) as a population-level effect to partition the influence of size on physical fitness outcomes, particularly long-term intermittent maximal performance (WELSMAN and ARMSTRONG, 2019). However, there was no need to include body dimensions for the short-term maximal outputs, as the influence of size on performance was neglectable.

5.2.3.2. Modeling developmental changes

We fitted a basic three-level polynomial growth model curve (GOLDSTEIN, 1986) to model physical fitness indicators against chronological age. The model describes each player's successive measurements over time, defining the player's change at each measurement point and its variation (level-1), differences in trajectories between players, and its variation (level-2), and differences in trajectories between players grouped by specialization onset, and its variation (level-3). To describe potential non-linear developmental changes during adolescence, we considered time (i.e., chronological age) coefficients up to the quadratic terms. In addition, we allowed for developmental trajectories to vary between players (level-2) and between players grouped by specialization onset.

5.2.3.3. *Prior distributions*

For interpretative convenience and to speed up computation, we standardized the outcomes by subtracting the mean and dividing by two standard deviations (GELMAN and HILL, 2007). Given that young players' physical fitness outcomes tends to be heterogeneous and the available imbalanced repeated measures data, we were intentionally conservative in our interpretations. Hence, we used weakly informative priors to regularize our estimates. We used multivariate normal priors (0,5) for the population-level parameter (i.e., intercept and slopes) and exponential (1) priors for the group-level parameters. For the data-level residuals, we used the default prior, Student-t (3, 0, 2.5) (BÜRKNER, 2017).

5.2.3.4. *Statistical software, code repository, and reproducibility*

The length of the chains and warm-up was sufficient to achieve convergence and obtain a reasonable, effective sample size. We ran four chains for 2,000 iterations with a warm-up length of 1,000 iterations for each model. The models were inspected and validated using posterior predictive checks (GABRY et al., 2019). The Bayesian multilevel models were fitted using R statistical language (TEAM, 2018) with the “brms” package (BÜRKNER, 2017), which call Stan (TEAM, 2014). To extract the posterior samples and visualize the results, we used the “tidybayes” (KAY, 2023) and “ggplot2” (WICKHAM, 2016) packages. The data, codes, and details about models' specifications and posterior predictive checks are available as supplementary material (see APPENDIX A) (<https://osf.io/2gfw5/>).

5.3. RESULTS

Characteristics of the sample at pre-season, as reference for description, are summarized in Table 3. Under-13 and under-15 players were mostly classified as early or average maturers with an approximately 2 to 1 distribution of cases, respectively. The distribution of players by the onset of specialization in youth basketball within age groups is summarized in Table 4.

Table 3. Descriptive statistics of the sample at pre-season by age group and sex.

	Under-13		Under-15		Under-17	
	Female	Male	Female	Male	Female	Male
Chronological age, years	12.5 (0.5)	12.6 (0.3)	14.2 (0.6)	14.2 (0.6)	16.0 (0.6)	15.9 (0.5)
Maturity offset, years	0.92 (0.67)	-0.44 (0.57)	^b	1.04 (0.83)	^b	^b
Estimated age at PHV ^a , years	11.6 (0.5)	13.1 (0.5)	^b	13.1 (0.5)	^b	^b
Stature, cm	163.3 (9.5)	165.4 (11.0)	164.3 (5.6)	176.6 (11.0)	167.7 (3.9)	186.5 (7.5)
Body mass, kg	56.9 (13.6)	56.8 (16.1)	58.0 (8.5)	65.3 (13.3)	59.2 (8.4)	80.3 (11.0)
Countermovement jump, cm	24.3 (3.9)	31.7 (6.7)	25.0 (3.9)	35.6 (5.8)	25.7 (4.1)	38.9 (6.0)
Line Drill test, s	37.36 (1.88)	34.71 (3.37)	35.67 (1.93)	33.57 (3.70)	36.29 (1.82)	31.70 (3.09)
Yo-yo recovery test – level I, m	372.7 (82.2)	516.4 (305.6)	516.2 (175.7)	899.2 (382.8)	528.0 (171.6)	1203.3 (348.0)
Performance score, z-score sum	-1.41 (0.59)	-0.25 (1.47)	-0.92 (0.63)	0.65 (1.11)	-0.91 (0.69)	1.74 (0.96)

^aPHV, peak height velocity.^bFemale under 15 and both female and male under 17 players were not classified by maturity status due to the lack of validity of the offset estimations.**Table 4.** Distribution of players by the onset of specialization within an age group and sex in the sample of young Brazilian players.

	Under-13		Under-15		Under-17		Total
	Female	Male	Female	Male	Female	Male	
Pre-puberty specialization	5	34	3	34	2	5	84
Mid-puberty specialization	12	21	9	15	1	3	60
Late-puberty specialization	5	Not possible	3	2	1	2	13
Unknown in the sample	0	7	0	12	0	6	25

Our models accounted for variation in the outcomes changes across a competitive season associated with age group, maturity status, and the onset of specialization. Hence, the effects of target groups can be interpreted as accounting for the other group effects. In the present study, our main focus was the contrasts by the onset of specialization. Predictions and uncertainty (68% credible intervals, i.e., approximately a standard deviation) of countermovement jump (Figure 9), Line drill test (Figure 10), yo-yo IR1 (Figure 11), and overall fitness score (Figure 12) changes across a competitive season are plotted. In addition, we contrasted players' physical fitness predictions by the onset of specialization within sex. We observed no substantial variation by the onset of specialization for female and male players in the basketball-specific physical fitness changes across a competitive season. However, the trend of changes across a competitive season varied by sex. Female players showed slight improvements in countermovement jump, yo-yo IR1, and overall performance score. In contrast, male players maintained their physical fitness levels throughout the competitive season. Overall, older players presented higher values for the indicators of physical fitness across the competitive season. There was no substantial variation in the physical fitness outcomes by maturity status in the responses across the competitive season. Supplementary

plots of predictions of changes in the physical fitness outcomes across a competitive season by age group and maturity status within sex are available at <https://osf.io/2gfw5/> (see Appendix A).

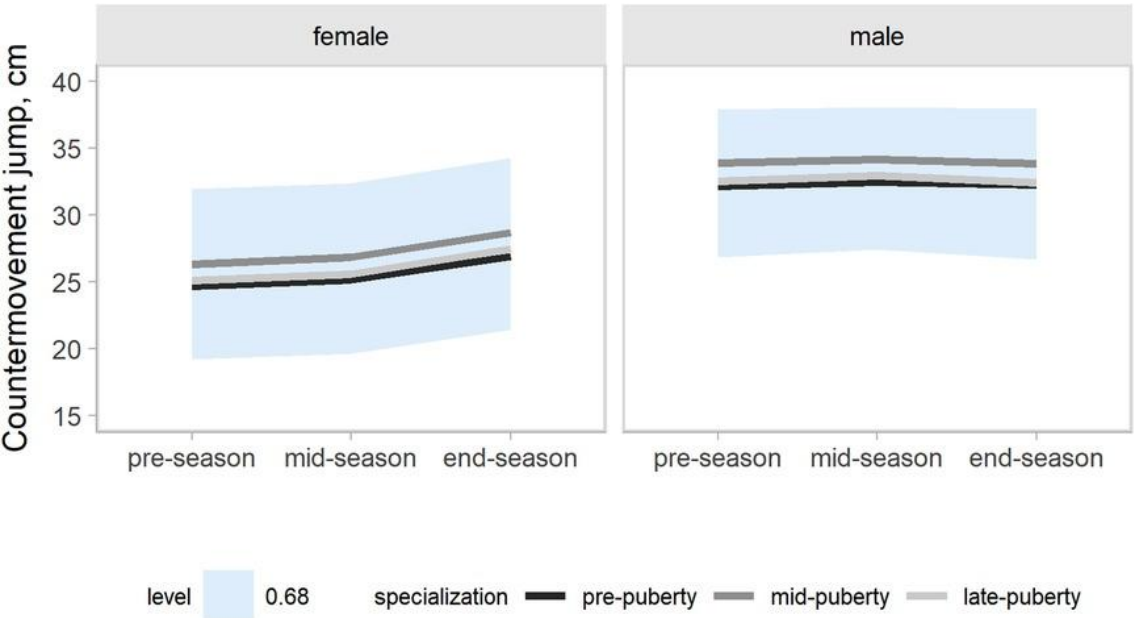


Figure 10. Changes in countermovement jump performance for young females and male basketball players within a basketball season by the onset of specialization. The shaded area represents the 68% credible interval, similar to a standard deviation.

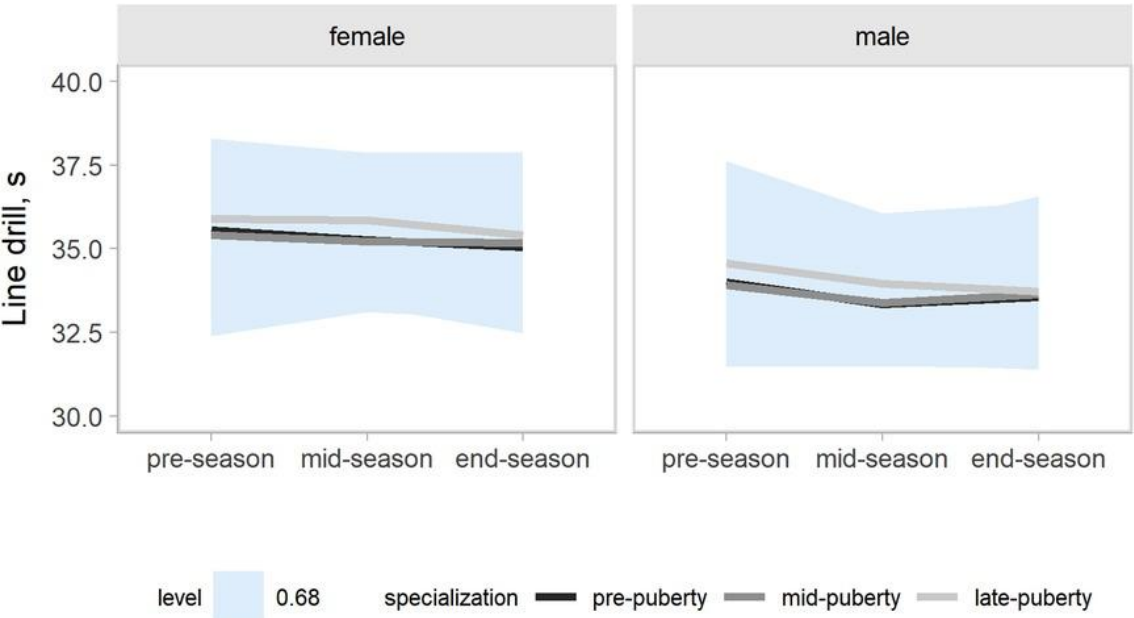


Figure 11. Changes in line-drill performance for young females and male basketball players within a basketball season by the onset of specialization. The shaded area represents the 68% credible interval, similar to a standard deviation.

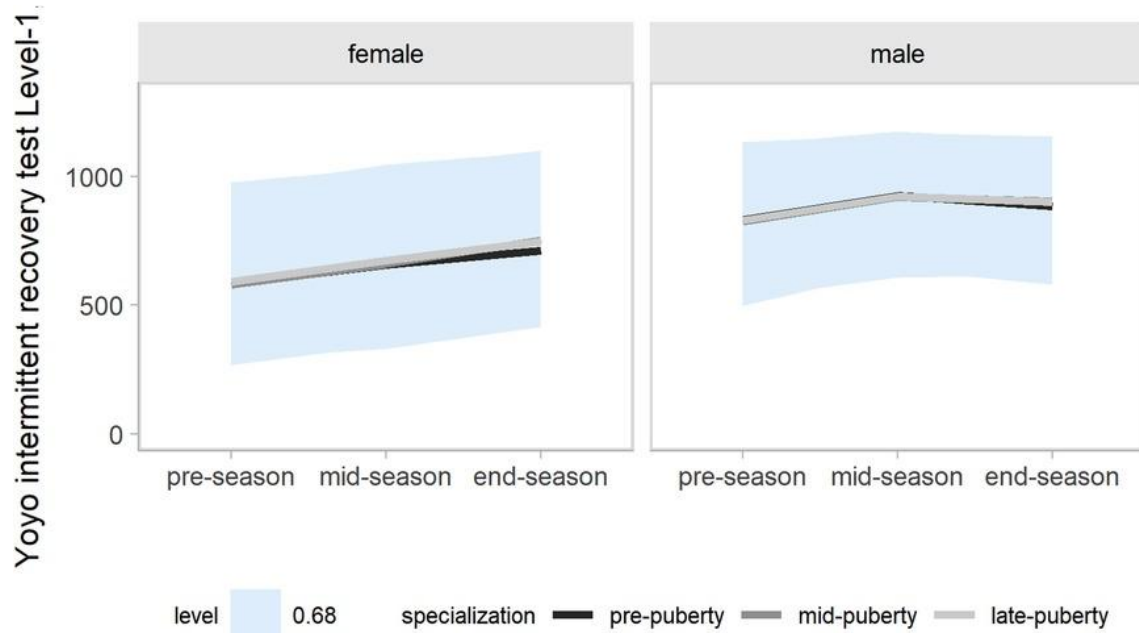


Figure 12. Changes in Yo-yo intermittent recovery test level 1 performance for young females and male basketball players within a basketball season by the onset of specialization. The shaded area represents the 68% credible interval, similar to a standard deviation.

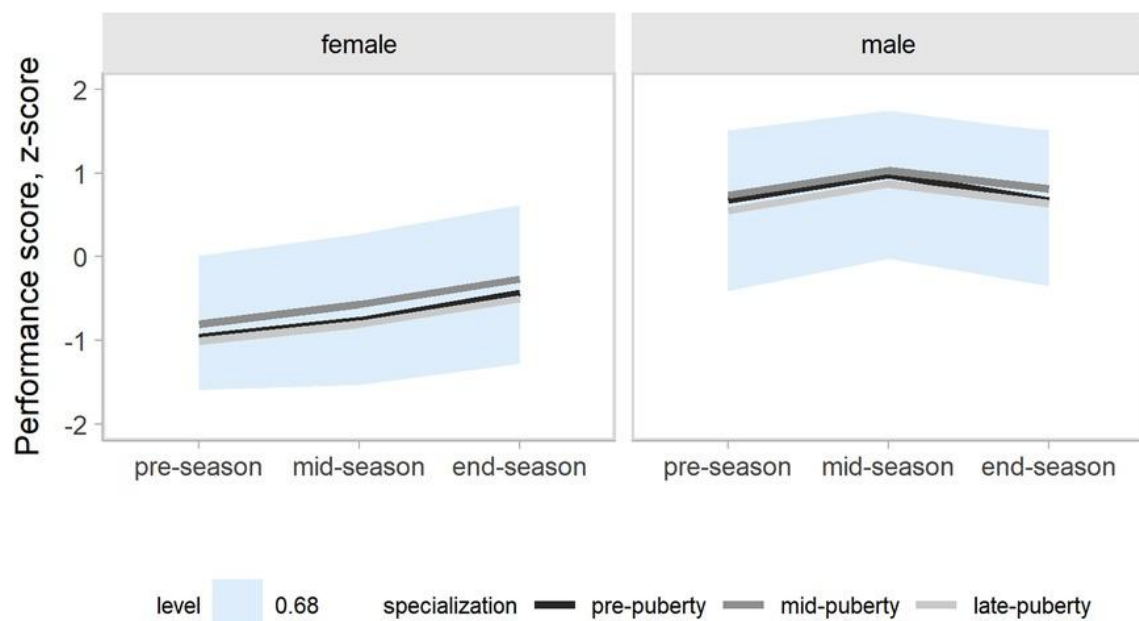


Figure 13. Changes in overall basketball-specific physical fitness index for young females and male basketball players within a basketball season by the onset of specialization. The shaded area represents the 68% credible interval, similar to a standard deviation.

Our three-level growth models accounted for variation in the outcomes changes between 11 and 17 years, accounting for the potential influence of specialization onset. Predictions and uncertainty (68% credible intervals) of countermovement jump (Figure 13), Line drill test (Figure 14), yo-yo IR1 (Figure 15), and overall fitness score (Figure 16) developmental changes are plotted, contrasting the onset of specialization within sex. Notably,

there was no substantial variation by the onset of specialization for both female and male players in the basketball-specific physical fitness developmental changes. However, we observed differences in the magnitude and pattern of developmental changes in physical fitness between female and male players when aligned by chronological age. The plots contrasting developmental changes by sex for countermovement jump (Supplementary Figure 1), Line drill test (Supplementary Figure 2), yo-yo IR1 (Supplementary Figure 3), and overall fitness score (Supplementary Figure 4) are available at <https://osf.io/2gfw5/>.

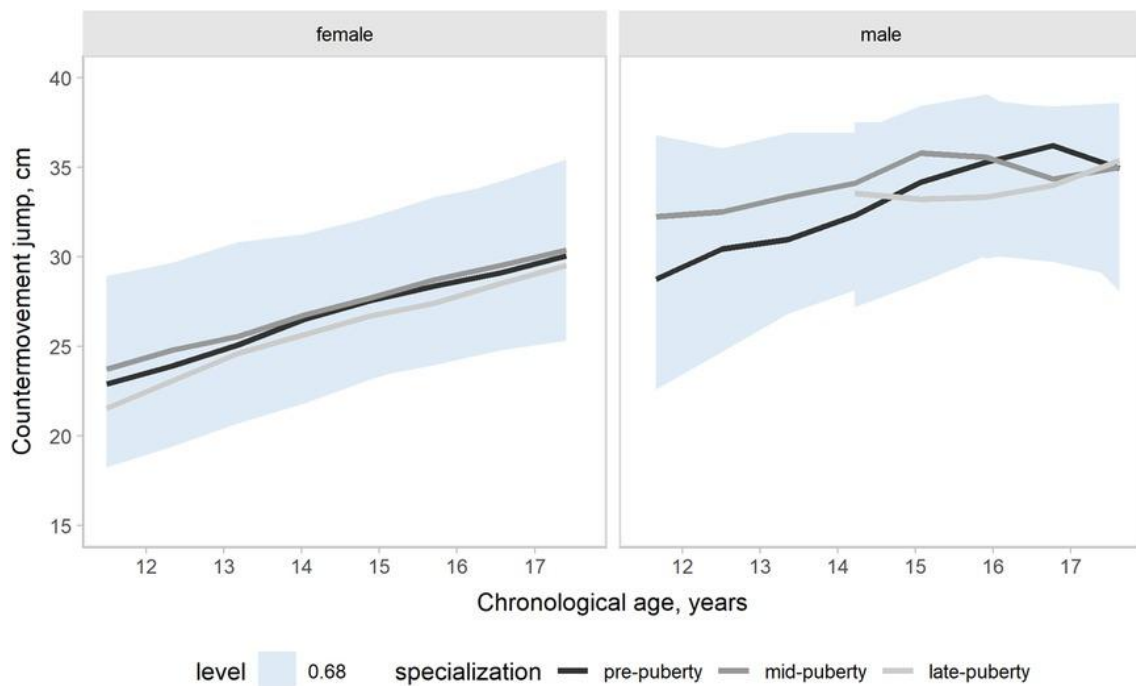


Figure 14. Developmental changes in countermovement jump performance for young females and male basketball players by specialization onset. The shaded area represents the 68% credible interval, similar to a standard deviation.

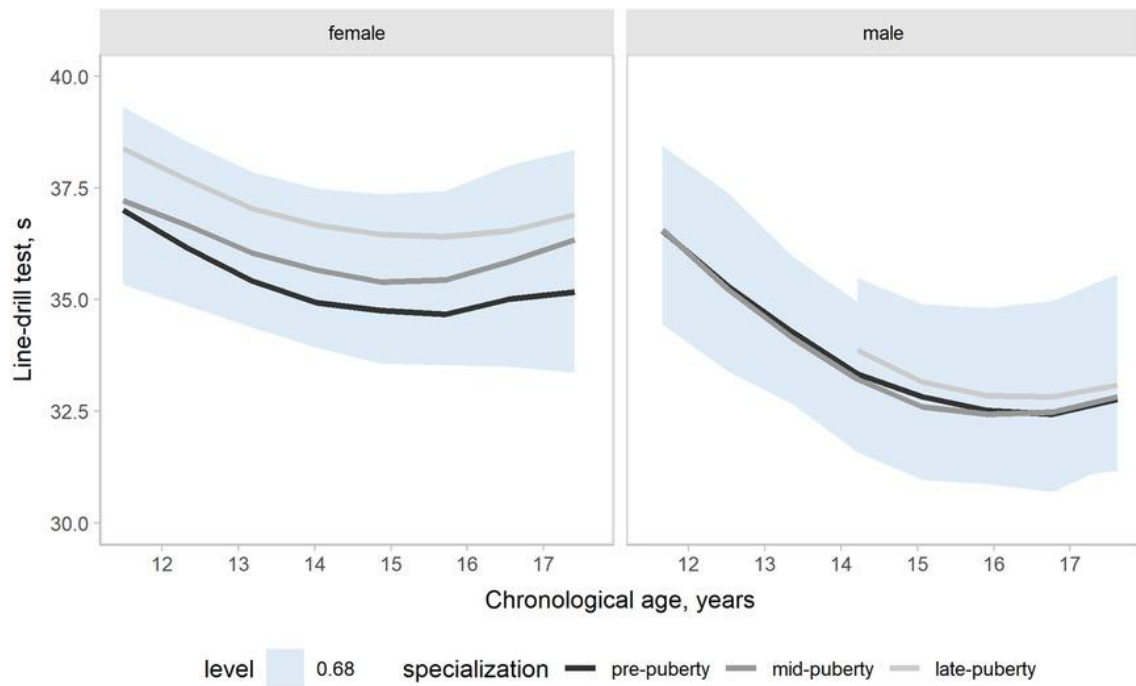


Figure 15. Developmental changes in line-drill performance for young females and male basketball players by specialization onset. The shaded area represents the 68% credible interval, similar to a standard deviation.

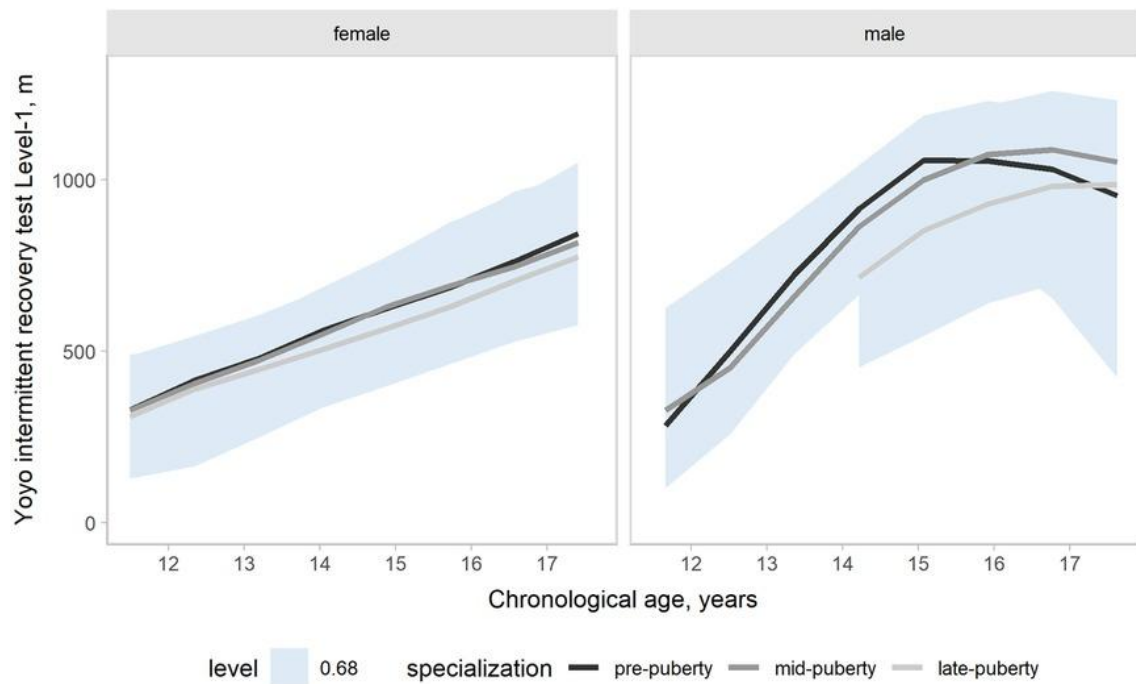


Figure 16. Developmental changes in Yo-yo intermittent recovery test level 1 performance for young females and male basketball players by specialization onset. The shaded area represents the 68% credible interval, similar to a standard deviation.

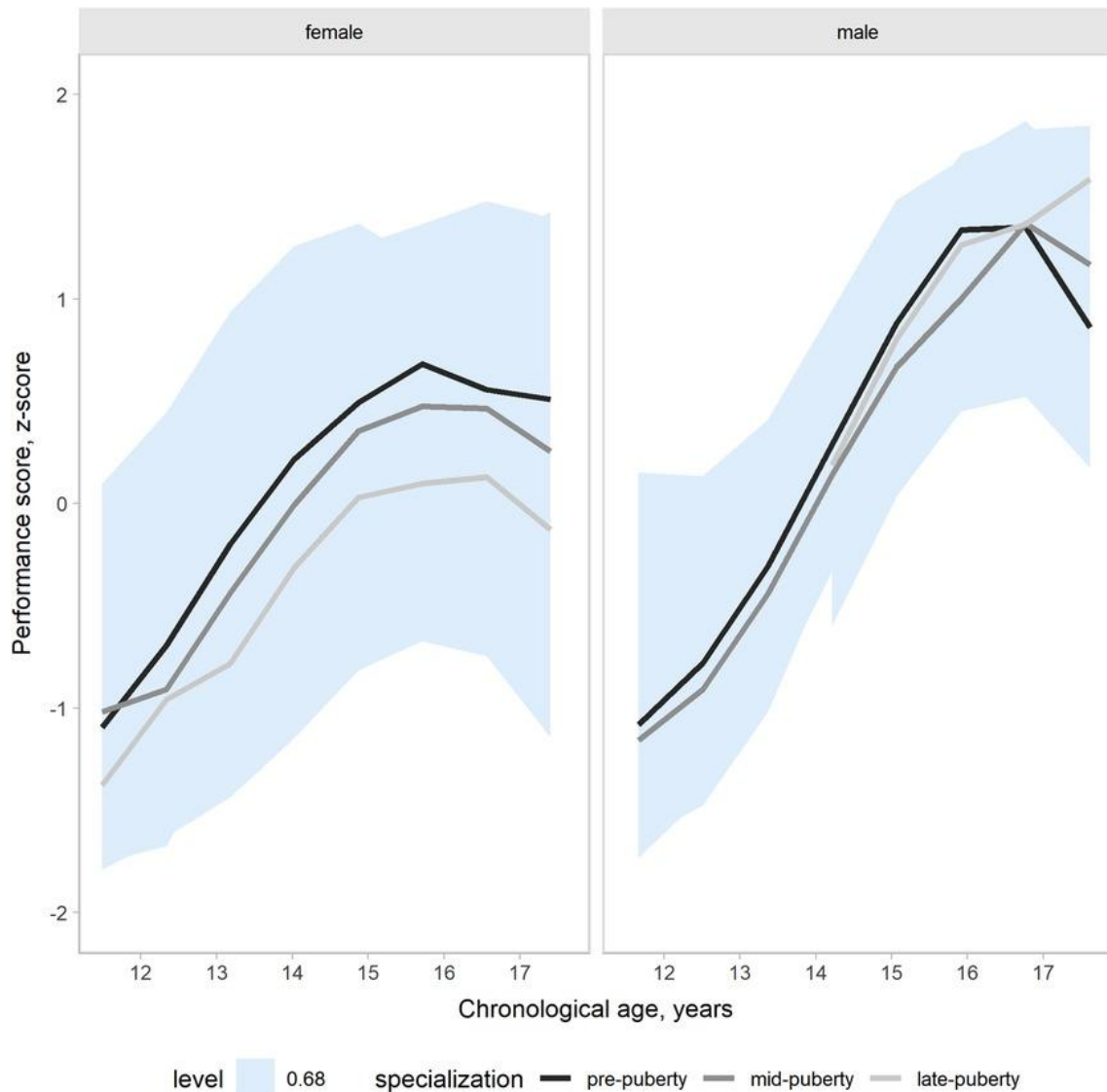


Figure 17. Developmental changes in overall basketball-specific physical fitness performance index for young females and male basketball players by specialization onset. The shaded area represents the 68% credible interval, similar to a standard deviation.

5.4.DISCUSSION

In the present study, we tested the assumption supporting early specialization, stating that there are basketball-specific physical fitness advantages of early specialization in young players (BRYLINSKY, 2010; KALETH and MIKESKY, 2010). The most interesting observation in this study is that players who specialize early in basketball (i.e., pre-puberty specialization) do not appear to have an advantage in basketball-specific physical fitness levels development. Conditional on our data, early specialization in youth basketball does not provide an advantage in developing physical across a season. Improvements in basketball-specific performance across a competitive season were apparent only for female players. In contrast,

male players appear to maintain their physical fitness levels across a competitive season, adjusting for age group and estimated maturity status. Physical fitness developmental advantages were also not observed for players with early specialization. Therefore, young basketball players who specialize before pubertal growth (early) do not appear to have better physical fitness and develop faster than those who specialize during or after the pubertal growth period.

The growth characteristics of the present sample of Brazilian female and male adolescent basketball players were consistent with other reports with heterogeneous samples of young athletes (MALINA, 1994) and young basketball players (CARVALHO et al., 2011; CARVALHO et al., 2018; LEONARDI et al., 2018; RAMOS et al., 2021; TORRES-UNDA et al., 2016). Overall, the somatic indicator suggests that the sample of female and male players across the age span of pubertal growth had an advanced maturity status. Nevertheless, caution is warranted when interpreting and generalizing the maturity status of young athletes based on somatic maturity indicators, as the prediction equations have limited validity (CARVALHO et al., 2018; KOZIEL and MALINA, 2018).

Sport specialization, in particular, early specialization, is a key issue in organized youth sports. Despite the interest and concerns surrounding children's early exposure to intense sports competition, little scientific information supports or refutes these risks (BRENNER, 2016; FABRICANT et al., 2016; HERMAN et al., 2022; MEDICINE AND FITNESS, 2000). It has been argued that there is a lack of evidence that specialization before puberty is necessary to achieve elite status and that specialization before puberty is more likely to be detrimental (JAYANTHI et al., 2013). Nevertheless, these interpretations are mainly based on inconsistent evidence with a potential sample bias (MOSEID et al., 2019). On the other hand, early specialization appears to have become the common *modus operandi* in competitive youth sports (BAKER et al., 2009; BRYLINSKY, 2010; HERMAN et al., 2022). The assumption that early sport specialization provides a physiological advantage for future athletic success (KALETH and MIKESKY, 2010) may result from interpreting the deliberate practice theory (ERICSSON et al., 1993) applied to youth sports. Conditional to our data and models, early specialization in youth basketball (i.e., pre-puberty specialization) does not provide an advantage in developing basketball-specific physical fitness or improved responses within a season.

Another issue that biases the discussion about sports specialization is the inconsistent definition of early specialization (DISANTI and ERICKSON, 2019; MOSHER et al., 2020; MOSHER et al., 2022). In some cases, the operational definition of early specialization is based on the stages of developmental models, establishing the age of 12 as a reference (CÔTÉ and

VIERIMAA, 2014). However, in other reports, it is unclear how early (or late) specialization is operationalized (MOSHER et al., 2022). Therefore, to understand the mechanisms behind early (and late) specialization and why it is potentially harmful or beneficial, first, it must be established what early specialization is and the best methods to assess it (MOSHER et al., 2020).

Youth sports participation and specialization can be conceptualized as a continuum. We propose that specialization can be defined and interpreted relative to biological maturation milestones describing the pubertal growth period, i.e., the age of initiation of the pubertal growth spurt and the age at peak height velocity (PHV). We used a meta-analysis to establish the references conditional on general population growth patterns (LIMA et al., 2020). We defined, in general, specialization as year-round participation in a single “signature” sport, with limited involvement in potential sport alternatives, with a deliberate focus on training and development in the pursuit of elite status (BAKER et al., 2009; DISANTI and ERICKSON, 2019; LIMA et al., 2020).

We believe that the main characteristics of young players' development were captured, allowing for variation between sports specificities and contexts. Hence, players who attain the conditions defined as specialization before about nine years and 11 years for girls and boys, respectively, are considered as experiencing early specialization. On the other hand, late specialization may be interpreted as those players who attain the conditions defined as specialization after the age at PHV, about 12 years for girls and 14 years for boys.

The study of the development of physical fitness levels of basketball players during a basketball-competitive season is limited, and even more in young players (DRINKWATER et al., 2005; MONTGOMERY et al., 2008). The interpretation of the data is limited by the small number of studies, each with small sample sizes and measurement errors associated with the performed tests (CATERISANO et al., 1997; FERIOLI et al., 2020; GONZALEZ et al., 2012; GONZALEZ et al., 2013). As a result, the changes (decreases or improvements across a season by competitive level or starters vs. nonstarters) are trivial or inconclusive. Nevertheless, the observations with young basketball players from the Australian national- and state-level developmental programs showed a trend of improvement in physical fitness assessments across a season (DRINKWATER et al., 2005), particularly in the Line drill test (MONTGOMERY et al., 2008). Also, the physical fitness changes within a season vary by sex and competitive level among young Australian basketball players (DRINKWATER et al., 2005; MONTGOMERY et al., 2008). The young male players in the present sample maintained their physical fitness levels across a competitive season. In contrast, the female players showed a slight improvement in

their fitness within a season. Nevertheless, given the variability in our predictions, a conservative interpretation and generalization should be taken.

Longitudinal data considering physical fitness development in youth basketball is scarce (CARVALHO et al., 2019; GUIMARAES et al., 2021; TE WIERIKE et al., 2014). Conditional on the data, physical fitness outcomes improved, on average, with age 11 to 17 for both female and male players. On average, young male players showed higher values in fitness indicators than young female players. It was apparent that players showed increased rates of fitness development overlapping with the period of pubertal growth. For female players, a leveling-off in fitness development was apparent earlier than for male players, particularly visible in the Line drill test. Sex-related differences in the timing and magnitude of the development of physical fitness outcomes are likely associated with sexual dimorphism during pubertal growth that underlies physiological functions (ARMSTRONG, 2018; MCMANUS and ARMSTRONG, 2011). Sex-related differences in fitness became apparent as girls, on average, attain biological milestones in puberty earlier than boys, albeit the large between-individual variation in the timing and tempo of biological maturation (ARMSTRONG, 2018).

Our study provided valuable data regarding the interpretation of seasonal variations and developmental changes in basketball-specific physical fitness variables in adolescent basketball players. Nevertheless, the available unbalanced sample size, context specificities, and maturity indicator limitations warrant caution when compared with other adolescent basketball players. However, the multilevel modeling in a fully Bayesian framework allows dealing with non-representative and imbalanced samples, with hierarchical sources of variation and cross-classified nesting (GELMAN and HILL, 2007). Bayesian methods comprise samples from the joint posterior density of the parameters (MCELREATH and KOSTER, 2014). It allows for direct probabilistic interpretation of credible (also referred to as compatibility or uncertainty intervals) intervals and posterior probabilities (MENGERSSEN et al., 2016). Bayesian methods should be of interest to those concerned with estimations of very small effects, typical of within-athletes changes in response to training, measured with noisy measurements, as is often the case with physical fitness outcomes.

Based on our data and models, early specialization before the onset of pubertal growth does not provide an advantage in basketball-specific physical fitness development across a season in youth basketball. Hence, the argument/myth that early sport specialization provides a fitness advantage for future athletic success does not hold. Overall, young athletes, coaches, and interested stakeholders should be conservative in their expectations of physical fitness

improvements across a season among young basketball players. Furthermore, we provide an operational framework to interpret specialization related to biological maturation milestones.

5.5.DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: <https://osf.io/2gfw5/>.

5.6.SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fspor.2022.1042494/full#supplementary-material> (Appendix A).

6. ACHIEVEMENT AND COMPETITIVENESS MOTIVATION IN YOUTH SPORT: A BAYESIAN HIERARCHICAL MODELING OF INDIVIDUAL- AND CONTEXTUAL-LEVEL DETERMINANTS⁴

ABSTRACT

The present study examined the influence of individual factors (sex, onset of specialization) and contextual factors (competitive age group, competitive level, sport, and state) on achievement and competitive motivation in young athletes. Specifically, we investigated whether early specialization would affect achievement and competitiveness motivations among young Brazilian athletes, while considering individual characteristics (sex) and contextual factors (competitive age group, competitive level, sport, and state). The study included 510 adolescent athletes aged 14.1 (1.9) years, ranging from 9.4 to 17.9 years. The sample consisted of 212 female athletes and 298 male athletes. Participants represented various sports (volleyball, n=136; basketball, n=233; futsal, n=19; gymnastics, n=49; football, n=73). We used Bayesian hierarchical models to fit the ordinal responses of the questionnaire items and describe the individual- and contextual-level sources of variation. The results indicated that, in general, the young athletes agreed with the statements in the Work and Family Orientation Questionnaire (WOFO) and the Deliberate Practice Motivation Questionnaire (DPMQ). Young male athletes had higher responses than female athletes in both questionnaire items. Overall, we did not find substantial variation in the achievement and competitiveness motivation of young athletes associated with specialization. There was minimal variation in the responses of the WOFO and DPMQ items across different age groups, competitive levels, and states, and at best, only small variation between sports. The present study contributes to our understanding of the reasons and motivations underlying deliberate practice, which can aid in improving the quality of practice exposure and retention of athletes in high-performance sports programs.

Keywords: Young athletes; Specialization; Selection; Multilevel modeling; Item response theory

6.1.INTRODUCTION

⁴ SOARES, A. L. A.; LIMA, A. B.; ALVES, A.C.; QUINAUD, R. T.; LEONARDI, T. J.; GONÇALVES, C.E.; CARVALHO, H.M. Achievement and competitiveness motivation in youth sport: A Bayesian hierarchical modeling of individual- and contextual-level determinants. Chapter submitted to review.

Youth sports programs often focus on performance development to attain sports expertise at adult ages. In particular, it has been generally assumed that accumulated sport-specific training and competition hours (i.e., deliberate practice) is essential to attain sports expertise (DE BRUIN et al., 2008; ERICSSON et al., 1993; GÜLLICH, 2018). Consequently, early engagement and commitment to sport-specific deliberate practice may be compelling for many coaches, parents, and children hoping to attain sports expertise and elite status. Conceptually, the engagement and commitment to sport-specific deliberate has been framed as sport specialization. However, there is a lack of consensus on its precise definition of sport specialization, assuming that year-round participation in a single sport, limited participation in potential sport alternatives, and a deliberate focus on training and development in that single sport in the pursuit of elite status are necessary premises for success (BAKER et al. 2009; DISANTI and ERICKSON, 2019; HILL and SIMONS, 1989; WIERSMA, 2000;).

However, the paths of specialization are highly dependent on contextual and cultural factors. For example, players who engage in youth sports academies at an early age, known as early specialization, appear to have a higher probability of achieving international competitive levels in late adolescence or attaining professional status in sports such as football (FORD et al., 2009), basketball, and ice hockey (FORSMAN et al. 2016). Early sport specialization has become dominant (JAYANTHI et al., 2015; WIERSMA, 2000), especially when youth sports programs prioritize talent development. Consequently, early specialization is often the prevailing approach for talent identification and development in most sports. It is possible that in many organized youth sports programs, the exclusive and selective nature of sports is further emphasized. As a result, young athletes involved in multi-sports developmental programs may have a very limited chance of entering talent development programs during their later pubertal years.

The potential negative consequences of early specialization, which can impact physical, psychological, and social development, have been extensively discussed (BAKER et al., 2009; BELL et al., 2018; BRENNER, 2016; DISANTI and ERICKSON, 2019; FABRICANT et al., 2016; JAYANTHI et al., 2019; MOSEID et al., 2019; MYER et al., 2015; POST et al., 2020; SMITH, et al., 2017). Specifically, early specialization has been associated with adverse psychosocial outcomes that may increase the risk of burnout or dropout from the sport (FRASER-THOMAS et al., 2008; LARSON et al., 2019). However, the available evidence-based data on this issue are inconsistent and limited (DISANTI and ERICKSON, 2019). Considering the ecologies of sport specialization and talent development environments, we need to account for confounding individual (e.g., age, body size, sex or age of specialization)

(SMITH et al., 2017) and contextual characteristics (e.g., sports context, competition level, socio-economic environment, or geographic variables) (DISANTI and ERICKSON, 2019). Considering an ecological perspective (BRONFENBRENNER, 1977; BRONFENBRENNER, 1979), these sources of confounding factors can be framed as person (sex, age, or body size), process (sport-specific deliberate practice), and context characteristics (competitive age-group, competitive level, sport, state).

Based on previous research, which is theoretically underpinned by Achievement Goal Theory (NICHOLLS, 1989), our focus is on achievement and competitiveness motivation. The role of athlete motivation has been emphasized as a crucial factor in identifying young athletes who progress through talent development programs (ELFERINK-GEMSER et al., 2004; ELFERINK-GEMSER et al., 2007, GONÇALVES et al. 2011, SOARES et al., 2020). Achievement motivation, which pertains to the motivation to improve performance, is a multidimensional construct (DE BRUIN et al., 2007; GILL et al., 1988; HELMREICH et al., 1978). To assess achievement dimensions in the context of youth sports, the Work and Family Orientation Questionnaire (HELMREICH et al., 1978) has been developed. It includes dimensions such as work (reflecting the willingness to work hard and perform well), mastery (where athletes are motivated when faced with challenging tasks and maintain high internal standards of excellence), and competitiveness (where athletes are motivated by the desire to win in competition against others) (DE BRUIN et al., 2007; GILL et al., 1988).

Furthermore, motivation is closely related to an athlete's commitment and willingness to engage in deliberate practice. It can be described as the desire to become an exceptional performer (excel) and the drive to improve in competitive environments (compete) (DE BRUIN et al., 2007; GONÇALVES et al., 2011). It is plausible that youth sports programs adopt an orientation toward achieving competitive success and aim to cultivate a strong drive in young athletes to excel and engage in practice at the highest standards of volume and intensity required for expert performance. To examine the relationship between deliberate practice and motivation, the Deliberate Practice Motivation Questionnaire was developed (DE BRUIN et al., 2007). Although originally designed for chess players, it has since been adapted for use in other sports as well (GONÇALVES et al., 2011).

The potential impact of individual and contextual characteristics on psychosocial dimensions among young athletes requires careful consideration in the analytical approach. Traditional single-level analyses, such as analysis of variance, are often inadequate for handling complex data structures, as is common in youth sports research (DIEZ-ROUX, 1998). Youth sport data inherently involve crossed or nested levels (e.g., female and male players nested by

competitive age group teams or clubs), where effects are likely to differ across various sub-groups (JUDD et al., 2017). Therefore, we adopt a Bayesian hierarchical/multilevel modeling approach (GELMAN et al., 2013). Bayesian hierarchical regression models enable the incorporation of individual and contextual characteristics to model constructs of interest within the context of youth sports. They also provide aggregated estimates for the target population, which significantly enhance estimations for small and sparse group data (GELMAN and HILL, 2007; GELMAN et al., 2013).

In the present study, we examined the influence of individual factors (sex, onset of specialization) and contextual factors (competitive age group, competitive level, sport, and state) on achievement and competitive motivation in young athletes. Specifically, we investigated whether early specialization would affect achievement and competitiveness motivations among young Brazilian athletes, while considering individual characteristics (sex) and contextual factors (competitive age group, competitive level, sport, and state).

6.2.METHODS

6.2.1.Sample

The present survey included a total sample of 510 adolescent athletes aged 14.1 (1.9) years, ranging from 9.4 to 17.9 years. The sample consisted of 212 female athletes and 298 male athletes. These participants represented various sports, including volleyball (n=136), basketball (n=233), futsal (n=19), gymnastics (n=49), and football (n=73). All athletes were affiliated with clubs and participated in competitions under the supervision of their respective sport state federation (Paraná, Santa Catarina, and São Paulo). Among the participants, there were 19 athletes classified as international-level, who were selected to represent Brazil in international competitions. Additionally, there were 99 athletes classified as state-level, selected to represent their state in competitions, while the remaining 392 athletes were classified as club-level.

Ethical approval for the study was obtained from the author's institutional ethics committee. The participants were provided with information about the purpose and nature of the survey, and they were informed that participation was voluntary and that they could withdraw from the study at any time. Written informed consent was obtained from the players as well as their parents or legal guardians.

6.2.2.Procedures

Chronological age and competitive age groups. Chronological age was calculated to the nearest 0.1 year by subtracting birth date from the day of testing. Considering variation by sport in competitive age grouping in Brazil, we assumed a two-year range, the most common competitive age groups in Brazilian youth sports and international South American youth competitions. It should be noted that competitive seasons in Brazil typically run between February/March and November/December). Hence, athletes were considered as under 11 (age up to 11.9 years), under 13 (age between 12.0 to 13.9 years), under 15 (age between 14.0 to 15.9 years), and under 17 (age between 16.0 to 17.9 years).

Sport-specific onset of specialization. The sport-specific onset of specialization was determined based on biological maturation milestones (LIMA et al., 2020; MENDES et al., 2021). The age of sport-specific onset of specialization refers to the self-reported age at which athletes began formal training and competition in their respective sports (MENDES et al., 2018). Biological maturation milestones considered were the age of initiation of the pubertal growth spurt and the age at peak height velocity. Detailed information on estimating sex-specific biological maturation milestones can be found in previous studies (LIMA et al., 2020; MENDES et al., 2021).

The reference age of initiation of the pubertal growth spurt was determined as 9.4 years (95% CI 9.0 to 9.8) for females and 11.1 years (95% CI 10.8 to 11.5) for males. The reference age at peak height velocity was found to be 11.9 years (95% CI 11.8 to 12.0) for females and 13.9 years (95% CI 13.8 to 14.0) for males. Athletes whose onset of specialization occurred before the sex-specific reference age of initiation of the pubertal growth spurt were categorized as pre-puberty specialization or early specialization (n = 220). Athletes whose onset of specialization fell between the sex-specific reference age of initiation of the pubertal growth spurt and the age at peak height velocity were classified as mid-puberty specialization (n = 170). Athletes whose onset of specialization occurred after the sex-specific reference age at peak height velocity were classified as late-puberty specialization or late specialization (n = 76). In cases where it was not possible to determine the onset of specialization, players were classified as unknown (n = 18).

Achievement and competitiveness motivation. Participants were instructed to complete two questionnaires, the Work and Family Orientation Questionnaire (WOFO) (HELMREICH et al., 1978) and the Deliberate Practice Motivation Questionnaire (DPMQ) (DE BRUIN et al., 2008), before practice sessions.

The Work and Family Orientation Questionnaire (WOFO) consists of 19 items that assess four dimensions of achievement: personal unconcern, work, mastery, and competitiveness. Participants rated these items on a 5-point Likert-type scale, ranging from 1 (completely disagree) to 5 (completely agree). In line with previous studies involving youth sport samples (CARVALHO et al., 2018; GONÇALVES et al., 2011; MENDES et al., 2021; SOARES et al., 2020), we only utilized the last three subscales.

The Deliberate Practice Motivation Questionnaire (DPMQ), originally designed for chess (DE BRUIN et al., 2007; DE BRUIN et al., 2008), consists of 18 items that assess two dimensions of deliberate practice: will to compete and will to excel. Participants rated these items on a 5-point Likert-type scale. The Portuguese version of the questionnaire has been previously translated and validated (GONÇALVES et al., 2011), and its reliability has been reported in previous studies involving youth sport (GONÇALVES et al., 2011).

6.2.3.Data analysis

We used Bayesian hierarchical models to analyze the responses of the athletes for each item in questionnaires. Each questionnaire was treated as a separate model. The S_n athletes in our study were indexed as $i = 1, \dots, n$, and y_i represented the response to each item j . Our base model accounted for cross-classified nesting within athletes i and questionnaire items j .

We assumed that the outcome of interest, y_i , followed an ordinal scale with five categories ($k \in 1, 2, 3, 4, 5$). To model the relative probabilities of each ordinal category, we introduced a set of thresholds τ_k ($k \in 1, 2, 3, 4$). These thresholds determined the boundaries between the categories. We employed a standard cumulative distribution function Φ to map the cumulative probabilities onto an unbounded parameter space, divided by the thresholds τ_k . The parameters for Φ were fixed with a mean $\mu = 0$ and a standard deviation $\sigma = 1$ for identification purposes.

$$\rho(y_i = k | \mu_{ij}, \tau_k, \tau_{k-1}) \sim \Phi(\tau_k - \mu_{ij}) - \Phi(\tau_{k-1} - \mu_{ij})$$

$$\mu_{ij} = v_i + v_j$$

$$v_i \sim \text{Normal}(0, \sigma_i)$$

$$v_j \sim \text{Normal}(0, \sigma_j)$$

$$\tau_k \sim \text{student} - t(3, 0, 2.5)$$

$$\sigma_i, \sigma_j \sim \text{Exponential}(1)$$

We extended our model to incorporate the estimation of each athlete's i response in item j based on their individual characteristics, such as competitive age group, sex, competitive level, specialization, sport, and geographic (state) characteristics. We partially pooled the outcome variable for each player (i), denoted by the indexes a, e, l, p, s , and r for competitive age group, sex, competitive level, sport, specialization, and state, respectively.

Sex was treated as a population-level effect, also known as a fixed effect, considering the challenge of estimating between-group variation when the number of groups is small (GELMAN and HILL, 2007). By employing a Bayesian hierarchical model, we were able to incorporate both individual-level factors (sex, specialization) and contextual factors (competitive age group, competitive level, sport, and state) to enhance our understanding of young athletes' achievement and competitive motivation. Therefore, the relationship between these discrete factors and the outcome variable (y) was captured by a series of varying intercepts:

$$\begin{aligned}\mu_{ij} &= v_i + v_j + \beta_e^{sex} + \alpha_a^{age} + \alpha_l^{level} + \alpha_p^{sport} + \alpha_s^{specialization} + \alpha_r^{state} \\ \beta_e^{sex} &\sim Normal(0,1) \\ \alpha_a^{age} &\sim Normal(0, \sigma_{age}), \text{ for } a = 1, 2, 3, 4 \\ \alpha_l^{level} &\sim Normal(0, \sigma_{level}), \text{ for } l = 1, 2, 3 \\ \alpha_p^{sport} &\sim Normal(0, \sigma_{sport}), \text{ for } p = 1, 2, 3, 4, 5 \\ \alpha_s^{specialization} &\sim Normal(0, \sigma_{specialization}), \text{ for } s = 1, 2, 3 \\ \alpha_r^{state} &\sim Normal(0, \sigma_{state}), \text{ for } r = 1, 2, 3 \\ \sigma_{age}, \sigma_{gender}, \sigma_{sport}, \sigma_{level}, \sigma_{specialization}, \sigma_{state} &\sim Exponential(1)\end{aligned}$$

For the priors of τ_k we regularized the estimates using a student-t (3, 0, 2.5) prior. As for the varying intercept parameters, we utilized an Exponential (1) prior.

To assess the performance of our models, we conducted posterior predictive checks (GABRY et al., 2019; VEHTARI et al., 2017). We ran three chains for 1,000 iterations, with a warm-up length of 500 iterations. Considering the computation time, the number and length of chains and warm-up iterations were sufficient to achieve convergence and obtain a reasonable effective sample size.

The Bayesian estimations were implemented using the R statistical language (TEAM, 2018) with the “brms” package (BÜRKNER, 2017), which interfaces with Stan (TEAM, 2020).

The data and model predictions were visualized using the “tidybayes” (KAY, 2023) and ggplot2” packages (WICKHAM, 2016).

6.3.RESULTS

Our hierarchical ordinal models estimated the probability of young athletes’ responses for each item, taking into account their sex, competitive age group, sport, competitive level, and state. We can compute weighted averages of these probabilities to represent the probability of item responses in any specified subset of the sample. Figures 17 and 18 display the estimated response probabilities for the items of the WOFO and DPMQ, respectively.

In the WOFO items, young athletes predominantly agreed (responses 4 and 5 on the Likert-type scale) with the statements. However, for items 7 (“I would rather do something I would feel confident and relaxed than something which is challenging and difficult”), 8 (“When the group I belong to plans an activity, I would rather take charge myself than just assist and have someone else organize it”), and 18 (“It annoys me when other people perform better than I do”), the responses were mainly neutral (response 3 on the Likert-type scale). A consistent pattern of never agreeing to neutral responses (responses 1, 2, and 3 on the Likert-type scale) was observed for item 9 (“I would rather learn easy, fun games than difficult, thought-provoking games”).

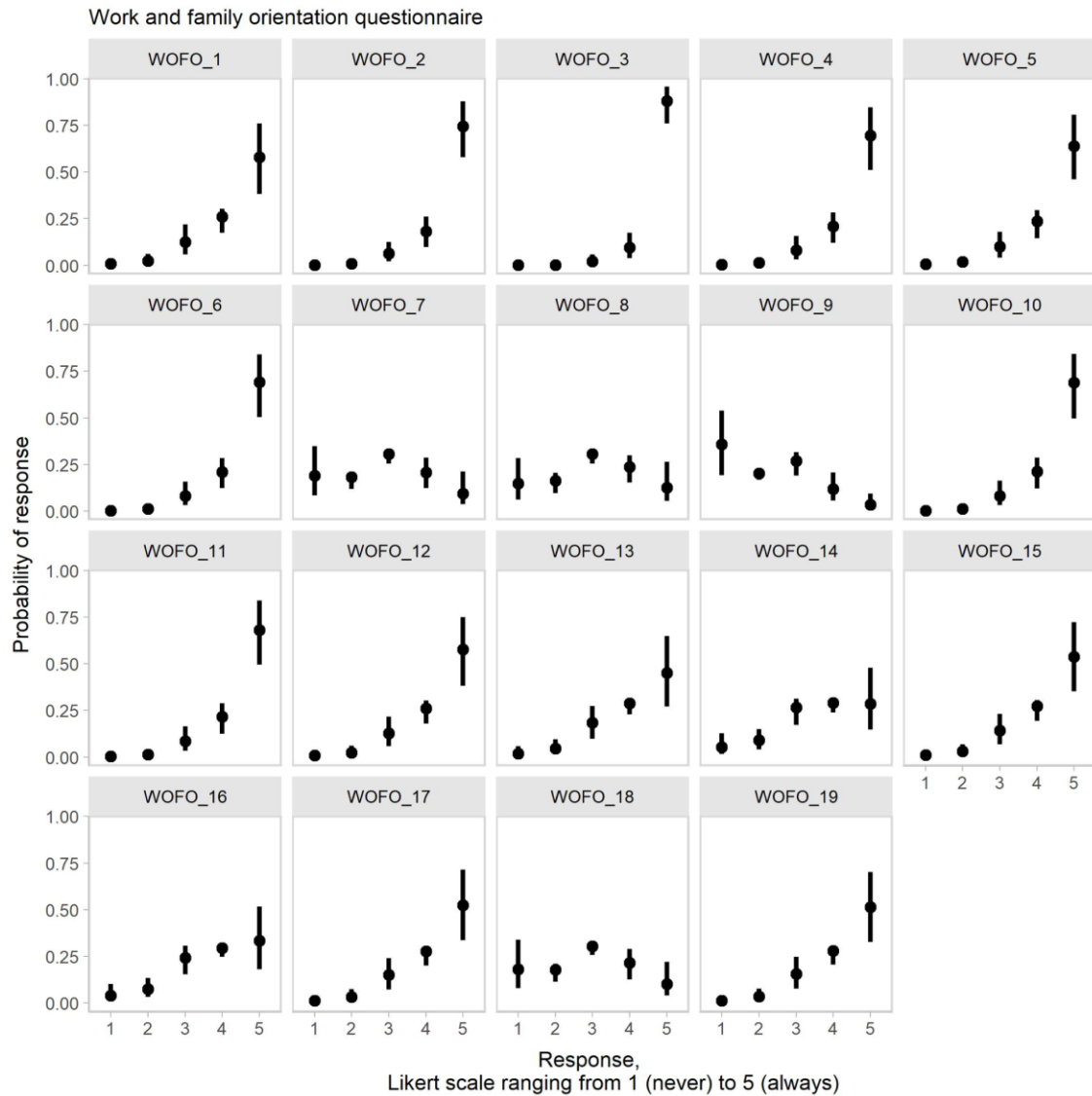


Figure 18. Posterior predictions of the probability of responses for the Work and family orientation questionnaire items in young Brazilian athletes. Uncertainty estimates represent the 68% credible intervals.

The athletes also exhibited a pattern of high agreement in the items of the DPMQ. Regarding items 17 (“When I enter a competition, gaining experience is more important to me than winning”) and 21 (“If I lose against a strong player or team who taught me when analyzing the performance afterwards, I don’t mind having lost”), the responses were evenly distributed from neutral to agreement (responses 3, 4, and 5 on the Likert-type scale). However, for items 15 (“I prefer playing the sport against friends rather than practicing at a high-performance level”) and 19 (“To me, winning is the most important thing in the sport”), the majority of responses indicated disagreement (response 1 on the Likert-type scale) or were neutral (response 3 on the Likert-type scale).

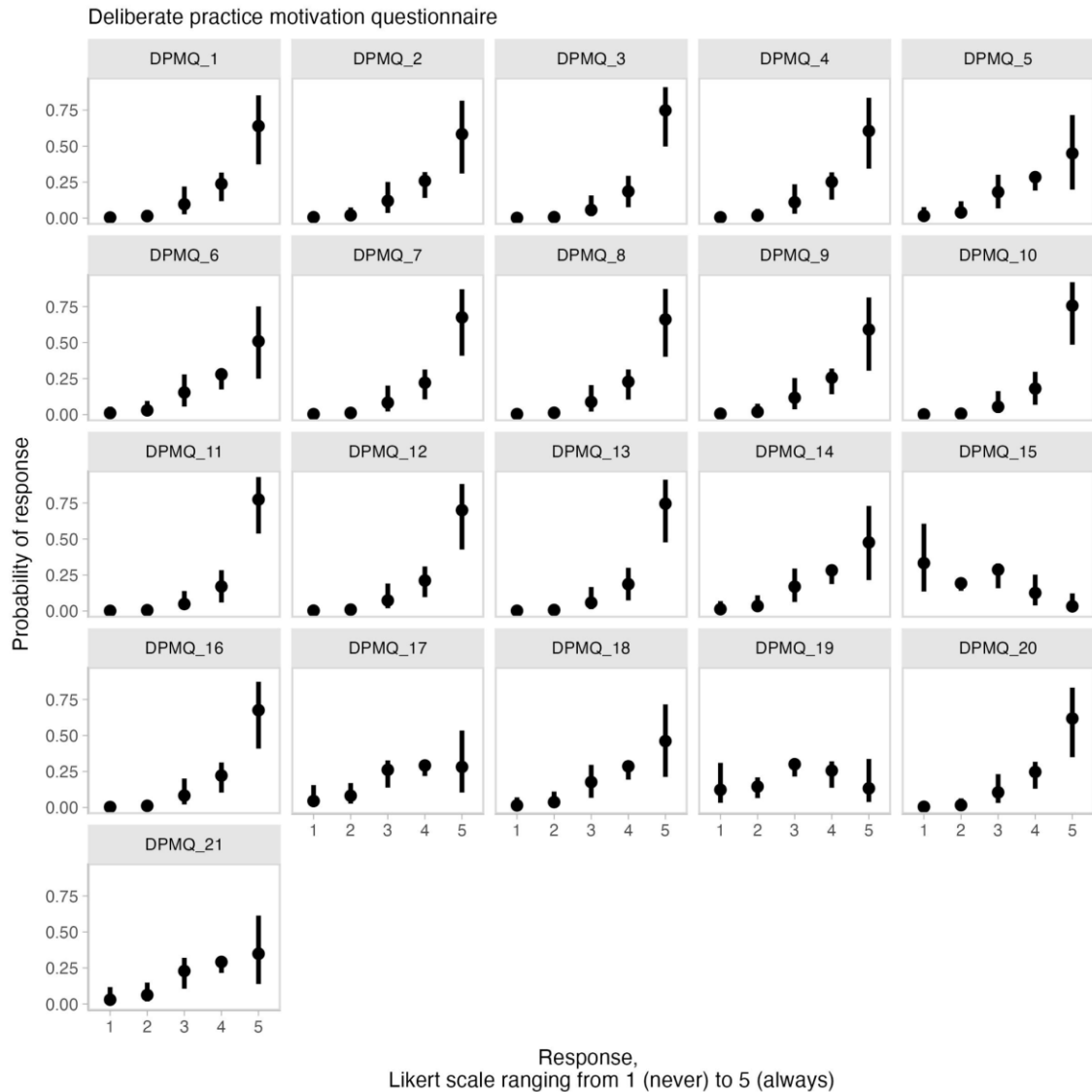


Figure 19. Posterior predictions of the probability of responses for Deliberate practice motivation questionnaire items in young Brazilian athletes. Uncertainty estimates represent the 68% credible intervals.

6.3.1. Individual-level determinants

Athletes' responses varied substantially based on sex for both the WOFO (Figure 19) and DPMQ items (Figure 20). Young male athletes had higher responses than female athletes in both questionnaire items. However, there were no differences in the responses to the questionnaires items between players with contrasting specialization onset (Figure 21 and Figure 22 for WOFO and DPMQ, respectively).

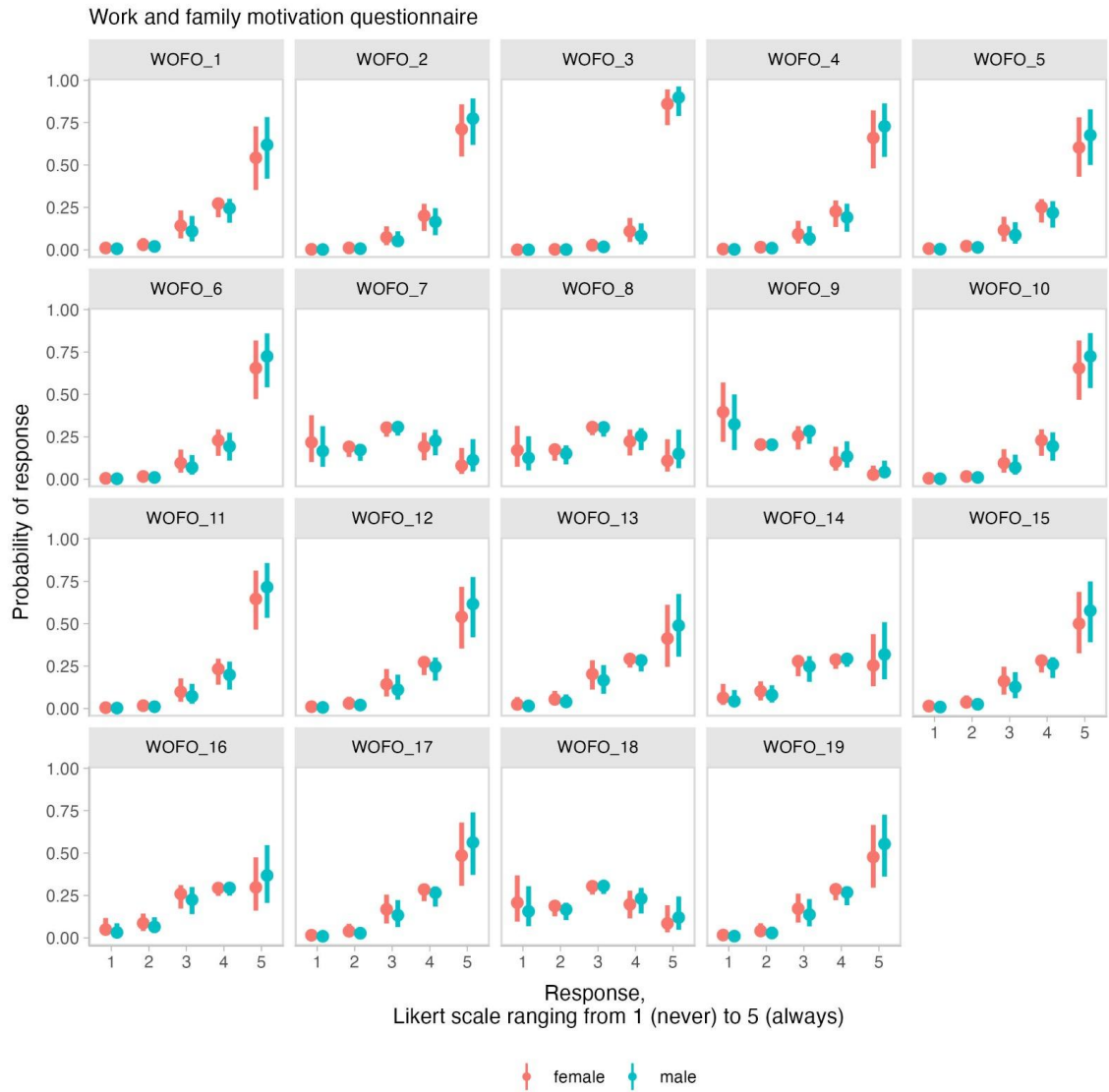


Figure 20. Posterior predictions of the probability of responses for Work and family orientation questionnaire items in young Brazilian athletes grouped by sex. Uncertainty estimates represent the 68% credible intervals.

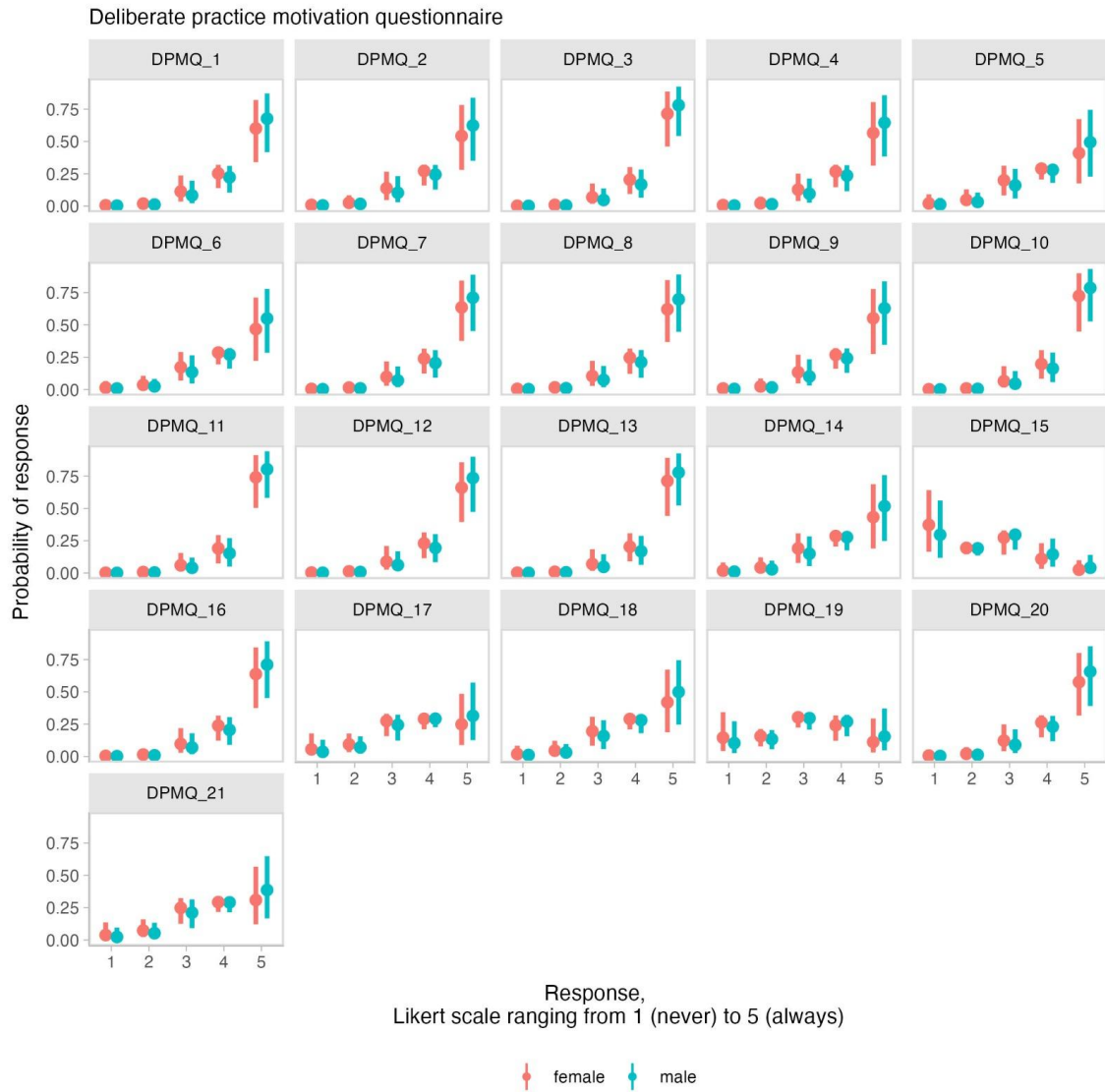


Figure 21. Posterior predictions of the probability of responses for Deliberate practice motivation questionnaire items in young Brazilian athletes grouped by sex. Uncertainty estimates represent the 68% credible intervals.

6.3.2.Contextual-level determinants

There was minimal variation in the responses of the WOFO and DPMQ items across different age groups, competitive levels, and states. At most, small variations were observed among sports in the responses to the WOFO and DPMQ items. Supplementary material (see APPENDIX B) includes estimated responses plotted by age group, competitive level, sport, and state.

6.4.DISCUSSION

Our study aimed to investigate the associations between individual characteristics (sex, onset of specialization) and contextual factors (competitive age group, competitive level, sport, and state) with achievement and competitive motivation in young athletes. Specifically, we were interested in examining whether early specialization would have an impact on achievement and competitiveness motivation among young athletes, while considering individual (sex) and contextual characteristics (competitive age group, competitive level, sport, and state) as potential factors. Overall, we did not find substantial variation in the achievement and competitiveness motivation of young athletes associated with specialization. Furthermore, our analytical approach allowed us to map the trends of responses for each item across the achievement and competitiveness motivation questionnaires, providing valuable insights into the athletes' perspectives.

The young athletes consistently provided higher responses in the ordinal categories (responses 4 and 5) of the Likert-type scales for the achievement and competitiveness motivation items. Since achievement and competitiveness motivation are multidimensional constructs (GILL et al., 1988; HELMREICH et al., 1978), a more detailed analysis can consider the dimensions of mastery (preference for challenging tasks), work (positive attitudes toward hard work and practice), and competitiveness (desire to win in interpersonal situations) as key aspects.

Athletes generally agreed with items related to mastery, such as “I find satisfaction in practicing and playing as well as I can” (WOFO item 2) or “Part of my enjoyment in doing things is improving my past performance” (WOFO item 6). In contrast, examples of lower or neutral responses indicated a trend of disagreement with statements such as “I would rather do something I would feel confident and relaxed than something which is challenging and difficult” (WOFO item 7) or “I would rather learn easy, fun games than difficult, thought-provoking games” (WOFO item 9).

From an achievement goal theory perspective (AMES, 1995), our observations suggest that the young athletes in the sample are primarily motivated by intrinsic factors rather than extrinsic factors. They appear to be driven by the need to improve themselves through personal effort. In youth sports environments, where competition with peers and performance-related feedback are prevalent and influential in coaches' selection decisions, it is noteworthy that the trend of disagreement or neutral responses persisted in items such as “It annoys me when other people perform better than I do” (WOFO item 18) and “To me, winning is the most important thing in the sport” (DPMQ item 19). This consistency implies that ego-involved climates, which prioritize comparison to others, do not seem to have a significant impact on these young

athletes. These observations were consistent across the sample, even when considering the potential effect of the young athletes' competitive level. It could be expected that in high-performing contexts, ego-involved factors might contribute to the perpetuation of high levels of achievement orientation based on comparisons with others (DE BRUIN et al., 2007).

Furthermore, motivation for deliberate practice, as measured by the will to excel and will to compete dimensions, was not found to be sensitive to players' competitive level. These findings regarding motivation for deliberate practice do not align with previous observations made with under 16 male basketball players (GONÇALVES et al. 2011), where motivation to excel emerged as the primary predictor for classifying players based on their competitive level. However, it is worth noting that higher levels of motivation for achievement, competitiveness, and deliberate practice have been recognized as crucial factors in maintaining youth engagement in sports programs and training sessions (SOARES et al., 2020).

A key finding from our observations points to the lack of influence of the onset of specialization on young athletes' motivation for achievement, motivation, and deliberate practice. It has been noted that burnout and dropout are often associated with low motivation, particularly in cases of early specialization (FRASER-THOMAS et al., 2008; LARSON et al., 2019). However, our data support the argument that the available evidence is inconsistent and limited in supporting strong causal inferences (DISANTI and ERICKSON, 2019). We have examined a broad range of youth sports training and competitive environments. While it may be reasonable to assume that high-performing environments in youth sports have the potential for negative impacts, data specific to these contexts are not yet available. To the best of our knowledge, our data represent the initial insights into achievement and competitive motivation, and deliberate practice motivation, which need to be replicated in other youth sports cultures to provide consistent interpretations regarding youth sport specialization, as a process with potential negative or positive effects on the athletes' development.

The assumption of negative effects on the psychosocial development of children and adolescents due to early specialization was not confirmed in our observations. The young female and male athletes in our sample appear to be capable of coping with the challenges they face in sports and forming their own interpretations of the practice climate, as well as the pressure from peers, coaches, and significant others. The notion of a "rocky road" to sport success (COLLINS and MACNAMARA, 2012; TAYLOR and COLLINS, 2019) does not appear to impact the motivation of the young athletes.

Overall, the present results require a closer examination in order to refine the analysis and develop a more nuanced interpretation. The practice environments play a crucial role in

promoting positive development, enhancing young athletes' perceived self-competence, autonomy, and desire for self-improvement (MACDONALD et al., 2011; SCANLAN et al., 1989; WIERSMA, 2001). Our observations revealed small variation associated with the sport context, highlighting the potential influence of sport-specific cultures on young athletes' achievement and competitiveness motivation. For instance, gymnasts tended to exhibit higher neutral responses compared to their counterparts in other sports. It is also worth considering that the varied structures of sport-specific careers, pedagogical training approaches, and competition within different sports may influence athletes' perceptions. Therefore, the results may be attributed to contextual changes in the training and competition processes, such as variations in coaching styles, parental involvement, or different opportunities and demands of competing activities in sports, such as social outings with friends or academic responsibilities during the athletes' adolescence (SANTOS and GONÇALVES, 2016). Furthermore, these results may be linked to the fact that the study was conducted within high-performance-oriented environments. It is important to emphasize that the present findings are closely tied to the specific context of sports settings that emphasize the acquisition of sport expertise.

Recent calls noting potential pitfalls in modeling decisions, misinterpretation of statistics and generalization have been raised in several scientific areas (AMRHEIN et al., 2019; SMALDINO and MCELREATH, 2016), particularly in psychology (COLLABORATION, 2015). Initial discussions have recently raised the potential to similar concerns in Sports Sciences and applied Sports Psychology research (MESQUIDA et al., 2022). In the present study, we deal with a complex data structure, which conservatory reflects youth sports contexts. Different sources of variation are present both associated to with the individuals and sports contexts, often hierarchical and/or nested. Hierarchical (multilevel) models offer a flexible and robust approach compared to classical models (completely pooled and unpooled regression) for data reduction (estimating associations) and predictions that can cope with unbalanced sample sizes and heterogeneity among clusters in the data (GELMAN and HILL, 2007; GELMAN et al., 2012). By conviction or convenience, Bayesian methods have attracted a great interest recently. Bayesian methods have tremendous flexibility to model the data yielding rich information about parameters that can be used cumulatively across progressive observations or experiments (KRUSCHKE, 2010). Particularly with complex data structures and non-normal distributions of the outcomes, Bayesian methods solves the problems of traditional methods (KRUSCHKE, 2010; MCELREATH, 2020). On the other hand, modeling ordinal outcomes with normal distribution approximations may produce serious inferential errors (LIDDELL and KRUSCHKE, 2018). Adhering to reporting guidelines (GABRY et al., 2019; KRUSCHKE,

2021) at least partially, we used and present an explanation of our Bayesian hierarchical model (likelihood function and prior probability distribution for the parameters) and describe the posterior distribution checking if the model mimicked the data meaningfully, report the details of the computation and further provide our data and code to allow a transparent and reproducible analysis.

In summary, the findings of this study indicate that young athletes across various sports, while accounting for sex, onset of specialization, competitive age group, competitive level, and state, exhibit high levels of achievement and competitiveness motivation. They also display strong motivation to engage in deliberate practice in their respective sports. However, it is important to acknowledge the limitations of the present study. It employs a cross-sectional approach, providing a snapshot of the variation in motivation for achievement, competitiveness, and deliberate practice among young athletes, which may change over the course of a season. Therefore, future studies should consider adopting a longitudinal approach to examine the dynamics of motivation for achievement, competitiveness, and deliberate practice within specific sport contexts (e.g., selection processes, injuries, sociodemographic factors) throughout a season. Nonetheless, this study contributes to our understanding of the reasons and motivations underlying deliberate practice, which can aid in the retention of athletes in high-performance sports programs. Furthermore, increased motivation to participate in sports can contribute to the development of sport expertise, which has been identified as an important predictor of personal growth among young athletes.

7. AN ECOLOGICAL APPROACH TO SOURCES OF ENJOYMENT IN YOUNG FEMALE ATHLETES ⁵

ABSTRACT

The present study used a bioecological approach to investigate the factors influencing enjoyment sources among young female athletes. It focused on personal characteristics (maturity status), process (accumulated deliberate practice), and contextual factors (age group, competition level, sport type, and state), as well as the dynamic interactions of time with personal characteristics and process. The study included 243 young female athletes, with repeated measures collected from a sub-sample of 84 athletes across competitive seasons. We modeled the responses to the Sources of Enjoyment in Youth Sports Questionnaire (SEYSQ) using Bayesian hierarchical modeling. The results indicated that, in general, the young female athletes agreed with the statements in the SEYSQ. When considering cross-sectional data, there was no variation in the responses to SEYSQ factors associated with process, person, and context. When aligning chronological age, menarche age, and accumulated sport-specific deliberate practice, the sport context emerged as an important in shaping changes in sources of enjoyment across the development of young Brazilian female athletes between 12 and 18 years. The study highlights the importance of incorporating time in ecological approaches to youth sport research through a repeated-measures design to operationalize the bioecological approach properly. The findings do not support the argument that early specialization may lead to low enjoyment and a compromise in commitment and sustained participation in youth sport programs.

Keywords: Youth sport; Talent development; Adolescence; Bioecological theory; Bayesian multilevel modeling.

7.1.INTRODUCTION

Organized youth sport programs tend to prioritize performance development, aiming to enhance athletes' competence in their path into adulthood and athletic maturity (CARVALHO et al., 2023; KALÉN et al., 2021). From a developmental perspective, there is a

⁵ SOARES, A. L. A.; LIMA, A. B.; POSSAMAI, K.; QUINAUD, R. T.; LEONARDI, T. J.; GONÇALVES, C.E.; CARVALHO, H.M. An ecological approach to sources of enjoyment in young female athletes. **Brazilian Journal of Sport Psychology and Human Development**, v.1, n.1, 2025. Accessed: August 28th, 2025.

consensus among stakeholders that sport expertise is positively correlated with extensive exposure to sport-specific deliberate practice (DE BRUIN et al., 2008; ERICSSON et al., 1993; GÜLLICH, 2018). Often, early specialization at pre-adolescent ages may be attractive to many national governing bodies, clubs, coaches, parents, and children who aspire to attain sport expertise and reach an elite level.

Recent studies have raised concerns about the potential negative impacts of early specialization on physical, psychological, and social development (BAKER et al., 2009; BELL et al., 2018; BRENNER, 2016; DISANTI and ERICKSON, 2019; FABRICANT et al., 2016; JAYANTHI et al., 2019; MOSEID et al., 2019; MYER et al., 2015; POST et al., 2020; SMITH et al., 2017). Early specialization has been associated with negative psychosocial outcomes, which may result in a decrease in enjoyment, burnout, or even dropping out of sport (BOYD and YIN, 1996; FRASER-THOMAS et al., 2008; LARSON et al., 2019). However, the available data on the link between psychological characteristics and individual, contextual, and social aspects of sport specialization is inconsistent and limited (DISANTI and ERICKSON, 2019). In this study, we examine three key issues when interpreting these links.

First, the complexity of factors and interactions involved in youth sport settings requires a stronger theoretical foundation (DISANTI and ERICKSON, 2021; MOULDS et al., 2022). To this end, the bioecological framework (BRONFENBRENNER and CECI, 1994; BRONFENBRENNER and MORRIS, 2007) is particularly appealing as it considers how an individual interacts with their environment in shaping the dynamics of development. It is important to note that this theory emphasizes the consideration of biological aspects in the modeling process. The bioecological theory focuses on four aspects of development: *person*, *process*, *context*, and *time* (also referred to as the PPCT model).

In the domain of youth sport research, it is possible to consider that *person* refers to the individual and their characteristics, such as sex, age, biological maturation, social relations and psychological characteristics such as motivation and enjoyment.

Process refers to the dynamic interaction between an individual and the environment through which development occurs (BRONFENBRENNER and CECI, 1994; BRONFENBRENNER and MORRIS, 2007). In young athletes' environment, this can be observed through their interactions with peers, coaches, and team members during training and competition over time. Given the complexity of assessing and measuring such interactions, deliberate practice can serve as a heuristic mediator and a proxy for *process* in young athletes.

In the PPCT model, *context* is described by four types or levels of systems that are considered influential to an individual's development: (i) *microsystem*, which represents the

immediate environment surrounding the individual, that can be represented by the age-group team, specifically the teammates and coach; (ii) *mesosystem*, which describes interactions between two or more microsystems, that may be represented by the interaction of age-group teams from different competitive levels; (iii) *exosystem*, which encompasses contexts in which individuals are not directly involved, but they are still influenced; (iv) *macrosystem*, which considers broad social influences, such as state sport governing bodies like sport federations.

The concept of *time* was a late addition to the bioecological framework (BRONFENBRENNER and MORRIS, 2007), referring to the varying temporal stages of development, including the progression of time over which development occurs, such as the chronological age of an individual. Individuals, institutions, and social relations are not static and follow a non-linear path of development. From this point of view, it is important to consider biological time, as there are considerable differences in the timing and timing of pubertal development among individuals, which can have an impact on physical function, performance and behavior.

Secondly, enjoyment is considered a key psychological outcome in youth sport (SCANLAN and LEWTHWAITE, 1986). This is because it is widely recognized as a primary reason for starting and continuing involvement in sport (MACDONALD et al., 2011; MCCARTHY et al., 2008; SCANLAN et al., 1989; WIERSMA, 2001). Enjoyment is a significant construct in several sport motivation theories, such as achievement goal theory (NICHOLLS, 1989), competence motivation theory (HARTER, 1978), and the sport commitment model (SCANLAN et al., 1993) that encompass the various facets of youth sport participation, including the evaluation of performance and success.

In youth sport research, enjoyment is commonly defined as a positive affective response to the sport experience, reflecting feelings of pleasure, liking, and fun (SCANLAN et al., 1993). The sport commitment model, which has consistent empirical support (SCANLAN et al., 1993; SCANLAN and LEWTHWAITE, 1986), suggests that sport enjoyment can arise from both intrinsic sources, such as perceptions of competence and control, and extrinsic aspects of competition, such as social recognition.

Enjoyment can result from both achievement, such as goal attainment, and non-achievement, such as social influences from parents or peers (SCANLAN and LEWTHWAITE, 1986). It is important to note that enjoyment is a complex concept that can be perceived differently by athletes, who experience the environment, and coaches, who play a role in shaping it. While there is substantial theoretical consensus on enjoyment, other conceptualizations should also be considered (KIMIECIK and HARRIS 1996).

Third, when studying the influence of person, process, and context characteristics on young athletes' enjoyment within an ecological framework, it is important to carefully consider the analytical approach. The theoretical approach and observed data present crossed or nested levels, where effects may vary between subgroups (JUDD et al., 2017). Therefore, traditional single-level analyses, such as analysis of variance, are often inappropriate (DIEZ-ROUX, 1998). To address this issue, hierarchical/multilevel modeling approach allows for appropriate analysis of nested or crossed data (GELMAN et al., 2012; GELMAN and HILL, 2007) .

Bayesian hierarchical regression models enable the modeling of constructs of interest as a function of individual, process, or contextual covariates in the context of youth sport. This provides aggregated estimates of a target population and significantly improves estimations of small and sparse group data, and capture dynamic changes overtime (GELMAN et al., 2013; GELMAN and HILL, 2007).

Given the previous observations, the objectives of the present study were to: (i) examine the influence of person (maturity status), process (deliberate practice accumulated), and contextual factors (including age group, competition level, sport type, and state) on the variation of enjoyment sources among young female athletes; (ii) examine the effect of the dynamic interactions of time with person characteristics (chronological age and biological age), process (years of deliberate practice accumulated in a specific sport), and context on the sources of enjoyment in sport for young female athletes. Specifically, we tested the validity of the assumption that early specialization has a negative association with enjoyment, particularly a decrease in enjoyment in young athletes (BOYD and YIN, 1996; FRASER-THOMAS et al., 2008; LARSON et al., 2019). Finally, we focused on young female athletes because most of the available information on youth sport is based on male athletes, despite the widespread participation of girls in organized sport (JOHNSTON et al., 2018).

7.2.MATERIALS AND METHODS

7.2.1.Study design and participants

Ethical approval was obtained from the author's institutional ethics committee. Participants were informed about the nature of the study, that participation was voluntary, and that they could withdraw from the study at any time. Players and their parents or legal guardians provided written informed consent.

7.2.2. Cross-sectional data

To gather the data, we started by conducting a cross-sectional survey followed by an analysis of repeated measurements using a mixed-longitudinal design with a sub-sample from the larger survey. Throughout the study, all players involved were engaged in regular training (approximately 300-400 minutes per week) during the competitive season, which typically runs from February/March to November/December in Brazil. The cross-sectional data was based on a survey from 2015 to 2022. We considered a total sample of 243 young female basketball and volleyball players aged, on average, 15.0 (2.1) years, ranging between 10.1 to 19.7 years.

7.2.3. Repeated measures data

From the total cross-sectional sample, we retained data with repeated measures collected from competitive seasons across the survey period. The sub-sample consisted of 83 young athletes aged, on average, 14.0 years (ranging from 11.5 to 18.1 years) at baseline, with 41 playing basketball and 42 playing volleyball. Observations were made pre-season (February/March), mid-season (July/August), and end-season (November/ December) for each of the competitive seasons, and the players were measured and tested within a week of each observation period. To be included in the analysis of repeated measures, the players had to have at least two measurements across the period of observation. The distribution of measurements per player was as follows: two measurements, n=28; three measurements, n=19; four measurements, n=19; five measurements, n=10; six measurements, n=7).

7.2.4. Measures

7.2.4.1. Outcomes variable

Participants were asked to complete the Portuguese-translated version (SANTOS and GONÇALVES, 2012) of the Sources of Enjoyment in Youth Sport Questionnaire (SEYSQ) (WIERSMA, 2001) before practice sessions. The SEYSQ was developed to assess young athletes' perceptions of enjoyment (WIERSMA, 2001), based on the on the sport commitment model (SCANLAN and LEWTHWAITE, 1986; SCANLAN et al., 1993). The SEYSQ consists

of six dimensions or themes: (i) Self-referenced competency pertains to the athlete's comparison of their current and past performances; (ii) Other-referenced competency and recognition (ORCR) involve being better than other athletes of the same age or in the same sport, and a sense of uniqueness and recognition from others for athletic participation; (iii) Competitive excitement pertains to the challenges and uncertainty of competition and the related emotional reactions; (iv) Effort expenditure involves playing and training hard during practice and competition; (v) Affiliation with peers pertains to forming friendships and connections with teammates in the team and sport; (vi) Positive parental involvement pertains to receiving support from the athlete's parent(s) for participating in sport.

The six dimensions of the SEYSQ have been tested and interpreted in light of the two-dimensional model of sport enjoyment, where sources of enjoyment can be located along an extrinsic/intrinsic and achievement/non-achievement continuum (SCANLAN and LEWTHWAITE, 1986; WIERSMA, 2001). The achievement-intrinsic quadrant encompasses self-referenced competency; the achievement-extrinsic quadrant includes ORCR; the non-achievement-intrinsic quadrant encompasses effort expenditure and competitive excitement (WIERSMA, 2001).

Social influences, such as affiliations with peers and positive parental involvement in sport, are encompassed in the non-achievement-extrinsic quadrant (WIERSMA, 2001). There has been consistent data contributing to the understanding of the construct of enjoyment in youth sport (MACDONALD et al., 2011; MCCARTHY et al., 2008; SCANLAN et al., 1989; WIERSMA, 2001). However, little attention has been given to testing the dimensional model of sport enjoyment and dimensions in the SEYSQ, taking into account patterns of specialization in youth sport.

The Portuguese version of the SEYSQ has 28 items, which are rated on a 5-point Likert-like scale ranging from 1 (not at all) to 5 (very much). We initially examined the fit of the original factorial structure in the Brazilian youth sport context by conducting a confirmatory factor analysis using a fully Bayesian framework. The results of this analysis and the details of modeling are available in the supplementary material (see Appendix C). The analysis confirmed the original factorial structure of the SEYSQ, which consists of six dimensions, although five items from the original scale were removed. For computational convenience, we considered the response $i = 1, \dots, n$ nested by dimension $j = 1, \dots, n = 6$.

7.2.5. Person outcomes

7.2.5.1.Chronological age

Chronological age was calculated to the nearest 0.1 year by determining the difference between the birth date and the date of observation.

7.2.5.2.Age at menarche and menarcheal status

Age at menarche was obtained through self-reported via interviews performed by the coaches (female coaches in all cases). Distance to age at menarche was calculated to the nearest 0.1 years by subtracting the menarche date from the date of observation. Players were classified as having early, average, or late maturation based on their age at menarche being minus or plus one year from the mean age at menarche for the Brazilian population.

The reference age at menarche (mean = 12.9 years, 95% CI: 12.7 to 13.1 years) was based on a meta-analysis of data from five studies in the Brazilian population, summarizing data recorded from 1972 to 1992 (DUARTE, 1993). Caution with the interpretation of menarche status is warranted and the issue is discussed elsewhere (SOARES et al., 2020). Hence, players were grouped into three groups of menarcheal status: early (cross-sectional sample, $n=100$; repeated measures sample, $n=38$), average (cross-sectional data, $n=109$; repeated measures sample, $n=41$), and late (cross-sectional sample, $n=18$; repeated measures sample, $n=4$). For cases where the age of menarche could not be determined or was not attained at the time of observation, the players were classified as unknown (cross-sectional sample, $n=16$; repeated measures sample, $n=1$).

7.2.6.Process outcomes

7.2.6.1.Sport-specific onset of specialization and accumulated deliberate practice

We considered the accumulated deliberate practice, or training experience, as the difference between the self-reported age when players started formal training and competition in their respective sports, referred to as the age of sport-specific onset of specialization (MENDES et al., 2018), and their chronological age at each observation. The sport-specific onset of specialization was interpreted considering biological maturation milestones (LIMA et al., 2020; MENDES et al., 2021). The biological maturation milestones considered were the age of initiation of the pubertal growth spurt and the age at peak height velocity. Information

on how the biological maturation milestones were estimated using data from a meta-analysis of growth studies is available elsewhere (LIMA et al., 2020; MENDES et al., 2021).

The reference age of initiation of the pubertal growth spurt was 9.4 (95% CI 9.0 to 9.8) years, and the reference age at peak height velocity was 11.9 (95% CI 11.8 to 12.0) years. Players who had an onset of specialization before the reference age of initiation of the pubertal growth spurt were categorized as pre-puberty specialization, i.e., early specialization (cross-sectional sample, $n=59$; repeated measures sample, $n=9$). Players whose onset of specialization was between the reference age of initiation of the pubertal growth spurt and the age at PHV were categorized as mid-puberty specialization (cross-sectional sample, $n=122$; repeated measures sample, $n=48$).

Those whose onset of specialization was after the reference age at PHV were classified as late-puberty specialization, i.e., late specialization (cross-sectional sample, $n=59$; repeated measures sample, $n=26$). In cases where the onset of specialization could not be determined, the players were classified as unknown (cross-sectional sample, $n=3$; repeated measures sample, $n=1$).

7.2.7.Context outcomes

7.2.7.1.Microsystem and mesosystem variables

Considering variation by sport in competitive age grouping in Brazil, we assumed a two-year range, the most common competitive age groups in Brazilian youth sport and international South American youth competitions. For the cross-sectional sample, athletes were considered as under 11 (age up to 11.9 years, $n=20$), under 13 (age between 12.0 to 13.9 years, $n=68$), under 15 (age between 14.0 to 15.9 years, $n=69$), under 17 (age between 16.0 to 17.9 years, $n=68$), and under 19 (age between 18.0 to 19.9 years, $n=18$).

The athletes selected to represent state-level teams were classified as state-level (cross-sectional sample, $n=57$; repeated measures sample, $n=14$), and the remaining were classified as club-level (cross-sectional sample, $n=186$; repeated measures sample, $n=70$).

7.2.7.2.Exosystem and macrosystem variables

The participants were young female players from basketball (cross-sectional sample, $n=171$, repeated-measures sample, $n=41$) and volleyball (cross-sectional sample, $n=72$, repeated-measures sample, $n=42$). All players were engaged in clubs and competitions supervised by the respective sport state federation [Paraná (cross-sectional sample, $n=72$), Santa Catarina (cross-sectional sample, $n=130$), and São Paulo (cross-sectional sample, $n=41$)].

7.2.8. Data analysis

7.2.8.1. Models specification

We used Bayesian hierarchical models to model the responses of the players in each item of the SEYSQ. We assume that our outcome of interest y , the probability of each player p response in dimension j in the SEYSQ, is five ordinal categories ($k \in \{1, 2, 3, 4, 5\}$). To model the relative probability of each ordinal category, we stated that the relative probabilities of the ordinal categories are conditional on a set of thresholds τ_k ($k \in \{1, 2, 3, 4\}$). We used a standard cumulative distribution function Φ to allow us to map the cumulative probabilities onto an unbounded parameter space divided up by the thresholds τ_k .

The parameters for Φ were fixed with a mean $\mu = 0$ and a standard deviation $\sigma = 1$ for identification. In our cross-sectional dataset, $\mu_{p[j]}$ is given as function nested by each player (captured by $\alpha_{p[j]}^{player}$), and person (i.e. maturity status, $\alpha_m^{menarche}$), process (i.e., specialization, $\alpha_s^{specialization}$) and context (i.e., age group, α_a^{age} ; competitive level, β_l^{level} ; sport, β_n^{sport} ; and state, α_r^{state}) characteristics. We considered competitive level (β_l^{level}) and sport (β_n^{sport}) as a population-effect (also referred to as fixed effect), given the difficulty of estimating the between-group variation when the number of groups is small (GELMAN and HILL, 2007). The predictors included in the models as discrete factors allow us to account for cross-classified nesting in the outcome of interest. Hence, the Bayesian hierarchical model allows us to incorporate person-, process-, and context-level factors to advance to our understanding of young athletes' enjoyment. The association of these discrete factors and y were captured by a series of varying intercepts:

$$p(y = k | \mu_{p[j]}, \tau_k, \tau_{k-1}) \sim \Phi(\tau_k - \mu_{p[j]}) - \Phi(\tau_{k-1} - \mu_{p[j]})$$

$$\begin{aligned}
\mu_{p[j]} &= \alpha_{p[j]}^{player} + \beta_l^{level} + \beta_n^{sport} + \alpha_a^{age} + \alpha_m^{menarche} + \alpha_s^{specialization} + \alpha_r^{state}, \text{ for } j = 1, \dots, J \\
\alpha_{p[j]}^{player} &= \text{Normal}(0, \sigma_p), \text{ for } p = 1, \dots, P \\
\beta_l^{level}, \beta_n^{sport} &\sim \text{Normal}(0, 1), \text{ for } l, n = 1, 2 \\
\alpha_a^{age} &\sim \text{Normal}(0, \sigma_{age}), \text{ for } a = 1, 2, 3, 4 \\
\alpha_s^{specialization} &\sim \text{Normal}(0, \sigma_{specialization}), \text{ for } s = 1, 2, 3 \\
\alpha_r^{state} &\sim \text{Normal}(0, \sigma_{state}), \text{ for } r = 1, 2, 3 \\
\tau_k &\sim \text{student} - t(3, 0, 2.5) \\
\sigma_p, \sigma_{age}, \sigma_{specialization}, \sigma_{state} &\sim \text{Exponential}(1)
\end{aligned}$$

For the repeated-measures data, we assumed that our $t = 1, \dots, n_t$ observations were nested within $j = 1, \dots, n_j$ dimensions, nested within $p = 1, \dots, n_p$ players:

$$p(y = k | \mu_{p[tj]}, \tau_k, \tau_{k-1}) \sim \Phi(\tau_k - \mu_{p[tj]}) - \Phi(\tau_{k-1} - \mu_{p[tj]})$$

We explicitly considered in our model *time* (BRONFENBRENNER and MORRIS, 2007) as *mesotime*, considering the joint influence of chronological age, distance to menarche (pubertal growth milestone), and accumulated years of sport-specific deliberate practice. For computational efficiency, the continuous outcomes were standardized by subtracting the mean and dividing by two standard deviations (GELMAN and HILL, 2007).

In our model, $\mu_{p[tj]}$ is given by the intercept $\alpha_{p[jt]}^{player}$, the slope terms $\beta_{p[jt]}^{age}$ (for chronological age), $\beta_{p[jt]}^{menarche}$ (for distance to menarche), and $\beta_{p[jt]}^{practice}$ (for accumulated sport-specific deliberate practice), indicating that each dimension for each player is given a unique intercept and slopes are issued from a normal distribution centered, respectively on α , β^{age} , $\beta^{menarche}$, and $\beta^{practice}$, the grand intercept and slopes, meaning that there might be different mean scores for each player.

The correlation between the varying intercepts and the varying slopes was estimated by modeling $\alpha_{p[jt]}^{player}$, the slope terms $\beta_{p[jt]}^{age}$, $\beta_{p[jt]}^{menarche}$, and $\beta_{p[jt]}^{practice}$, as issued from the same multivariate normal distribution (a multivariate normal distribution is a generalization of the usual normal distribution to more than one dimension), centered on 0 and with some covariance matrix S . Lastly, we included context-level variables in the model by considering

the cross-classified nesting of sport and competitive level. Hence, the joint association of time-varying outcomes, discrete context factors, and y_i were captured by a series of varying intercepts and varying slopes:

$$\mu_{p[j]} = \alpha_{p[tj]}^{player} + \beta_{p[tj]}^{age} + \beta_{p[tj]}^{menarche} + \beta_{p[tj]}^{practice} + \beta_l^{level} + \beta_n^{sport}$$

$$\begin{bmatrix} \alpha_{p[tj]}^{player} \\ \beta_{p[tj]}^{age} \\ \beta_{p[tj]}^{menarche} \\ \beta_{p[tj]}^{practice} \end{bmatrix} \sim MVNormal \left(\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, S \right)$$

$$S =$$

$$\begin{bmatrix} \sigma_\alpha^2 & \sigma_\alpha \sigma_{\beta^{age}p} & \sigma_\alpha \sigma_{\beta^{menarche}p} & \sigma_\alpha \sigma_{\beta^{practice}p} \\ \sigma_\alpha \sigma_{\beta^{age}p} & \sigma_{\beta^{age}}^2 & \sigma_{\beta^{age}} \sigma_{\beta^{menarche}p} & \sigma_{\beta^{age}} \sigma_{\beta^{practice}p} \\ \sigma_\alpha \sigma_{\beta^{menarche}p} & \sigma_{\beta^{age}} \sigma_{\beta^{menarche}p} & \sigma_{\beta^{menarche}}^2 & \sigma_{\beta^{menarche}} \sigma_{\beta^{practice}p} \\ \sigma_\alpha \sigma_{\beta^{practice}p} & \sigma_{\beta^{age}} \sigma_{\beta^{practice}p} & \sigma_{\beta^{menarche}} \sigma_{\beta^{practice}p} & \sigma_{\beta^{practice}}^2 \end{bmatrix}$$

$$\alpha, \beta^{age}, \beta^{menarche}, \beta^{practice} = Normal(0,5)$$

$$\sigma_\alpha, \sigma_{\beta^{age}}, \sigma_{\beta^{menarche}}, \sigma_{\beta^{practice}} = Normal(0,1)$$

$$\beta_l^{level}, \beta_n^{sport} \sim Normal(0,1), \text{ for } l, n = 1, 2$$

$$\tau_k \sim \text{student} - t(3, 0, 2.5)$$

$$R = LKJcorr(2)$$

$$R = \begin{bmatrix} 1 & \rho & \rho & \rho \\ \rho & 1 & \rho & \rho \\ \rho & \rho & 1 & \rho \\ \rho & \rho & \rho & 1 \end{bmatrix}$$

Where R is the correlation matrix, ρ is the correlation between intercepts and slopes used for the computation of the covariance matrix S .

7.2.8.2. Prior distributions

For the priors of τ_k , we regularized the estimates using a student-t(3, 0, 2.5) prior. We used a weakly regularizing prior for the binary population-level parameters, normal(0,1) prior. For continuous variables included as population-level effects we used a normal(0,5) prior.

We used an exponential(1) prior for the varying intercept parameters. In the model with repeated measures, we expected the prior distribution to peak around a zero correlation by using the LKJ(2) prior to the parameter that controls the strength of the correlation matrices.

7.2.8.3. Posterior predictive checks and computation

We used posterior predictive checks to inspect our models (GABRY et al., 2019; VEHTARI et al., 2017). For each model, we run four chains for 3,000 iterations with a warm-up length of 1,000 iterations. The number and length of the chains and warm-up were sufficient to achieve convergence and obtain a reasonable effective sample size, given the computation time.

Bayesian estimations were implemented via R statistical language (TEAM, 2018) with the “brms” package (BÜRKNER, 2017), which call Stan (TEAM, 2020). The data and model predictions were visualized using the “ggplot2” package (WICKHAM, 2016). A repository containing the data and code allowing to recreate the analyses and figures is available at <https://osf.io/mj6rh/>.

7.3.RESULTS

The age at menarche in the present sample of young female athletes was, on average, 12.1 (90%CI 11.1 to 13.0) years. The young female basketball and volleyball players in the present analysis were, on average, on time in maturity status. The distribution of onset of specialization in the sample was balanced, with about 50% of the players classified as pre-puberty or late-puberty specialization, and the remaining half sample classified as mid-puberty specialization.

Except for one player, all players categorized as pre-puberty specialization were basketball players, which represents about 34% of the basketball sample. In contrast, about 57% of the volleyball sample (40 out of 70 players) were classified as late-puberty specialization. On average, the young female basketball players had an earlier onset of deliberate practice compared to volleyball.

Our hierarchical ordinal model estimate the probability of young female players' response in each factor of the SEYSQ, given the athletes' specialization onset, menarcheal status, menarcheal status, sport, competitive level and state, considering the cross-sectional sample. Estimated probabilities of response varied by age group, specialization onset, menarcheal status, sport, competitive level, and state are provided as supplementary material. In Figure 22 is displayed the estimated response probabilities in the factors of the SEYSQ for the cross-sectional sample adjusted for process, person and context characteristics.

The posterior predictions of the probability of responses for the SEYSQ factors in young Brazilian athletes are displayed in Figure 23. The estimated parameters in the Bayesian hierarchical ordinal model for the cross-sectional sample are summarized in Supplementary table 2. In general, the young female athletes mainly agreed (response 5 in the Likert-like scale) with the statements in each factor of the SEYSQ.

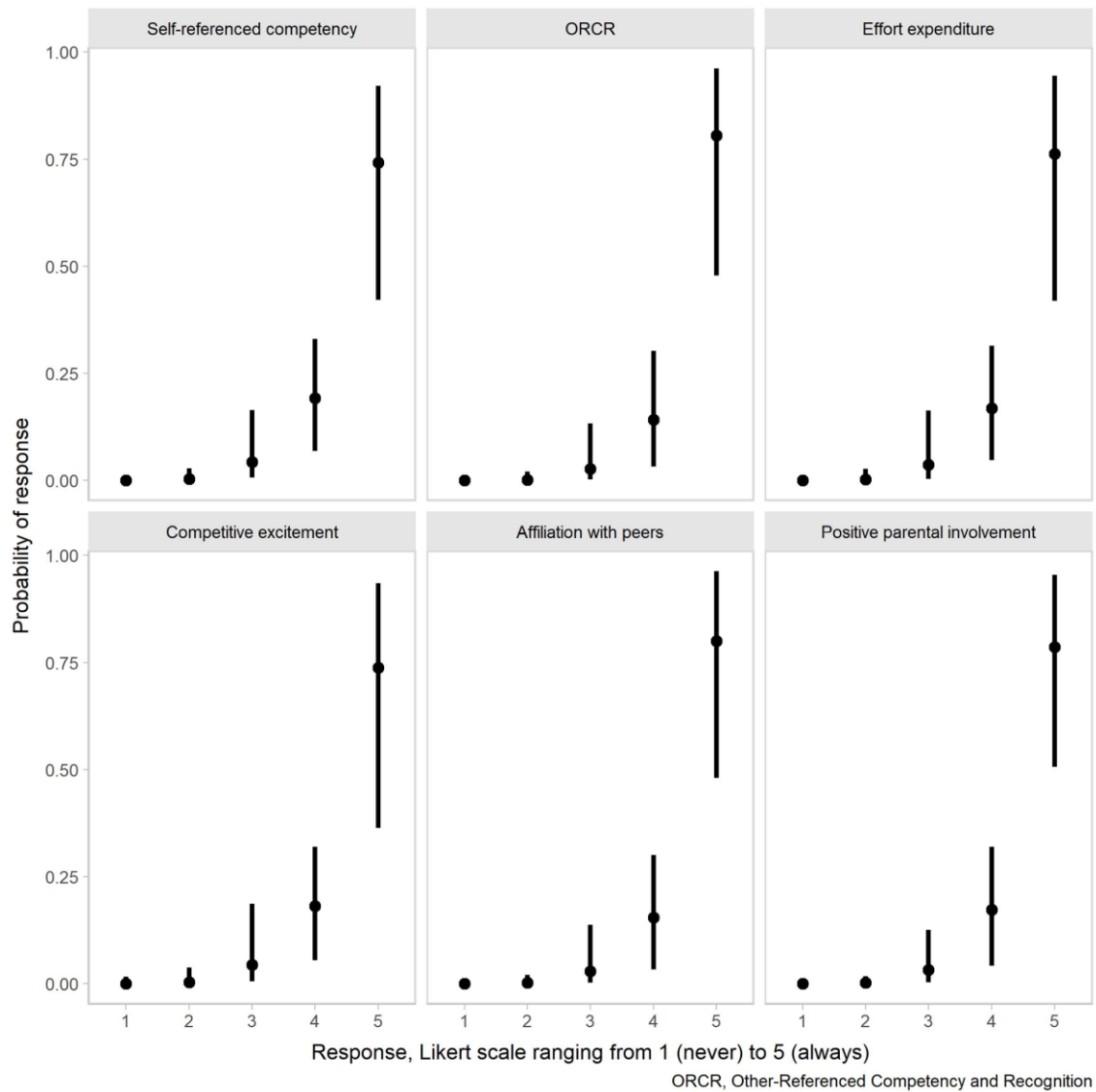


Figure 22. Posterior predictions of the probability of responses for the Source of Enjoyment in youth sports questionnaire factors in young Brazilian athletes. Uncertainty estimates represent the 50% credible intervals.

Notably, there was no variation in the responses by SEYSQ factors associated with process (onset of specialization), person (menarcheal status), and context (age group, sport, competitive level, and state). Estimated responses plotted by age group, specialization onset, menarcheal status, sport, competitive level, and state are provided as supplementary material.

The posterior predictions of the probability of longitudinal responses aligned by chronological age (upper panels), distance to menarche (middle panels), and accumulated years of deliberate practice (lower panels) in young Brazilian athletes grouped by sport are displayed in Figure 2 for Self-referenced competency, Figure 3 for ORCR, Figure 4 for Effort expenditure, Figure 5 for Competitive excitement, Figure 6 for Affiliation with peers, and Figure 7 for Positive parental involvement.

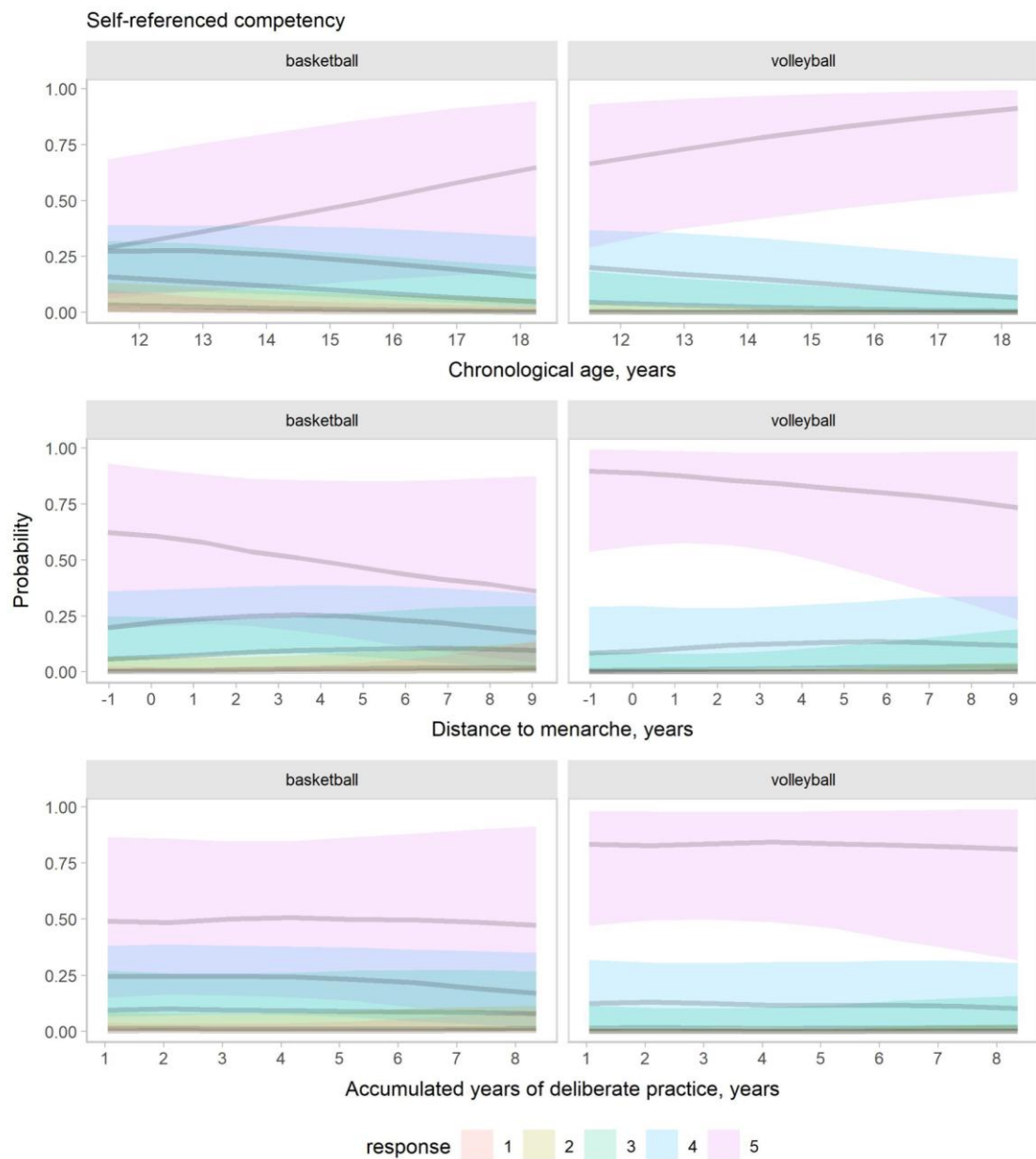


Figure 23. Posterior predictions of the probability of longitudinal responses for Self-referenced competency aligned by chronological age (upper panel), distance to menarche (middle panel), and accumulated years of deliberate practice (lower panel) in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 50% credible intervals.

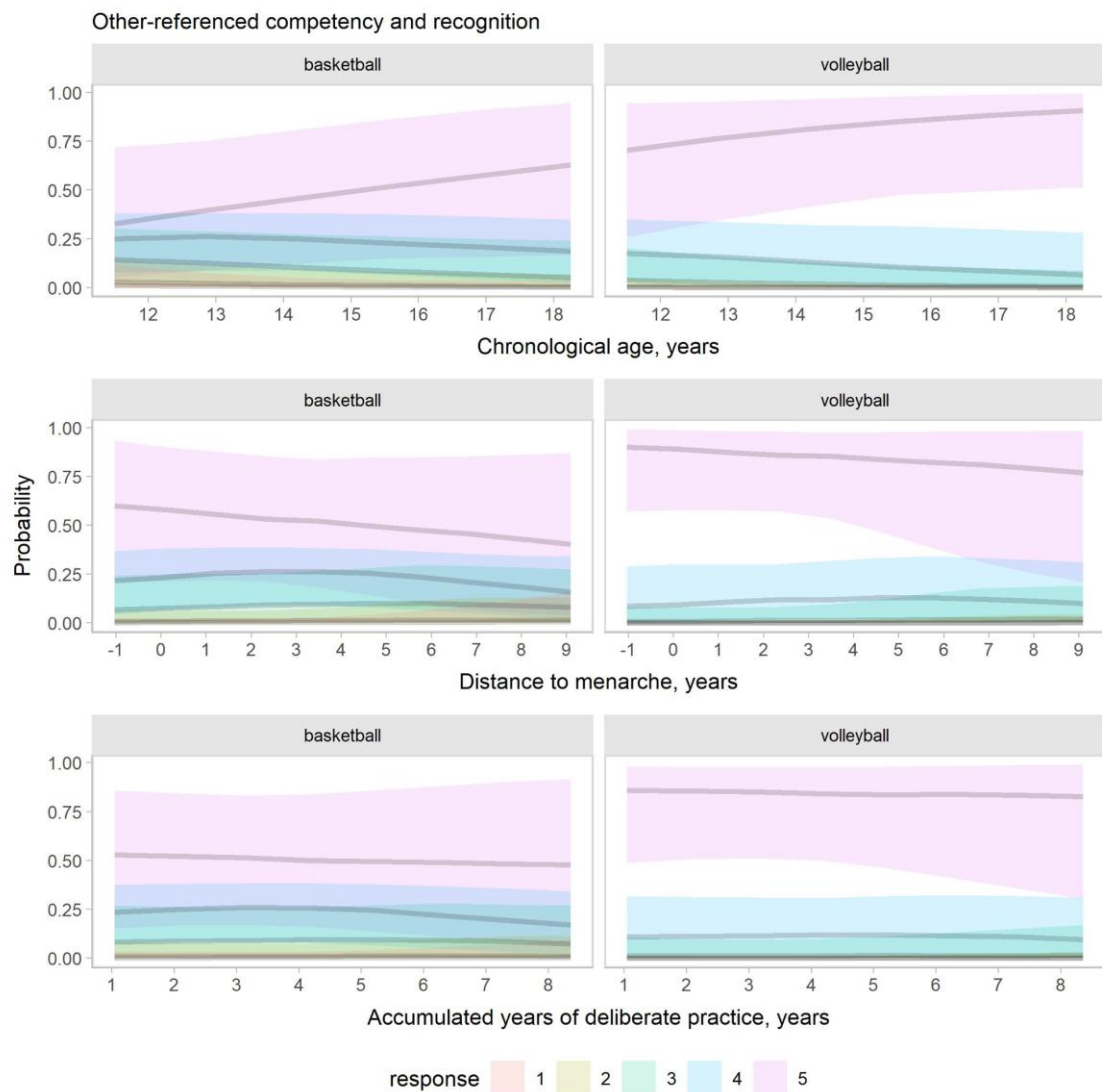


Figure 24. Posterior predictions of the probability of longitudinal responses for Other-referenced competency and recognition aligned by chronological age (upper panel), distance to menarche (middle panel), and accumulated years of deliberate practice (lower panel) in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 50% credible intervals.

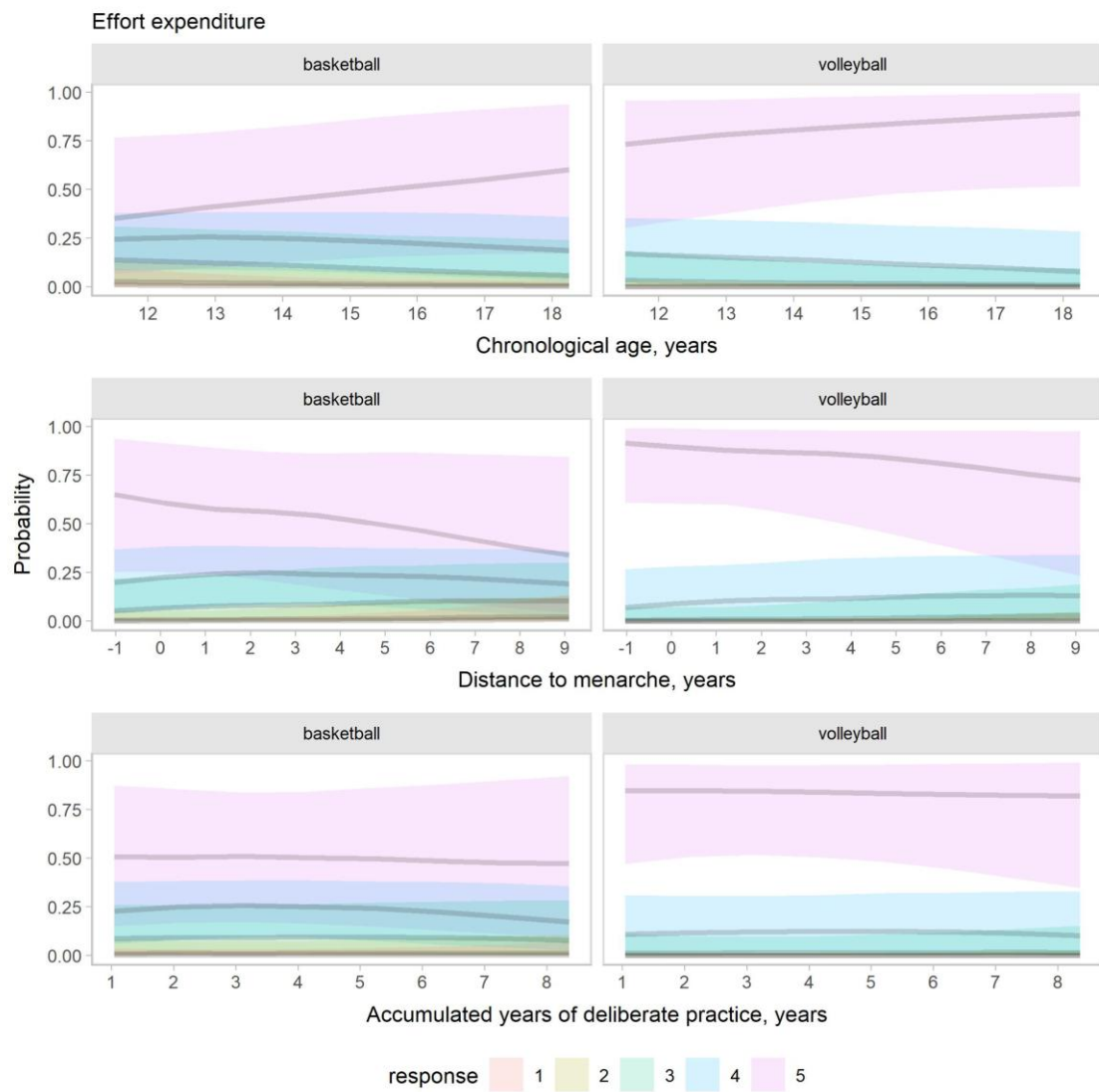


Figure 25. Posterior predictions of the probability of longitudinal responses for Effort expenditure aligned by chronological age (upper panel), distance to menarche (middle panel), and accumulated years of deliberate

practice (lower panel) in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 50% credible intervals.

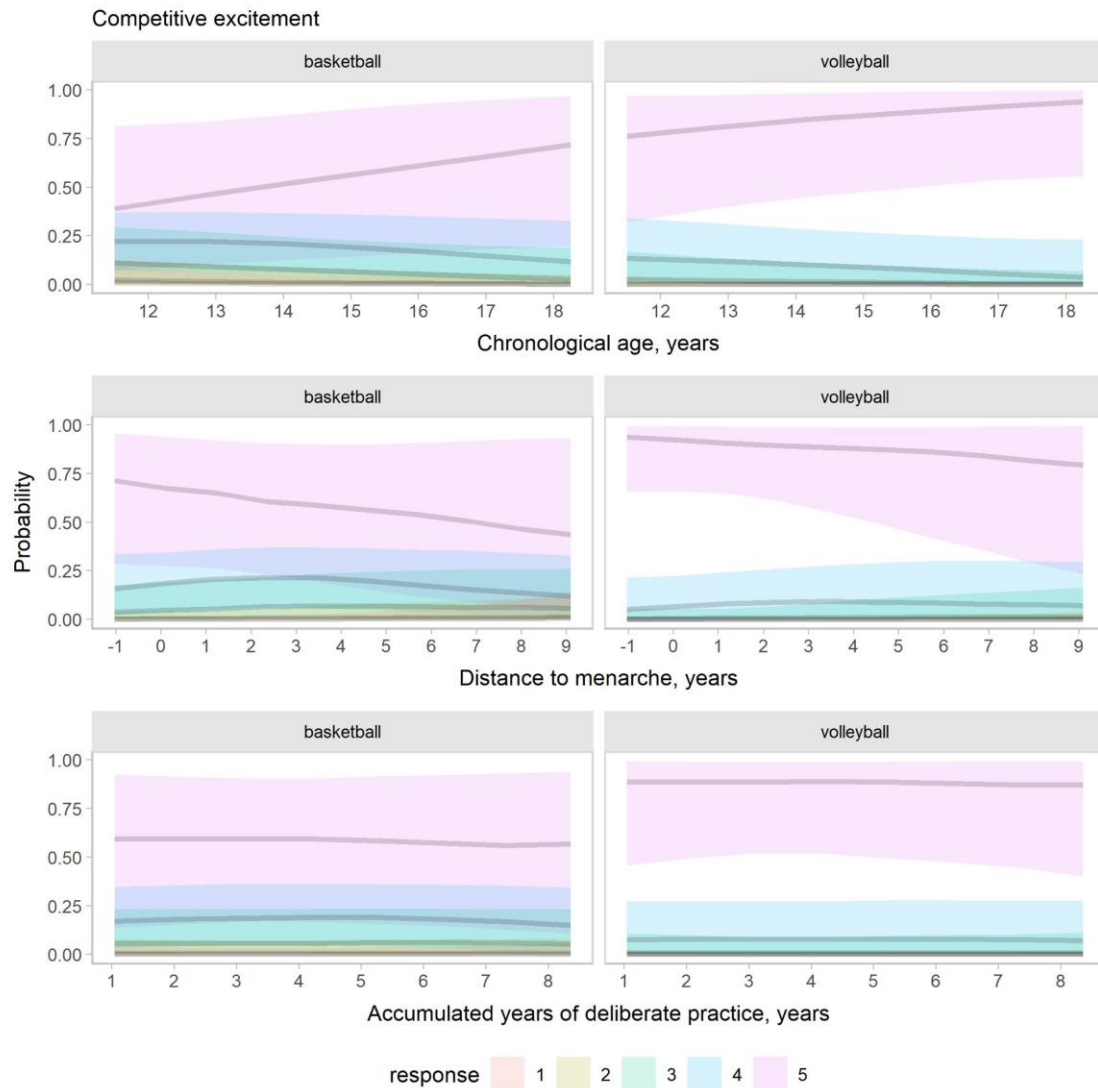


Figure 26. Posterior predictions of the probability of longitudinal responses for competitive excitement aligned by chronological age (upper panel), distance to menarche (middle panel), and accumulated years of deliberate practice (lower panel) in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 50% credible intervals.

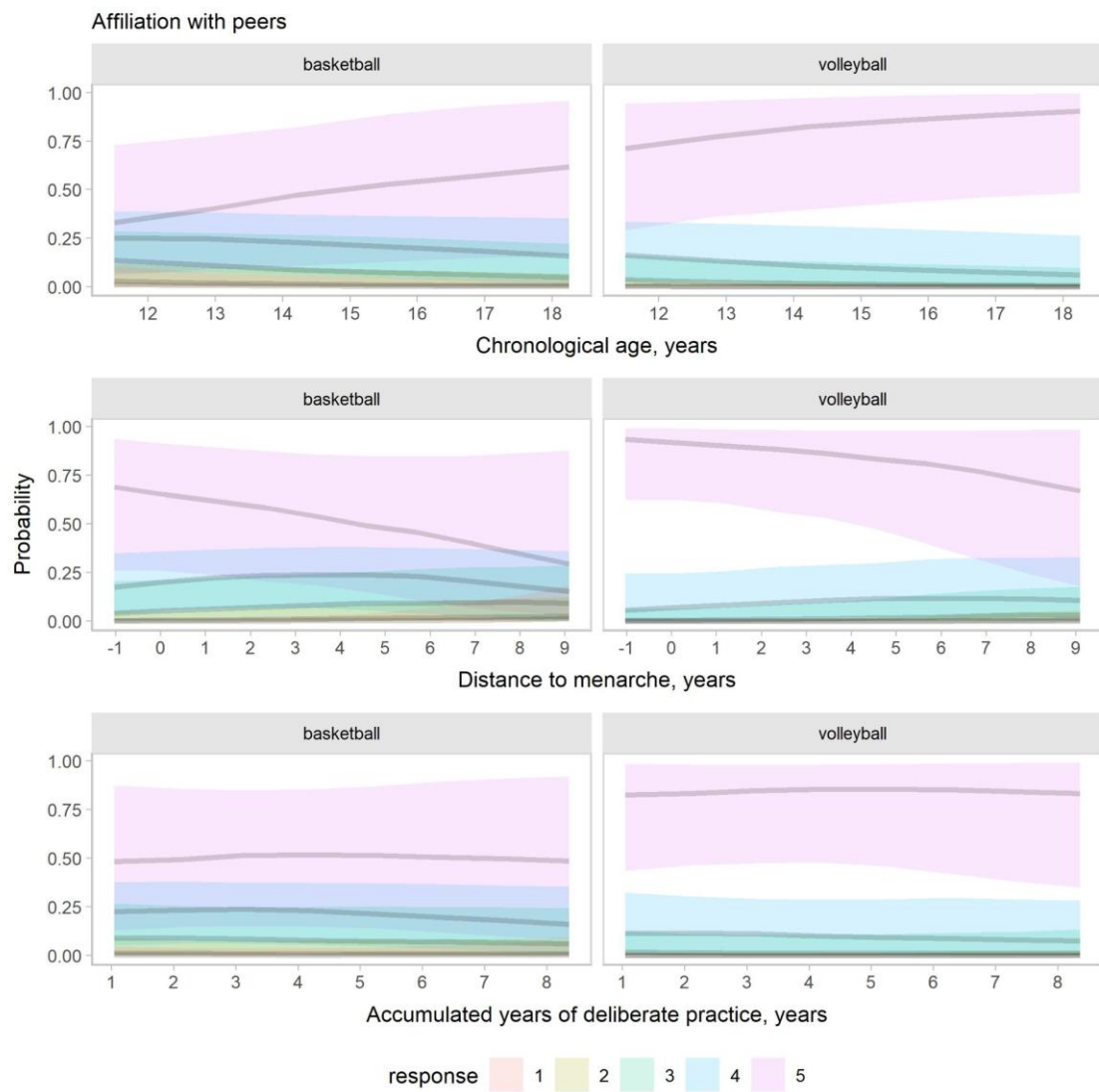


Figure 27. Posterior predictions of the probability of longitudinal responses for Affiliation with peers aligned by chronological age (upper panel), distance to menarche (middle panel), and accumulated years of deliberate

practice (lower panel) in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 50% credible intervals.

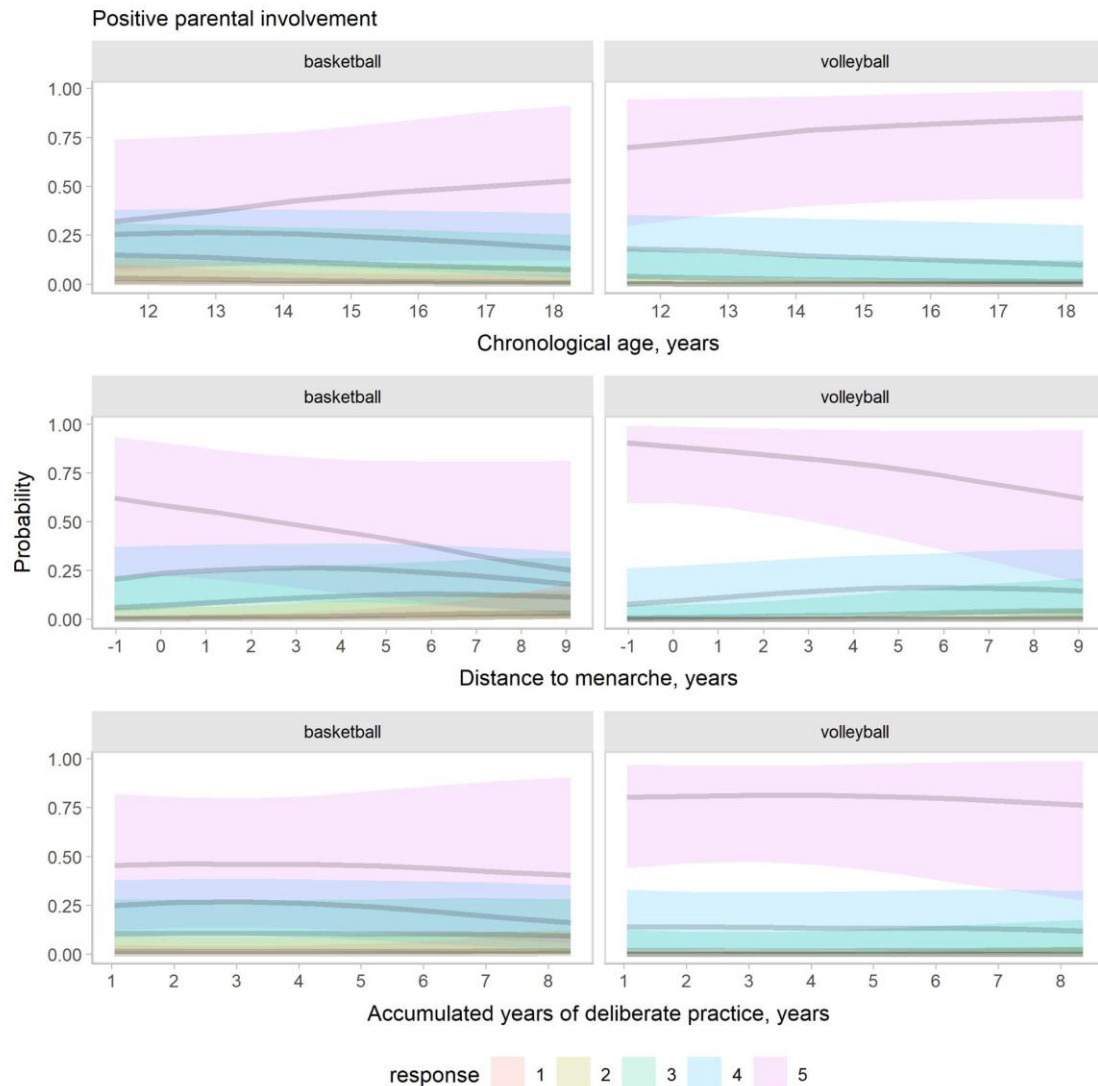


Figure 28. Posterior predictions of the probability of longitudinal responses for Positive parental involvement aligned by chronological age (upper panel), distance to menarche (middle panel), and accumulated years of deliberate practice (lower panel) in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 50% credible intervals.

The estimated parameters in the Bayesian hierarchical ordinal model for the repeated-measures sample are summarized in Supplementary table 3. There was substantial variation between female basketball and volleyball players' longitudinal responses in all SEYSQ factors. There was a consistent trend in all SEYSQ factors showing that the young female volleyball players had higher response values (response 5 in the Likert-like scale) than basketball players. On the other hand, there was no substantial influence of competitive level on longitudinal responses in all factors of the SEYSQ. There was a trend of an increase in the probability of response 5 on the Likert-like scale for all SEYSQ factors with chronological age, and a

corresponding decrease in all other Likert-like scale responses. However, as the young female players were biologically older, there was a substantial decrease in the probability of response 5 on the Likert-like scale for all SEYSQ factors, particularly noticeable for the basketball players. The patterns in the probability of responses for all SEYSQ factors were stable with accumulated years of deliberate practice, although there was substantial variation between players and within factors (Supplementary table 2).

However, the probability of response 5 on the Likert-like scale in the basketball players was substantially lower than in volleyball players. Overall, the responses of biologically mature, older, and more experienced basketball players were more evenly distributed between the 1 to 5 responses in the Likert-like scale of the SEYSQ factors.

7.4.DISCUSSION

Enjoyment in youth sport plays a key role in understanding commitment and sustained participation (MCCARTHY et al., 2008; SCANLAN et al., 1993; WIERSMA, 2001). The current study sought to bring a bioecological approach to investigate changes in sources of enjoyment among young female athletes. This was accomplished through two steps: first, investigating whether sources of enjoyment variations could be explained by person, process, and context factors, and second, examining changes in sources of variation while considering the interactions of time with process (accumulated sport-specific deliberate practice) and person (chronological age and distance to a biological maturation milestone), while also allowing for the influence of context (sport and competitive level).

Youth sport programs that encourage year-round specialization in a single sport with an emphasis on those aspiring for elite status have become the norm (BELL et al., 2016; BUCKLEY et al., 2017; DISANTI and ERICKSON, 2019; SMITH, 2015). These programs are often assume that maximizing sport-specific, coaching-led deliberate practice would effectively lead to expert performance (DE BRUIN et al., 2008; ERICSSON et al., 1993; GÜLLICH, 2018). Despite the interest in early specialization, there is limited available data explicitly studying the consequences of early specialization, in contrast to the abundance of reviews, commentaries, or editorials (MOSHER et al., 2020). The limited data suggested that early specialization may lead to low motivation and enjoyment, which can increase the risk of burnout and dropout (FRASER-THOMAS et al., 2008; LARSON et al., 2019).

A key finding from the present study points to the lack of influence of the onset of specialization on the enjoyment of young female athletes in sport. On the other hand, we noted

a large variation between players in the patterns of responses in the SEYSQ dimensions (both within- and between-dimensions responses) when aligned for accumulated sport-specific deliberate practice (see Supplementary Table 3), and a large variation between contexts (see Figures 22 to 27). The assumption of negative effects due to early specialization on enjoyment of female adolescent athletes was not confirmed in the present observations.

Our data do not support this argument, as evidence-based data on this topic is inconsistent and limited to draw strong causal inferences (DISANTI and ERICKSON, 2019). The young female athletes of our sample may be able to cope with the sport challenges they are facing, and to construct their own interpretations about the practice climate, pressure from peers, coaches and significant others.

The “rocky road” for sport success (COLLINS and MACNAMARA, 2012; TAYLOR and COLLINS, 2019) does not seem to affect the young female athletes’ beliefs and expectations. It is worth noting that our study has a narrow focus, as it only explores a limited range of youth sport training and competitive environments, all of which are focused on the development of athletes aspiring for elite status.

While concerns about potential negative impacts of early specialization are likely valid in high-performing environments of youth sport, the data available for such specific contexts are not yet sufficient. As far as we know, our data provide the first insights into enjoyment that need to be replicated in other cultures of youth sport to provide more consistent interpretations about youth sport specialization.

From an achievement goal theory perspective (AMES, 1995), our observations suggest that the development of the young female athletes in the sample appears to be influenced more by intrinsic sources, such as the need to improve oneself through personal effort, than by extrinsic factors such as recognition of competence by others. The high values of response 5 on the Likert-like scale for ORCR across time potentially reflect the direct competition with peers and performance-related feedback that are ever-present and often serve as the basis for selection decisions made by coaches in youth sport environments.

Overall, the young female athletes consistently responded in the higher ordinal category (i.e., responses of 5 on the Likert-like scales) of the SEYSQ factors. When analyzing the cross-sectional survey data of young female basketball and volleyball players, the study did not find significant relationships between young female athletes’ sources of enjoyment and person, process, and contextual factors.

However, when incorporating time into the design and analysis, the study revealed deeper links between the influence of personal, process, and contextual factors on the

developmental changes in the sources of enjoyment among the young female athletes. In particular, the longitudinal data displayed a clear pattern of variation in the responses by sport.

Volleyball players consistently responded in the higher ordinal category of the Likert-like scale of the SEYSQ factors, showing a trend of increasing the response for all factors of the SEYSQ with chronological age. On the other hand, the young female basketball players had a lower probability of response 5 on the Likert-like scales of the SEYSQ factors and a more pronounced decrease in these responses when considering the biological maturation age. Overall, these observations were consistent across the sample, even when considering the potential effect of the competitive level of the young athletes.

By aligning the three chronosystems, it is possible to identify that interpretations about the enjoyment of young female athletes across adolescence using only chronological age will be incomplete at best. The present data showed that as the young female players were becoming more mature, their perceptions of enjoyment changed notably, particularly among young Brazilian basketball players.

The present results need to be seen with more detail in order to refine the analysis and elaborate a more nuanced interpretation. The practice environments seem to be key to foster young athletes' positive development, increase their perceived self-competence, autonomy, and desire to improve themselves (MACDONALD et al., 2011; SCANLAN et al., 1989; WIERSMA, 2001).

Our observations identified small variation associated with the sport context, highlighting the sport-specific cultures that potentially influence young athletes' perceptions. It may be reasonable also to consider that the varying structures of a sport-specific career, pedagogical approaches to training, and competition in different sport may influence players' perceptions. Hence, the results may be a consequence of contextual changes in the training process and competition (e.g., different coaching styles, parental involvement) or different offers and demands of competing activities in sport (e.g., nights out with friends, school results) in the period of the athlete's adolescence (SANTOS and GONÇALVES, 2016).

In addition, these results may be tied to the fact that the observations are from high-performance-oriented environment. Nevertheless, the young athletes' enjoyment across the sport contexts mainly comes from perceptions of self-competence, and physical exertion, which represents for the athlete a sense of commitment and hard work in practice and games (WIERSMA, 2001). Experiences in learning and improving skills and abilities, exerting effort, and excitement associated with competitive sport have also been consistently reported in research as being enjoyable to athletes (BAKKER et al., 1993; BOYD and YIN, 1996).

Our analytical approach allowed us to map the trends of responses in each dimension of the SEYSQ, specifically considering how person (chronological age and age at menarche), process (represented by the accumulated exposure to sport-specific deliberate practice), and context (represented by different competitive levels across two team sport) mutually influence the young female athletes' enjoyment sources over time. The model fits were examined via posterior predictive checks (i.e., comparing data generated under each model with observed data), which showed that the models fit well (see Supplementary material).

Our observations add to the criticism of interpretations of ecological approaches when failing to accurately operationalize Bronfenbrenner's PPCT research model (NAVARRO et al., 2022; TUDGE et al., 2009; TUDGE et al., 2016), particularly failing to consider time (BRONFENBRENNER, 2005). In sport, it is important to emphasize that the influence of time is measured in years through a continuous commitment to training and competition. The present study assesses a path (or a process) rather than an episodic contact with one or multiple sports (CÔTÉ et al., 2020).

We must acknowledge that our research setting is complex, but not too complex to allow for an explanation. Without external influences and personal development, the ecosystem under scrutiny would remain static. The observed changes over time shed light on the constellation of variables that interact to shape individual trajectories regarding enjoyment in sport.

As we are dealing with social relationships, we must be cautious in interpreting the findings as a translation of the real world and not as mere theoretical elaborations. Our aim, when hypothesizing a model with its explanatory mechanisms, is always to discern the common forms and structures that are transversal to the diversity of bioecological settings.

Finally, caution should be exercised in generalizing the results of the present study. Although often overlooked in youth sport research, selection bias based on who was included in the datasets should be considered. In the present study, selection bias is a concern, more so in the basketball context (approximately 25% of the cross-sectional sample was available for repeated measures) than in the volleyball context (approximately 58% of the cross-sectional sample was available for repeated measures). Youth sport contexts present a challenging context for follow-up studies, with many factors contributing to attrition, including sport selection and injury (KEMPER, 2007).

In summary, self-referenced competence, other-referenced competence and recognition, effort expenditure, affiliation with peers, and positive parental involvement are key sources of enjoyment for playing sport among young female athletes from basketball and

volleyball, adjusting for age-group, the onset of specialization, competitive level, sport, and state. The results of the present study do not support the argument that early specialization may lead to low enjoyment, and consequent compromise in commitment and sustained participation in youth sport programs.

By aligning the three chronosystems (chronological age, menarche age, and accumulated sport-specific deliberate practice), it was possible to identify the importance of the sport context to the changes in the sources of enjoyment across the development of young Brazilian female athletes between 12 and 18 years. Overall, our findings underscore the necessity of incorporating time in ecological approaches to youth sport research through repeated-measures design to properly operationalize Bronfenbrenner's PPCT research model.

7.5.LIMITATIONS

Our analytical approach allowed us to map the trends of responses in each factor of the SEYSQ, specifically considering how person (chronological age and age at menarche), process (represented by the accumulated exposure to sport-specific deliberate practice), and context (represented by different competitive levels across two team sports) mutually influence the young female athletes' enjoyment sources over time. The model fits were examined via posterior predictive checks (i.e., comparing data generated under each model with observed data), which showed that the models fit well (see APPENDIX). Our observations add to the criticism of interpretations of ecological approaches when failing to accurately operationalize Bronfenbrenner's PPCT research model (NAVARRO et al., 2022; TUDGE et al., 2009; TUDGE et al., 2016;), particularly failing to consider time (BRONFENBRENNER, 2005). It is important to stress that, in sport, the influence of time is measured in years through a continued commitment to training and competition. With the present study we assess a path (or a process) and not an episodic contact with one or multiple sports (CÔTÉ et al., 2020).

We must acknowledge that our research setting is complex, but not too complex to allow for an explanatory power. Without external influences and personal development, the ecosystem under scrutiny would remain static. The observed changes over time shed light on the constellation of variables that interact to shape individual trajectories regarding enjoyment in sport. As we are dealing with social relationships, we must be cautious in interpreting the findings as a translation of the real world and not as mere theoretical elaborations. Our aim, when hypothesizing a model with its explanatory mechanisms, is always to discern the common forms and structures that are transversal to the diversity of bioecological settings.

7.6.ACKNOWLEDGEMENTS

The authors thank the patience and cooperation of the young athletes and coaches in the research project.

7.7.FUNDING

This work was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Conselho Nacional de Desenvolvimento Científico e Tecnológico (grant number Finance code 001).

7.8.DATA AVAILABILITY STATEMENT

All codes used to extract, model, and plot the data in this review are available at <https://osf.io/mj6rh/>.

7.9.CODE AVAILABILITY

All codes used to extract, model, and plot the data in this review are available at <https://osf.io/mj6rh/>.

8. GENERAL DISCUSSION

This thesis critically examined youth athlete development in basketball through a multidimensional lens, addressing gaps between theory and practice in current structured sport development systems. Across three empirical studies and a comprehensive scoping review, the findings consistently highlighted the conceptual fragility, inadequate analytical approaches, and empirical inconsistencies surrounding early sport specialization. This work also proposed a broader pedagogical and more ecological framework for understanding performance, motivation, and enjoyment in youth sport.

8.1.CONTRADICTIONS IN SELECTION PRACTICES AND TALENT IDENTIFICATION

The scoping review demonstrated that studies on youth basketball overwhelmingly focus on physical performance, anthropometry, and physiology, with limited integration of psychosocial or pedagogical dimensions. Most studies primarily consider dimensions that may be determinants of athletes 'potential performance achievement in senior years, attempting to predict those who may be considered talented. This compartmentalized view of talent mirrors the operational logic of youth selection systems, where decisions are often based on physical maturity or immediate performance indicators (CARVALHO et al., 2018; SOARES et al., 2019; SOARES et al., 2020). However, young athletes 'development is a nonlinear and unpredictable process influenced by biological, psychological, and contextual variables (ABBOTT et al., 2005). The continued reliance on early selection and exclusionary practices may thus limit access to developmental resources and create cumulative disadvantages for late maturing or socially marginalized athletes (COBLEY et al., 2009; CUMMING et al., 2017).

The limitations of, and the caution needed when, interpreting data based on estimations of biological maturation stages have been rarely discussed elsewhere (CARVALHO et al., 2018; CARVALHO and GONÇALVES, 2023; KOZIEL and MALINA, 2018). This is because cumulative technical and predictive errors may interfere with results, consequently impacting interpretations and decision-making on talent selection. In our data analysis, we used a conservative interpretation of estimation. Even so, we understand that decision-makers should be careful when applying estimative equations for maturity status to determine competitive and training exposures and to modulate sport systems. For example, Bio-banding classifies and groups players according to estimated maturity status (CUMMING et al. 2017). Its purpose is

based on the assumption that players are better suited and have adjusted opportunities to play with and against those with equivalent size and physical conditions. On the other hand, this kind of interpretation still needs to consider the pedagogical characteristics of the game, where inter-individual differences may determine game actions and decision-making procedural aspects. Artificially, this approach groups players and may determine the type of experiences players will have the opportunity to undertake. According to our findings, psychobehavioural aspects related to personal and social factors are perceived as more influential than in-game experiences.

Similar bias may occur when stakeholders do not take biological maturation into account when interpreting performance in young athletes, especially during growth and maturation processes, thereby causing the RAE (BILGIÇ and IŞIN, 2022; CARVALHO and GONÇALVES, 2023; COBLEY et al., 2009, RIBEIRO et al., 2020). This is a reflection of competitive structures where players are artificially grouped by chronological age based on a cut-off date. For example, participants may be born near or far from the determined date yet compete in the same category. In Brazilian basketball, for instance, the competitive age group is determined by the year players were born (between January 1st and December 31st). The RAE is present in the first competitive age groups, but tends to diminish in later stages of player development at different levels (ARRIETA et al., 2016; DE SUBIJANA and LORENZO, 2018). Since accumulated years do not bring advantages for the development of physical capacities, coaches could expect that the development of these capacities will occur according to advances in growth and development over the years. This suggests that coaches should spend more time teaching game aspects and perceptual-motor skills, which will provide better conditions for players to perform in older age groups, when neuromuscular aspects are expected to be better developed, rather than selecting players too early and thus limiting access to quality coaching and facilities in early ages.

The efforts to bring better conceptualization and guidelines for sport programs are great around the world (BERGERON et al., 2015; CÔTÉ and VIERIMAA, 2014; DIFIORI et al., 2018; LAPRADE et al., 2016). Recently, the Brazilian Olympic Committee published the *Sport Development Framework* (COMITÊ OLÍMPICO BRASILEIRO, 2023), based on a similar approach to provide sport organizations with guidelines and standards for their developmental programs. The Brazilian framework models the ideas previously discussed in this study and attempts to translate other countries' guidelines into Brazilian contexts and systems. Even while recognizing the influences of inter-individual differences, the recommendations for practical intervention still lack empirical evidence to promote adequate

interventions by coaches and other stakeholders. Taken together, the findings across studies affirm that youth sport participation cannot be reduced to the function of training volume or performance benchmarks alone. Rather, the athlete's experience is co-constructed within social, personal, pedagogical, and institutional structures. Coaches, parents, and sport managers must recognize their responsibility in promoting inclusive, developmentally appropriate environments that prioritize long-term engagement, well-being, and personal growth at both competitive and recreational levels. Practices should stimulate athletes to focus on learning new skills and developing their abilities while fostering positive and respectful relationships (MOULDS et al., 2022).

8.2. CHALLENGING THE ASSUMPTIONS ON EARLY SPECIALIZATION

There is still a lack of consensus about the definition of early specialization. Its robust conceptualization and definition could allow more objective and reliable comparisons between studies' findings in different contexts and samples.

The first empirical study demonstrated that early specialization and accumulated years of experience in specific training do not yield measurable advantages in physical capacity performance among adolescent basketball players. No significant differences were found between early and late specialized players in functional fitness performance variables such as vertical jump, sprint speed, and aerobic capacity. These findings challenge the prevailing assumption – rooted in the *deliberate practice framework* (ERICSSON et al., 1993) – that early intensive and specific training accelerates physical and physiological development. Instead, biological maturation (PHV status) explained much of the inter-individual variability, consistent with prior studies indicating that growth and maturity – not accumulated sport-specific hours – are stronger predictors of performance in youth athletes during childhood and adolescence (AREDE et al., 2019; AREDE et al., 2019; FORSMAN et al., 2016; MALINA et al., 2015).

Despite the widespread institutional adoption of early specialization as a strategic pillar in youth sport systems (BAKER et al., 2009; WIERSMA, 2000), longitudinal evidence to support its effectiveness remains scarce and contradictory. Moesch et al. (2011) and Güllich (2013) suggest that athletes who reach elite status often experience more diversified early sport exposure, delaying specialization until mid- or late adolescence. However, a question that may emerge relates to the causal effect of this phenomenon: Are elite athletes a consequence of the nurturing process of engaging in and practicing multiple modalities, or are they survivors of the

selection system due to their potential disposition? These findings question the validity of current early selection practices, particularly in settings like Brazil (POSSAMAI et al., 2024; RIBEIRO et al., 2021), where development models remain heavily influenced by performance expectations in adulthood. This influence leads to multiple biases and misinterpretations that may affect players' career progression and access to different opportunities (CARVALHO and GONÇALVES, 2023; GONÇALES et al., 2012).

Current consensus statements in youth sport highlight the potential links of sport specialization, particularly early specialization, with dropout and burnout in youth sport, and this concern is generalized to talent development contexts (BERGERON et al., 2015; CÔTÉ et al., 2009; LAPRADE et al., 2016). However, prior studies have shown that the predictors for dropout may be more related to environmental and relational settings than to the amount of time athletes spend practicing sport (MOSHER et al., 2020). Even so, while the continuity of adolescent players engaged in basketball practice through their adolescence years may be influenced by the age they began specialized training, it was observed that those who dropped out were the athletes who started later in basketball (LEONARDI et al., 2019; SOARES et al., 2020).

It has been noted that the perceived reasons for practitioners dropping out of sport participation were: (a) less support from their coaches, (b) more pressure to succeed in sport than from others, and (c) fewer friends in the sport. These reasons were mostly related to perceptions of competence and motivation. Athletes' perception of competence may also be influenced by technical skill competence (BIDAURRAZAGA-LETONA et al., 2019), which is related to their own perceptions as a consequence of the selection process throughout their career (BACK et al., 2022; MOULDS et al., 2022). Moreover, athletes' accumulated experience brings a higher perception of the context and influences the level of commitment young athletes have within sport practice (BACK et al., 2022; MOULDS et al., 2022). All these factors are likely directly related to other fields besides sport in athletes' lives, such as academic and professional perspectives and expectations (QUINAUD et al., 2022).

Based on our data, we verified that players who had earlier engagement in specific sport training did not have any advantages in physical fitness for basketball performance compared to their peers. While specialization per se was not associated with negative physical outcomes, it did not support the argument that earlier engagement guarantees enhanced performance. These findings lead us to reflect on youth sport training and the need to expose youngsters to high amounts of time and intense training loads, given that physical capacities tend to improve through the increase in chronological age, associated with biological

maturation processes. Our findings are limited by the interpretation of physical and physiological performance based on field tests. Further studies should also consider variations associated with perceptual-motor skills and in-game competencies, alongside the development, training-learning processes, and coaches' intervention.

Therefore, the assumption that early specialization may lead to dropout from sport participation was not confirmed in our findings. In our samples, achievement and competitiveness motivation, and the sources of enjoyment were not influenced by the timing of specialization, but by individual, social, and contextual characteristics. It may be reasonable to argue that sport specialization is not necessarily a predictor for lacking enjoyment or increasing the probability of dropping out of sport participation. Similar results were found in prior studies, where Larson et al. (2019) showed no associations between burnout and dropout with early specialization among young swimmers aged 12–13 years.

Thus, different influences – such as coach-athlete relationships, social and parental support, relationships with peers, and the alignment of achievement expectations with personal, professional, and social life dimensions – merit analysis from a more comprehensive perspective (e.g., a multidimensional approach). This would provide deeper insights into the links between dropout and enjoyment in talent development contexts.

8.3.A MULTIDIMENSIONAL UNDERSTANDING OF YOUTH ATHLETE DEVELOPMENT

The second and third studies of this thesis reinforced the view that athlete development cannot be fully understood through physical indicators alone. In the second study, Bayesian hierarchical models revealed that motivational profiles varied not only by individual characteristics (e.g., age, sex, accumulated training experience) but also by team context, pointing to the influence of psychosocial environments. Athletes with more accumulated experience tended to show higher levels of 'will to excel,' whereas younger and less experienced players displayed more competitive drive ('will to compete'). This shift in motivational orientation over time echoes theories of self-determination and achievement goals in sport (ISOARD-GAUTHEUR et al., 2013; VALLERAND and LOSIER, 1999) and supports findings that emphasize the role of perceived competence and autonomy support (FRASER-THOMAS et al., 2008).

In the third study, enjoyment was shown to be shaped by dynamic interactions between individual perceptions and contextual features, such as peer relationships, coaching behavior,

and match experiences. This is consistent with Bronfenbrenner's bioecological model (BRONFENBRENNER and MORRIS, 2007), in which developmental outcomes result from person–process–context–time interactions. Notably, athletes who reported higher levels of enjoyment were also more likely to continue participating in sport, as emotional well-being is a buffer against burnout and dropout (BACK et al., 2022).

Importantly, these two studies revealed that neither enjoyment nor motivation was strongly predicted by early specialization status or competitive setting, but rather by the social dynamics established within sport environments and contexts. These findings contradict widely held concerns that early specialization alone causes emotional exhaustion and dropout (JAYANTHI et al., 2015). Instead, they suggest that enjoyment is not simply a personal trait but emerges from dynamic interactions between the athlete and their environment, which over time play a more central role in shaping long-term engagement. Therefore, oversimplified claims about the dangers or benefits of early specialization fail to account for the complex, multidimensional nature of youth sport participation.

8.4.METHODOLOGICAL ADVANCES AND RESEARCH GAPS

It is clear that the body of evidence needs to overcome current limits in conceptual, methodological, and analytical approaches to provide higher quality information that can guide sport programs and coaches' decisions, and to plan interventions in youth populations, thereby bridging the gap between academic research and real-world sport settings.

This thesis employed a multidimensional and ecological approach to assess the development of youth basketball players, incorporating physical, psychological, and contextual variables across nested levels of analysis. One of the key methodological contributions was the adoption of a Bayesian hierarchical/multilevel modeling approach, which allowed for more robust estimations despite the small and selective samples typical of youth sport programs. This analytical strategy enabled the inclusion of contextual and individual-level covariates, thereby respecting the complex and nested structure of youth sport systems. Rather than relying solely on traditional inferential statistics, this thesis advanced toward a more flexible and integrative modeling framework that reflects the ecological realities of youth athlete development.

Another methodological innovation was the classification of the onset of specialization not simply by age, but by integrating contextual cues and self-reported training histories. In most empirical studies on youth sport specialization, age 12 is often used as a cut-off to distinguish early and late specializers. This threshold, widely adopted following Côté's DMSP

(CÔTÉ et al., 2009), presumes an universal developmental milestone. However, this assumption is problematic for at least two reasons. First, the choice of age 12 is arbitrary and culturally conditioned, reflecting the Canadian school system and sociocultural organization of sport in that context (CÔTÉ et al., 2009; CÔTÉ and VIERIMAA, 2014). This threshold aligns with the transition between elementary and secondary education in Canada and may not be appropriate in countries with different developmental, educational, or sport structures, such as Brazil. Second, biological maturation and the timing of peak height velocity vary significantly across individuals. Thus, fixed chronological markers may fail to capture the nuances of developmental timing and readiness for specialization (ARMSTRONG, 2018; MALINA et al., 2015).

In this thesis, the onset of specialization was established through a more context-sensitive lens, considering athletes' self-reported age of exclusive engagement in basketball, reduced participation in other sports, and year-round competition, all aligned with their biological maturity status. This refined operationalization of specialization advances the methodological rigor of studies in this area by accounting for the ecological specificity of participants. It further aligns with calls for contextualized and culturally informed definitions of specialization, especially in diverse and unequal environments such as Brazilian youth sport systems (LIMA et al. 2020; MOSHER et al., 2020).

Additionally, this study foregrounds the persistent gaps in longitudinal evidence regarding the effects of early specialization on physical, psychological, and motivational trajectories. While the debate around the risks and benefits of early specialization has grown, much of the literature remains inconclusive, fragmented, and dominated by single-dimension findings in cross-sectional designs. This thesis contributes to the field by examining these outcomes across a competitive season and by disaggregating effects by age, sex, and maturity status, thereby offering a more granular understanding of youth development dynamics.

The underrepresentation of female athletes and early age categories in the scientific literature should be addressed. Institutions and researchers are encouraged to prioritize inclusive sampling, ensure the visibility of diverse profiles, and tailor practices to the specific needs of different groups. The scoping review showed an underrepresentation of girls' samples in the scientific field. Differences between female and male player development lead to different rates of development and the timing at which it may occur. Specific knowledge on female populations demands a more in-depth comprehension, as there are specific needs and characteristics that should be considered in training interventions with female players (ANDREYO et al., 2025).

In alignment with the principles of open science and scientific transparency, the datasets and coding structures used in this thesis were made openly available in a public repository. This practice not only ensures the reproducibility and verifiability of analytical procedures but also fosters the possibility of reanalysis, meta-research, and broader collaborative use of the data. Making research data accessible are increasingly recognized as a scientific norm and a responsibility in publicly funded research, supporting the integrity, efficiency, and credibility of academic production (MUNAFÒ et al., 2017). By adopting an open data policy, this thesis contributes to the sustainable advancement of knowledge in youth sport research and invites critical engagement from the broader scientific community.

8.5.LIMITATIONS

Despite its contributions, this thesis also faces limitations. The samples were restricted to specific regional programs in Brazil, and some longitudinal analyses were constrained by interruptions caused by the COVID-19 pandemic. During this period, many of the programs were interrupted, and a substantial number of participants dropped out of participation in sport.

Other institutional relationship issues with sport organizations that participated in the studies limited the number of visits for data collection. These issues included the continuity of sport programs through the years, researchers' logistics, clubs' and associations' competitive schedules, and a lack of financial resources, which collectively limited more visits in some contexts.

The maturity offset method, though widely used, presents known limitations in accuracy, particularly during peak growth phases. This limitation emphasizes the need for continued refinement of analytical tools and the importance of methodological transparency in future research.

Caution is warranted when interpreting the findings of this study. The sample population was selected based on participation in specific sport programs, which introduces a potential bias and limits the generalizability of our results to a wider population of youth athletes. Therefore, it is important to study diverse populations at different levels of participation and competition.

9. CONCLUSION

The objective of this doctoral thesis was to investigate youth basketball development through a multidimensional and pedagogically grounded lens. Across four interrelated studies, the work addressed key themes such as early specialization, physical fitness development, achievement and competitiveness motivation, and sport enjoyment, highlighting how these elements interact within the broader context of youth sport formation. The findings underscore that youth basketball should not be viewed solely as a preparatory stage for high performance, but rather as a complex and dynamic educational process, deeply embedded within social, relational, and institutional environments.

By combining a scoping review, empirical analyses, and theoretical reflections, the thesis contributes to advancing the scientific understanding of youth sport in several ways. First, it maps the existing knowledge base and exposes critical methodological and thematic gaps in the scientific literature. Second, it challenges dominant assumptions about early specialization and physical advantages. Third, it reveals that motivational climates and interpersonal dynamics within sport institutions shape athletes' experiences and long-term engagement. Finally, it emphasizes that enjoyment, a key determinant of continued participation and personal growth, is more related to social and contextual dynamics and interactions than to exposure to training and competition specialization. Early specialization as a phenomenon in initial ages of sports participation did not bring physical fitness advantages for young basketball players, however it was not such negative as studies have discussed previously.

Together, these studies affirm the need for multidimensional, evidence-informed, and pedagogically oriented practices in youth basketball. The integration of physical, psychological, social, and contextual variables offers a more ecological and realistic view of sport development. Further studies should provide deeper insights into socioeconomical influences into young developmental patterns and better understand the inherent influences in pedagogical intervention and relationships.

This thesis reinforces the importance of research that transcends performance metrics and embraces the complexity of athlete development. It calls upon coaches, policymakers, and other stakeholders to reflect on their practices and to build youth sport environments that are not only effective but also provide opportunities for different kinds of people and expectations within ethical, equitable, and enjoyable environments, but also to provide adequate intervention with the athlete as the major focus on sports systems. Future investigations should continue to bridge the gap between scientific knowledge and practical implementation, ensuring that youth

basketball provides environments where young people can grow through effective intervention and practices, fostering their development not only as athletes but also as individuals.

REFERENCES

- ABBOTT, A. et al. Unnatural selection: talent identification and development in sport. **Nonlinear Dynamics, Psychology, and Life Sciences**, v. 9, n. 1, p. 61–88, Jan. 1st, 2005.
- AMES, C. Achievement goals, motivational climate, and motivational processes. In: ROBERTS, G. (ed). **Motivation in sport and exercise**. Champaign, IL, US, Human Kinetics Books: 161-176. 2005
- AMRHEIN, V.; TRAFIMOW, D.; GREENLAND, S. Inferential Statistics as Descriptive Statistics: There Is No Replication Crisis if We Don't Expect Replication. **The American Statistician**, v. 73, n. sup1, p. 262–270, 2019.
- ANDERSON, B.J. et al. Intensive training and sports specialization in young athletes. American Academy of Pediatrics. Committee on Sports Medicine and Fitness. **Pediatrics**, v. 106, n. 1 Pt 1, p. 154–157, July 1st, 2000.
- ANDREYO, E et al. A Needs Analysis and Training Considerations for Female Adolescent Basketball Players. **Strength and Conditioning Journal Japan**, v. 32, n. 5, p. 44–63, 2025.
- AREDE, J. et al. Physical conditioning of U16 national team players: mediator effect of previous sport experiences and strength and conditioning practices. **Journal of Human Sport and Exercise**, v. 14, n. 4, 19 jun. 2019.
- AREDE, J. et al. Jump higher, run faster: effects of diversified sport participation on talent identification and selection in youth basketball. **Journal of Sports Sciences**, v. 37, n. 19, p. 2220–2227, 4 jun. 2019.
- ARMSTRONG, N. **Development of the youth athlete**. London: Routledge, 2019.
- ARRIETA, H. et al. Relative age effect and performance in the U16, U18 and U20 European Basketball Championships. **Journal of Sports Sciences**, v. 34, n. 16, p. 1530–1534, 1 ago. 2016.
- BACK, J. et al. Drop-out from team sport among adolescents: A systematic review and meta-analysis of prospective studies. **Psychology of Sport and Exercise**, v. 61, n. 61, p. 102205, abr. 2022.
- BACK, J. et al. Psychosocial Predictors of Drop-Out from Organised Sport: A Prospective Study in Adolescent Soccer. **International Journal of Environmental Research and Public Health**, v. 19, n. 24, p. 16585, 9 dez. 2022.
- BAILEY, R.; COLLINS, D. The Standard Model of Talent Development and Its Discontents. **Kinesiology Review**, v. 2, n. 4, p. 248–259, nov. 2013.
- BAILEY, R. et al. Participant Development in Sport; An Academic Review. **SportsCoachUK**. 2010. Available in:

<<https://research.birmingham.ac.uk/en/publications/participant-development-in-sport-an-academic-review>>.

BAKER, J. **Early Specialization in Youth Sport: A requirement for adult expertise? High Ability Studies**. Vol. 14, No. 1. 2003. Available in:
<https://www.researchgate.net/publication/251213541_Early_Specialization_in_Youth_Sport_A_requirement_for_adult_expertise>.

BAKER, J.; COBLEY, S.; FRASER-THOMAS, J. What do we know about early sport specialization? Not much! **High Ability Studies**, v. 20, n. 1, p. 77–89, jun. 2009.

BAKER, J.; SCHORER, J.; WATTIE, N. Compromising Talent: Issues in Identifying and Selecting Talent in Sport. **Quest**, v. 70, n. 1, p. 48–63, 20 jul. 2018.

BAKER, J.; WATTIE, N. Innate talent in sport. **Current Issues in Sport Science (CISS)**, v. 3, 3 maio 2018.

BAKER, J.; WATTIE, N.; SCHORER, J. A proposed conceptualization of talent in sport: The first step in a long and winding road. **Psychology of Sport and Exercise**, v. 43, n. 1, p. 27–33, jul. 2019.

BAKER, J.; YOUNG, B. 20 years later: deliberate practice and the development of expertise in sport. **International Review of Sport and Exercise Psychology**, v. 7, n. 1, p. 135–157, jan. 2014.

BAKKER, F. C. et al. Motivation of young elite speed skaters. **International Journal of Sport Psychology**, p. 432–442, 1 jan. 1990.

BALISH, S.; CÔTÉ, J. The influence of community on athletic development: an integrated case study. **Qualitative Research in Sport, Exercise and Health**, v. 6, n. 1, p. 98–120, 7 fev. 2013.

BANGSBO, J.; IAIA, F. M.; KRUSTRUP, P. The Yo-Yo Intermittent Recovery Test. **Sports Medicine**, v. 38, n. 1, p. 37–51, 2008.

BARREIROS, A.; CÔTÉ, J.; FONSECA, A. M. From early to adult sport success: Analysing athletes' progression in national squads. **European Journal of Sport Science**, v. 14, n. sup1, p. S178–S182, 23 abr. 2012.

BARTH, M.; GÜLLICH, A.; EMRICH, E. The rich get richer and the poor get poorer - the Matthew mechanism as an approach to explain selection effects and the occurrence of multiple medalists in the “production” of international success in alpine ski racing. **Current Issues in Sport Science (CISS)**, 31 jul. 2018.

BELL, D. R. et al. Sport Specialization and Risk of Overuse Injuries: A Systematic Review With Meta-analysis. **Pediatrics**, v. 142, n. 3, p. e20180657, 22 ago. 2018.

BELL, D. R. et al. Prevalence of Sport Specialization in High School Athletics. **The American Journal of Sports Medicine**, v. 44, n. 6, p. 1469–1474, 26 fev. 2016.

BERGERON, M. F. et al. International Olympic Committee consensus statement on youth athletic development. **British journal of sports medicine**, v. 49, n. 13, p. 843–51, 2015.

BIDAURRAZAGA-LETONA, I. et al. Longitudinal Field Test Assessment in a Basque Soccer Youth Academy: A Multilevel Modeling Framework to Partition Effects of Maturation. **International Journal of Sports Medicine**, v. 36, n. 03, p. 234–240, 27 nov. 2014.

BIDAURRAZAGA-LETONA, I. et al. Progression in Youth Soccer. **Journal of Strength and Conditioning Research**, v. 33, n. 9, p. 2548–2558, set. 2019.

BILGIÇ, M.; IŞIN, A. Embarking on a journey: a bibliometric analysis of the relative age effect in sport science. **German Journal of Exercise and Sport Research**, 22 jan. 2022.

BOSCO, C.; LUHTANEN, P.; KOMI, P. V. A simple method for measurement of mechanical power in jumping. **European Journal of Applied Physiology and Occupational Physiology**, v. 50, n. 2, p. 273–282, jan. 1983.

BOYD, M. P.; YIN, Z. Cognitive-affective sources of sport enjoyment in adolescent sport participants. **Adolescence**, v. 31, n. 122, p. 383–395, 1996.

BRENNER, J. S. Sports Specialization and Intensive Training in Young Athletes. **PEDIATRICS**, v. 138, n. 3, p. e20162148–e20162148, 29 ago. 2016.

BRONFENBRENNER, U. Toward an experimental ecology of human development. **American Psychologist**, v. 32, n. 7, p. 513–531, 1977.

BRONFENBRENNER, U. **The Ecology of Human Development — Harvard University Press**. Available in: <<https://www.hup.harvard.edu/books/9780674224575>>.

BRONFENBRENNER, U. **Making human beings human: Bioecological perspectives on human development**. Thousand Oaks: Sage Publications, 2005.

BRONFENBRENNER, U.; CECI, S. J. Nature-nuture reconceptualized in developmental perspective: A bioecological model. **Psychological Review**, v. 101, n. 4, p. 568–586, 1994.

BRONFENBRENNER, U.; MORRIS, P. A. The Bioecological Model of Human Development. **Handbook of Child Psychology**, v. 1, n. 1, 1 jun. 2007.

BRYLINSKY, J. Practice Makes Perfect and Other Curricular Myths in the Sport Specialization Debate. **Journal of Physical Education, Recreation & Dance**, v. 81, n. 8, p. 22–25, out. 2010.

BUCKLEY, P. S. et al. Early Single-Sport Specialization: A Survey of 3090 High School, Collegiate, and Professional Athletes. **Orthopaedic Journal of Sports Medicine**, v. 5, n. 7, p. 232596711770394, jul. 2017.

BÜRKNER, P.-C. brms: An R Package for Bayesian Multilevel Models Using Stan. **Journal of Statistical Software**, v. 80, n. 1, 2017.

CAMPBELL, F. et al. Mapping reviews, scoping reviews, and evidence and gap maps (EGMs): the same but different— the “Big Picture” review family. **Systematic Reviews**, v. 12, n. 1, 15 mar. 2023.

CARVALHO, H. M. et al. Predictors of maximal short-term power outputs in basketball players 14-16 years. **European Journal of Applied Physiology**, v. 111, n. 5, p. 789–796, 1 maio 2011.

CARVALHO, H. M.; GONÇALVES, C. E. Coaching in Sports: Implications for Researchers and Coaches. **Springer eBooks**, p. 467–477, 1 jan. 2020.

CARVALHO, H. M.; CARLOS EDUARDO GONÇALVES. Mismatches in youth sports talent development. **Frontiers in sports and active living**, v. 5, 16 jun. 2023.

CARVALHO, H. M. et al. Growth, functional capacities and motivation for achievement and competitiveness in youth basketball: an interdisciplinary approach. **Journal of Sports Sciences**, v. 36, n. 7, p. 742–748, 12 jun. 2017.

CARVALHO, H. M. et al. Validity and usefulness of the Line Drill test for adolescent basketball players: a Bayesian multilevel analysis. **Research in Sports Medicine**, v. 25, n. 3, p. 333–344, 10 abr. 2017.

CARVALHO, H. M. et al. Pubertal development of body size and soccer-specific functional capacities in adolescent players. **Research in Sports Medicine**, v. 25, n. 4, p. 421–436, 17 ago. 2017.

CARVALHO, H. M. et al. Longitudinal Changes of Functional Capacities Among Adolescent Female Basketball Players. **Frontiers in Physiology**, v. 10, 4 abr. 2019.

CARVALHO, H. M. et al. Participation in the under-18 Euroleague Next Generation Tournament does not predict attaining NBA, Euroleague, or Eurocup. **International Journal of Sports Science & Coaching**, v. 18, n. 2, p. 523–531, 9 ago. 2022.

CATERISANO, A. et al. The Effects of a Basketball Season on Aerobic and Strength Parameters Among College Men: Starters vs. Reserves. **The Journal of Strength & Conditioning Research**, v. 11, n. 1, p. 21, 1 fev. 1997.

COAKLEY, J. The “Logic” of Specialization. **Journal of Physical Education, Recreation & Dance**, v. 81, n. 8, p. 16–25, out. 2010.

COBLEY, S. et al. Annual Age-Grouping and Athlete Development. **Sports Medicine**, v. 39, n. 3, p. 235–256, 2009.

COLLINS, D.; MACNAMARA, Á. The Rocky Road to the Top. **Sports Medicine**, v. 42, n. 11, p. 907–914, nov. 2012.

COMITÊ OLÍMPICO BRASILEIRO, **Modelo de Desenvolvimento Esportivo**. Available in: <<https://www.cob.org.br/time-brasil/modelo-de-desenvolvimento-esportivo>>. 2023.

CÔTÉ, J.; JENNIFER, M. M. The development of skill in sport. **Skill Acquisition in Sport**, p. 295–312, 25 jun. 2012.

CÔTÉ, J. et al. When “where” Is More Important than “when”: Birthplace and Birthdate Effects on the Achievement of Sporting Expertise. **Journal of Sports Sciences**, v. 24, n. 10, p. 1065–1073, out. 2006.

CÔTÉ, J.; LIDOR, R.; HACKFORT, D. ISSP Position stand: to Sample or to specialize? Seven Postulates about Youth Sport Activities That Lead to Continued Participation and Elite Performance. **International Journal of Sport and Exercise Psychology**, v. 7, n. 1, p. 7–17, jan. 2009.

CÔTÉ, J. et al. Youth sport research: Describing the integrated dynamic elements of the personal assets framework. **International Journal of Sport Psychology**, v. 51, n. 6, p. 562–578, 2020.

CÔTÉ, J.; VIERIMAA, M. The developmental model of sport participation: 15 years after its first conceptualization. **Science & Sports**, v. 29, n. 1, p. S63–S69, out. 2014.

CRANE, J.; TEMPLE, V. A systematic review of dropout from organized sport among children and youth. **European Physical Education Review**, v. 21, n. 1, p. 114–131, 31 out. 2015.

CUMMING, S. P. et al. Bio-banding in Sport: Applications to Competition, Talent Identification, and Strength and Conditioning of Youth Athletes. **Strength and Conditioning Journal**, v. 39, n. 2, p. 34–47, abr. 2017.

DAVIDS, K.; BUTTON, C.; BENNETT, S. **Dynamics of skill acquisition: A constraints-led approach**. Champaign, Il: Human Kinetics, 2008.

DE BOSSCHER, V. et al. **Successful Elite Sport Policies : an International Comparison of the Sports Policy Factors Leading to International Sporting Success (SPLISS 2.0) in 15 Nations**. Maidenhead: Meyer & Meyer Sports, 2015.

DE BOSSCHER, V. et al. A Conceptual Framework for Analysing Sports Policy Factors Leading to International Sporting Success. **European Sport Management Quarterly**, v. 6, n. 2, p. 185–215, jun. 2006.

DE BOSSCHER, V. et al. Explaining International Sporting success: an International Comparison of Elite Sport Systems and Policies in Six Countries. **Sport Management Review**, v. 12, n. 3, p. 113–136, ago. 2009.

DE BOSSCHER, V.; DE RYCKE, J. Talent development programmes: a retrospective analysis of the age and support services for talented athletes in 15 nations. **European Sport Management Quarterly**, v. 17, n. 5, p. 590–609, 13 jun. 2017.

BRUIN, A. B. H. et al. Deliberate practice predicts performance over time in adolescent chess players and drop-outs: A linear mixed models analysis. **British Journal of Psychology**, v. 99, n. 4, p. 473–497, nov. 2008.

DE BRUIN, A. B. H.; RIKERS, R. M. J. P.; SCHMIDT, H. G. The Influence of Achievement Motivation and Chess-Specific Motivation on Deliberate Practice. **Journal of Sport and Exercise Psychology**, v. 29, n. 5, p. 561–583, out. 2007.

BRUIN, A. B. H. et al. Deliberate practice predicts performance over time in adolescent chess players and drop-outs: A linear mixed models analysis. **British Journal of Psychology**, v. 99, n. 4, p. 473–497, nov. 2008.

DE SUBIJANA, C. L.; LORENZO, J. Relative Age Effect and Long-Term Success in the Spanish Soccer and Basketball National Teams. **Journal of Human Kinetics**, v. 65, n. 1, p. 197–204, 31 dez. 2018.

DELORME, N.; RADEL, R.; RASPAUD, M. Relative age effect and soccer refereeing: A “Strategic Adaptation” of relatively younger children? **European Journal of Sport Science**, v. 13, n. 4, p. 400–406, jul. 2013.

DIEZ-ROUX, A. V. Bringing context back into epidemiology: variables and fallacies in multilevel analysis. **American Journal of Public Health**, v. 88, n. 2, p. 216–222, fev. 1998.

DIFIORI, J. P. et al. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. **British Journal of Sports Medicine**, v. 48, n. 4, p. 287–288, 24 jan. 2014.

DIFIORI, J. P. et al. The NBA and Youth Basketball: Recommendations for Promoting a Healthy and Positive Experience. **Sports Medicine**, v. 48, n. 9, p. 2053–2065, 30 jun. 2018.

DISANTI, J. S.; ERICKSON, K. Youth sport specialization: a multidisciplinary scoping systematic review. **Journal of Sports Sciences**, v. 37, n. 18, p. 2094–2105, 28 maio 2019.

DISANTI, J. S.; ERICKSON, K. Challenging our understanding of youth sport specialization: an examination and critique of the literature through the lens of Bronfenbrenner’s Person-Process-Context-Time Model. **International Review of Sport and Exercise Psychology**, v. 14, n. 1, p. 1–23, 24 fev. 2020.

DOWNING, C.; REDELIUS, K.; SANNA NORDIN-BATES. A systematic review of quantitative studies concerning psychological aspects of early specialisation. **International journal of sport and exercise psychology**, p. 1–27, 19 set. 2023.

DRINKWATER, E. J. et al. Characterizing changes in fitness of basketball players within and between seasons. **International Journal of Performance Analysis in Sport**, v. 5, n. 3, p. 107–125, dez. 2005.

DRINKWATER, E. J.; PYNE, D. B.; MCKENNA, M. J. Design and Interpretation of Anthropometric and Fitness Testing of Basketball Players. **Sports Medicine**, v. 38, n. 7, p. 565–578, 2008.

DUARTE, M. DE F. DA S. Maturação física: uma revisão da literatura, com especial atenção à criança brasileira. **Cadernos de Saúde Pública**, v. 9, n. suppl 1, p. S71–S84, 1993.

DUDA, J. L.; NICHOLLS, J. G. Dimensions of achievement motivation in schoolwork and sport. **Journal of Educational Psychology**, v. 84, n. 3, p. 290–299, 1992.

ELFERINK-GEMSER, M. et al. Relation between multidimensional performance characteristics and level of performance in talented youth field hockey players. **Journal of Sports Sciences**, v. 22, n. 11-12, p. 1053–1063, nov. 2004.

ELFERINK-GEMSER, M. T. et al. Multidimensional performance characteristics and standard of performance in talented youth field hockey players: A longitudinal study. **Journal of Sports Sciences**, v. 25, n. 4, p. 481–489, 15 fev. 2007.

ERICSSON, K. A.; KRAMPE, R. T.; TESCH-RÖMER, C. The role of deliberate practice in the acquisition of expert performance. **Psychological Review**, v. 100, n. 3, p. 363–406, 1993.

EVELETH, P. B.; TANNER, J. M. **Worldwide variation in human growth**. Cambridge ; New York ; Port Chester: Cambridge University Press, 1990.

FABRICANT, P. D. et al. Youth sports specialization and musculoskeletal injury: a systematic review of the literature. **The Physician and Sportsmedicine**, v. 44, n. 3, p. 257–262, 3 maio 2016.

FARMER, H. S. Model of career and achievement motivation for women and men. **Journal of Counseling Psychology**, v. 32, n. 3, p. 363–390, 1985.

FERIOLI, D. et al. Seasonal changes in physical capacities of basketball players according to competitive levels and individual responses. **PLOS ONE**, v. 15, n. 3, p. e0230558, 19 mar. 2020.

FIGUEIREDO, A. J. et al. Characteristics of youth soccer players who drop out, persist or move up. **Journal of Sports Sciences**, v. 27, n. 9, p. 883–891, jul. 2009.

FORD, P. R. et al. The Role of Deliberate Practice and Play in Career Progression in sport: the Early Engagement Hypothesis. **High Ability Studies**, v. 20, n. 1, p. 65–75, jun. 2009.

FORSMAN, H. et al. The role of sport-specific play and practice during childhood in the development of adolescent Finnish team sport athletes. **International Journal of Sports Science & Coaching**, v. 11, n. 1, p. 69–77, fev. 2016.

FRASER-THOMAS, J.; CÔTÉ, J.; DEAKIN, J. Understanding dropout and prolonged engagement in adolescent competitive sport. **Psychology of Sport and Exercise**, v. 9, n. 5, p. 645–662, set. 2008.

GABRY, J. et al. Visualization in Bayesian workflow. **Journal of the Royal Statistical Society: Series A (Statistics in Society)**, v. 182, n. 2, p. 389–402, 2019.

GARCIA-MAS, A. et al. Análisis de las relaciones entre la motivación, el clima motivacional y la ansiedad competitiva en jóvenes jugadores de equipo mediante una red Bayesiana. **Anales de Psicología**, v. 31, n. 1, 1 jan. 2015.

GARCÍA-RUBIO, J. et al. From Junior to Elite in Soccer: Exploring the Relative Age Effect and Talent Selection in Spanish Youth National Teams. **Children**, v. 9, n. 10, p. 1543, 10 out. 2022.

GARCÍA, M. S. et al. Relative age effect in lower categories of international basketball. **International Review for the Sociology of Sport**, v. 49, n. 5, p. 526–535, 30 out. 2012.

HEWSON, P. Bayesian Data Analysis 3rd ed. In: A. Gelman, J. B. Carlin, H. S. Stern, D. B. Dunson, A. Vehtari and D. B. Rubin, 2013 Boca Raton, Chapman and Hall-CRC 676 pp., £44.99 ISBN 1-439-84095-4. **Journal of the Royal Statistical Society: Series A (Statistics in Society)**, v. 178, n. 1, p. 301–301, 12 dez. 2014.

GELMAN, A. B.; HILL, J. **Data analysis using regression and multilevel/hierarchical models**. Cambridge ; New York: Cambridge University Press, 2006.

GELMAN, A.; HILL, J.; YAJIMA, M. Why We (Usually) Don't Have to Worry About Multiple Comparisons. **Journal of Research on Educational Effectiveness**, v. 5, n. 2, p. 189–211, abr. 2012.

GIL, S. M. et al. The relative age effect in young athletes: A countywide analysis of 9–14-year-old participants in all competitive sports. **PLOS ONE**, v. 16, n. 7, p. e0254687, 16 jul. 2021.

GILL, D. L.; DZEWALTOWSKI, D. A.; DEETER, T. E. The Relationship of Competitiveness and Achievement Orientation to Participation in Sport and Nonsport Activities. **Journal of Sport and Exercise Psychology**, v. 10, n. 2, p. 139–150, jun. 1988.

GLATTHORN, J. F. et al. Validity and Reliability of Optojump Photoelectric Cells for Estimating Vertical Jump Height. **Journal of Strength and Conditioning Research**, v. 25, n. 2, p. 556–560, fev. 2011.

GOLDSTEIN, H. Efficient statistical modelling of longitudinal data. **Annals of Human Biology**, v. 13, n. 2, p. 129–141, jan. 1986.

GONÇALVES, C. E. B.; RAMA, L. M. L.; FIGUEIREDO, A. B. Talent Identification and Specialization in Sport: An Overview of Some Unanswered Questions. **International Journal of Sports Physiology and Performance**, v. 7, n. 4, p. 390–393, dez. 2012.

GONÇALVES, C. E.; CARVALHO, H. M. Revisiting the Relative Age Effect From a Multidisciplinary Perspective in Youth Basketball: A Bayesian Analysis. **Frontiers in Sports and Active Living**, v. 2, 2 fev. 2021.

GONÇALVES, C. E. et al. Why do They Engage in Such Hard Programs? The Search for Excellence in Youth Basketball. **Journal of Sports Science & Medicine**, v. 10, n. 3, p. 458, set. 2011.

GONÇALVES, C. E. B.; RAMA, L. M. L.; FIGUEIREDO, A. B. Talent Identification and Specialization in Sport: An Overview of Some Unanswered Questions. **International Journal of Sports Physiology and Performance**, v. 7, n. 4, p. 390–393, dez. 2012.

GONZALEZ, A. M. et al. Performance Changes in NBA Basketball Players Vary in Starters vs. Nonstarters Over a Competitive Season. **Journal of Strength and Conditioning Research**, v. 27, n. 3, p. 611–615, mar. 2013.

GONZALEZ, A. M. et al. Performance Changes in National Collegiate Athletic Association Division I Women Basketball Players During a Competitive Season. **Journal of Strength and Conditioning Research**, v. 26, n. 12, p. 3197–3203, dez. 2012.

GRAINGER, A. et al. “Athletes”, “Talents”, and “Players”: Conceptual Distinctions and Considerations for Researchers and Practitioners. **Sports Medicine**, 29 ago. 2024.

GUIMARÃES, E. et al. The role of growth, maturation and sporting environment on the development of performance and technical and tactical skills in youth basketball players: The INEX study. **Journal of Sports Sciences**, p. 1–13, 23 nov. 2020.

GÜLLICH, A. Selection, de-selection and progression in German football talent promotion. **European Journal of Sport Science**, v. 14, n. 6, p. 530–537, 19 nov. 2013.

GÜLLICH, A. Sport-specific and non-specific practice of strong and weak responders in junior and senior elite athletics – A matched-pairs analysis. **Journal of Sports Sciences**, v. 36, n. 19, p. 2256–2264, 9 mar. 2018.

GÜLLICH, A.; BARTH, M. Effects of Early Talent Promotion on Junior and Senior Performance: A Systematic Review and Meta-Analysis. **Sports Medicine**, 3 nov. 2023.

HADDAWAY, N. R. et al. PRISMA2020: an R Package and Shiny App for Producing PRISMA 2020-compliant Flow diagrams, with Interactivity for Optimised Digital Transparency and Open Synthesis. **Campbell Systematic Reviews**, v. 18, n. 2, 27 mar. 2022.

HARTER, S. Effectance Motivation Reconsidered Toward a Developmental Model. **Human Development**, v. 21, n. 1, p. 34–64, 1978.

HEDSTRÖM, P.; YLIKOSKI, P. Causal Mechanisms in the Social Sciences. **Annual Review of Sociology**, v. 36, n. 1, p. 49–67, jun. 2010.

HELMREICH, R. L. et al. Achievement Motivation and Scientific Attainment. **Personality and Social Psychology Bulletin**, v. 4, n. 2, p. 222–226, abr. 1978.

HERMAN, D. C. et al. Systematic Review of Health Organization Guidelines Following the AMSSM 2019 Youth Early Sport Specialization Summit. **Sports Health: A Multidisciplinary Approach**, p. 194173812110513, 20 out. 2021.

HILL, G. M.; SIMONS, J. A Study of the Sport Specialization on High School Athletics. **Journal of Sport and Social Issues**, v. 13, n. 1, p. 1–13, mar. 1989.

HOWE, M. J. A.; DAVIDSON, J. W.; SLOBODA, J. A. Innate talents: reality or myth? - White Rose Research Online. **Whiterose.ac.uk**, jun. 1998.

ISOARD-GAUTHEUR, S.; GUILLET-DESCAS, E.; DUDA, J. L. How to achieve in elite training centers without burning out? An achievement goal theory perspective. **Psychology of Sport and Exercise**, v. 14, n. 1, p. 72–83, jan. 2013.

JAYANTHI, N. et al. Sports Specialization in Young Athletes. **Sports Health: A Multidisciplinary Approach**, v. 5, n. 3, p. 251–257, 25 out. 2013.

JAYANTHI, N. A. et al. Sports-Specialized Intensive Training and the Risk of Injury in Young Athletes. **The American Journal of Sports Medicine**, v. 43, n. 4, p. 794–801, 2 fev. 2015.

JAYANTHI, N. A. et al. Health Consequences of Youth Sport Specialization. **Journal of Athletic Training**, v. 54, n. 10, p. 1040–1049, out. 2019.

JOHNSTON, K. et al. Talent Identification in Sport: A Systematic Review. **Sports Medicine**, v. 48, n. 1, p. 97–109, 29 out. 2018.

JONES, B. D.; LAWRENCE, G. P.; HARDY, L. New evidence of relative age effects in “super-elite” sportsmen: a case for the survival and evolution of the fittest. **Journal of Sports Sciences**, v. 36, n. 6, p. 697–703, 19 jun. 2017.

JUDD, C. M.; WESTFALL, J.; KENNY, D. A. Experiments with More Than One Random Factor: Designs, Analytic Models, and Statistical Power. **Annual Review of Psychology**, v. 68, n. 1, p. 601–625, 3 jan. 2017.

KALÉN, A. et al. The influence of initial selection age, relative age effect and country long-term performance on the re-selection process in European basketball youth national teams. **Journal of Sports Sciences**, p. 1–7, 30 set. 2020.

KALÉN, A. et al. Talent Selection Strategies and Relationship With Success in European Basketball National Team Programs. **Frontiers in Psychology**, v. 12, 11 jun. 2021.

KALÉN, A. et al. Senior and youth national team competitive experience: influence on player and team performance in European basketball championships. **International Journal of Performance Analysis in Sport**, v. 17, n. 6, p. 832–847, 2 nov. 2017.

KALETH, A. S.; MIKESKY, A. E. Impact of Early Sport Specialization. **Journal of Physical Education, Recreation & Dance**, v. 81, n. 8, p. 29–37, out. 2010.

KAY, M. Tidy Data and “Geoms” for Bayesian Models [R package tidybayes version 3.0.7]. **R-project.org**, 15 set. 2024.

KEMPER, H. C. G. et al. A fifteen-year longitudinal study in young adults on the relation of physical activity and fitness with the development of the bone mass: the Amsterdam Growth and Health Longitudinal Study. **Bone**, v. 27, n. 6, p. 847–853, dez. 2000.

KIMIECIK, J. C.; HARRIS, A. T. What Is Enjoyment? A Conceptual/Definitional Analysis with Implications for Sport and Exercise Psychology. **Journal of Sport and Exercise Psychology**, v. 18, n. 3, p. 247–263, set. 1996.

KOZIEŁ, S. M.; MALINA, R. M. Modified Maturity Offset Prediction Equations: Validation in Independent Longitudinal Samples of Boys and Girls. **Sports Medicine**, v. 48, n. 1, p. 221–236, 12 jun. 2017.

KRUSCHKE, J. K. What to believe: Bayesian methods for data analysis. **Trends in Cognitive Sciences**, v. 14, n. 7, p. 293–300, jul. 2010.

KRUSCHKE, J. K. Bayesian Analysis Reporting Guidelines. **Nature Human Behaviour**, 16 ago. 2021.

KRUSTRUP, P. et al. The Yo-Yo Intermittent Recovery Test: Physiological Response, Reliability, and Validity. **Medicine & Science in Sports & Exercise**, v. 35, n. 4, p. 697–705, abr. 2003.

LAPRADE, R. F. et al. AOSSM Early Sport Specialization Consensus Statement. **Orthopaedic Journal of Sports Medicine**, v. 4, n. 4, p. 232596711664424, 28 abr. 2016.

LARKIN, P.; REEVES, M. J. Junior-elite football: time to re-position talent identification? **Soccer & Society**, v. 19, n. 8, p. 1–10, 31 jan. 2018.

LARKIN, P. et al. Talent identification in youth basketball: Talent scouts' perceptions of the key attributes for athlete development. **International Sport Coaching Journal**, v. 10, n. 2, p. 1–9, 2022.

LARSON, H. K. et al. Markers of Early Specialization and Their Relationships With Burnout and Dropout in Swimming. **Journal of Sport and Exercise Psychology**, v. 41, n. 1, p. 46–54, fev. 2019.

LEITE, N. et al. The Influence of Contextual Aspects in Talent Development: Interaction Between Relative Age and Birthplace Effects in NBA-Drafted Players. **Frontiers in Sports and Active Living**, v. 3, 22 mar. 2021.

LEONARDI, T. J. et al. Biological maturation, training experience, body size and functional capacity of adolescent female basketball players: A Bayesian analysis. **International Journal of Sports Science & Coaching**, v. 13, n. 5, p. 713–722, 22 abr. 2018.

LIDDELL, T. M.; KRUSCHKE, J. K. Analyzing ordinal data with metric models: What could possibly go wrong? **Journal of Experimental Social Psychology**, v. 79, p. 328–348, 1 nov. 2018.

LIMA, A. B. et al. Deliberate Practice, Functional Performance and Psychological Characteristics in Young Basketball Players: A Bayesian Multilevel Analysis. **International Journal of Environmental Research and Public Health**, v. 17, n. 11, p. 4078, 1 jun. 2020.

LIMA, A. B. et al. Longitudinal Meta-Analysis of Peak Height Velocity in Young Female Athletes. **Cureus**, 1 maio 2024.

LLOYD, R. S. et al. National Strength and Conditioning Association Position Statement on Long-Term Athletic Development. **Journal of Strength and Conditioning Research**, v. 30, n. 6, p. 1491–1509, jun. 2016.

LOGAN, K.; CUFF, S. Organized Sports for Children, Preadolescents, and Adolescents. **Pediatrics**, v. 143, n. 6, p. e20190997, 2019.

PELLETIER, D. Anthropometric standardization reference manual: Abridged edition. Edited by T.G. Lohman, A.F. Roche, and R. Martorell. vi + 90 pp. Champaign, IL: Human Kinetics Books. 1991. **American Journal of Human Biology**, v. 4, n. 3, p. 425–425, 1992.

MAAYAN, Z.; LIDOR, R.; ARNON, M. The Birthplace Effect in 14–18-Year-Old Athletes Participating in Competitive Individual and Team Sports. **Sports**, v. 10, n. 4, p. 59, 11 abr. 2022.

MACDONALD, D. J. et al. The Role of Enjoyment and Motivational Climate in Relation to the Personal Development of Team Sport Athletes. **The Sport Psychologist**, v. 25, n. 1, p. 32–46, mar. 2011.

MADARAME, H. Age and sex differences in game-related statistics which discriminate winners from losers in elite basketball games. **Motriz: Revista de Educação Física**, v. 24, n. 1, 1 fev. 2018.

MADARAME, H. Are regional differences in basketball already established in under-18 games? **Motriz: Revista de Educação Física**, v. 24, n. 3, 3 dez. 2018.

MALINA, R. M. Physical growth and biological maturation of young athletes. **Exercise and Sport Sciences Reviews**, v. 22, p. 389–433, 1994.

MALINA, R. M.; BOUCHARD, C.; BEUNEN, G. Human Growth: Selected Aspects of Current Research on Well-Nourished Children. **Annual Review of Anthropology**, v. 17, n. 1, p. 187–219, out. 1988.

MALINA, R. M. et al. Maturity Offset in Gymnasts. **Medicine & Science in Sports & Exercise**, v. 38, n. 7, p. 1342–1347, jul. 2006.

MALINA, R. M. et al. Characteristics of youth soccer players aged 13–15 years classified by skill level. **British Journal of Sports Medicine**, v. 41, n. 5, p. 290–295, 29 jan. 2007.

MALINA, R. M. et al. Biological maturation of youth athletes: assessment and implications. **British Journal of Sports Medicine**, v. 49, n. 13, p. 852–859, 17 jun. 2015.

KAWAMORI, N.; HAFF, G. G. The optimal training load for the development of muscular power. **Journal of Strength and Conditioning Research**, v. 18, n. 3, p. 675–684, 1 ago. 2004.

MAZZEI, L. C. et al. Política do esporte de alto rendimento no Brasil: Análise da estratégia de investimentos nas confederações olímpicas. **Revista Portuguesa de Ciências do Desporto**, v. 14, n. 2, p. 58–73, 2025.

MCAULEY, A. B. T.; BAKER, J.; KELLY, A. L. Defining “elite” status in sport: from chaos to clarity. **German Journal of Exercise and Sport Research**, v. 52, 5 ago. 2021.

MCCARTHY, N.; COLLINS, D.; COURT, D. Start hard, finish better: further evidence for the reversal of the RAE advantage. **Journal of Sports Sciences**, v. 34, n. 15, p. 1461–1465, 14 dez. 2015.

MCCARTHY, P. J.; JONES, M. V.; CLARK-CARTER, D. Understanding enjoyment in youth sport: A developmental perspective. **Psychology of Sport and Exercise**, v. 9, n. 2, p. 142–156, mar. 2008.

MCELREATH, R. **Statistical rethinking : a Bayesian course with examples in R and Stan**. Boca Raton: Crc Press/Taylor & Francis Group, 2016.

MCELREATH, R.; KOSTER, J. Using Multilevel Models to Estimate Variation in Foraging Returns. **Human Nature**, v. 25, n. 1, p. 100–120, 13 fev. 2014.

MCGARRY, T.; O'DONOGHUE, P.; SAMPAIO, J. **Routledge handbook of sports performance analysis**. New York: Routledge, 2013.

MCMANUS, A. M.; ARMSTRONG, N. Physiology of Elite Young Female Athletes. **The Elite Young Athlete**, p. 23–46, 2010.

MENDES, F. G. et al. Multidimensional characteristics of young Brazilian volleyball players: A Bayesian multilevel analysis. **PLOS ONE**, v. 16, n. 4, p. e0250953, 30 abr. 2021.

MENDES, F. G. et al. Retrospective analysis of accumulated structured practice: A Bayesian multilevel analysis of elite Brazilian volleyball players. **High Ability Studies**, v. 29, n. 2, p. 255–269, 3 jul. 2018.

MENGERSEN, K. L. et al. Bayesian Estimation of Small Effects in Exercise and Sports Science. **PLOS ONE**, v. 11, n. 4, p. e0147311, 13 abr. 2016.

MESQUIDA, C. et al. Replication concerns in sports and exercise science: a narrative review of selected methodological issues in the field. **Royal Society Open Science**, v. 9, n. 12, dez. 2022.

MIGUEL, C. G. et al. Developmental changes in the physical fitness of young female and male basketball players: a Bayesian analysis. **The Journal of Sports Medicine and Physical Fitness**. 2025.

MIRWALD, R. L. et al. An assessment of maturity from anthropometric measurements. **Medicine & Science in Sports & Exercise**, v. 34, n. 4, p. 689–694, abr. 2002.

MOESCH, K. et al. Late specialization: the key to success in centimeters, grams, or seconds (cgs) sports. **Scandinavian Journal of Medicine & Science in Sports**, v. 21, n. 6, p. e282–e290, 15 mar. 2011.

MONTGOMERY, P. G. et al. Seasonal progression and variability of repeat-effort line-drill performance in elite junior basketball players. **Journal of Sports Sciences**, v. 26, n. 5, p. 543–550, mar. 2008.

MOORE, S. A. et al. Enhancing a Somatic Maturity Prediction Model. **Medicine & Science in Sports & Exercise**, v. 47, n. 8, p. 1755–1764, ago. 2015.

MOSEID, C. H. et al. The association between early specialization and performance level with injury and illness risk in youth elite athletes. **Scandinavian Journal of Medicine & Science in Sports**, v. 29, n. 3, p. 460–468, 6 dez. 2018.

MOSEID, C. H. et al. The prevalence and severity of health problems in youth elite sports: A 6-month prospective cohort study of 320 athletes. **Scandinavian Journal of Medicine & Science in Sports**, v. 28, n. 4, p. 1412–1423, 19 fev. 2018.

MOSEID, C. H. et al. The association between physical fitness level and number and severity of injury and illness in youth elite athletes. **Scandinavian Journal of Medicine & Science in Sports**, v. 29, n. 11, p. 1736–1748, jul. 2019.

MOSHER, A.; FRASER-THOMAS, J.; BAKER, J. What Defines Early Specialization: A Systematic Review of Literature. **Frontiers in Sports and Active Living**, v. 2, 27 out. 2020.

MOSHER, A. et al. Revisiting Early Sport Specialization: What's the Problem? **Sports Health: A Multidisciplinary Approach**, v. 14, n. 1, p. 194173812110497, 15 out. 2021.

MUNAFÒ, M. R. et al. A manifesto for reproducible science. **Nature Human Behaviour**, v. 1, n. 1, jan. 2017.

MURRAY, R. M.; SABISTON, C. M. Understanding Relationships Between Social Identity, Sport Enjoyment, and Dropout in Adolescent Girl Athletes. **Journal of Sport and Exercise Psychology**, v. 44, n. 1, p. 1–5, 2021.

MYER, G. D. et al. Sport Specialization, Part I. **Sports Health: A Multidisciplinary Approach**, v. 7, n. 5, p. 437–442, 6 ago. 2015.

NAVARRO, J. L. et al. Bored of the rings: Methodological and analytic approaches to operationalizing Bronfenbrenner's PPCT model in research practice. **Journal of Family Theory & Review**, v. 14, n. 2, p. 233–253, jun. 2022.

NICHOLLS, J. G. **The competitive ethos and democratic education**. Cambridge, Mass.: Harvard U.P., 1989.

OPEN SCIENCE COLLABORATION. Estimating the reproducibility of psychological science. **Science**, v. 349, n. 6251, 28 ago. 2015.

OSTOJIC, S. M. et al. The biological age of 14-year-old boys and success in adult soccer: do early maturers predominate in the top-level game? **Research in Sports Medicine (Print)**, v. 22, n. 4, p. 398–407, 2014.

OUZZANI, M. et al. Rayyan—a Web and Mobile App for Systematic Reviews. **Systematic Reviews**, v. 5, n. 1, dez. 2016.

PASULKA, J. et al. Specialization patterns across various youth sports and relationship to injury risk. **The Physician and Sportsmedicine**, v. 45, n. 3, p. 344–352, 10 abr. 2017.

PEARSON, D. T.; NAUGHTON, G. A.; TORODE, M. Predictability of physiological testing and the role of maturation in talent identification for adolescent team sports. **Journal of Science and Medicine in Sport**, v. 9, n. 4, p. 277–287, 1 ago. 2006.

POSSAMAI, K.; QUINAUD, R. T.; CARVALHO, H. M.. Tendências de participação esportiva de jovens atletas de basquetebol de Santa Catarina. **Revista Brasileira de Ciências do Esporte**, v. 46, 1 jan. 2024.

POST, E. G. et al. Sport-Specific Associations of Specialization and Sex With Overuse Injury in Youth Athletes. **Sports Health: A Multidisciplinary Approach**, v. 12, n. 1, p. 194173811988685, 14 nov. 2019.

QUINAUD, R. T. et al. The positive impact of sports participation on life skills' development: a qualitative study with medical students. **Sport in Society**, v. 26, n. 4, p. 1–16, 2 fev. 2022.

RAMOS, S. et al. Training Experience and Maturation, Morphological, and Fitness Attributes as Individual Performance Predictors in Male and Female Under-14 Portuguese Elite Basketball Players. **Journal of Strength and Conditioning Research**, p. 1, fev. 2019.

RIAZA, A. R. et al. Impact of the Relative Age Effect on Competition Performance in Basketball: A Qualitative Systematic Review. **International Journal of Environmental Research and Public Health**, v. 17, n. 22, p. 8596, 19 nov. 2020.

RIBEIRO JUNIOR, D. B. et al. From Talent Identification to Novo Basquete Brasil (NBB): Multifactorial Analysis of the Career Progression in Youth Brazilian Elite Basketball. **Frontiers in Psychology**, v. 12, 16 mar. 2021.

RIBEIRO JUNIOR, D. B. et al. The relative age effect on normo-stature and higher stature individuals in youth Brazilian basketball. **E-Balónmano.Com**, 16(1), 2020. Available in: <<https://revista-ebalonmano.unex.es/index.php/ebalonmano/article/view/2496/2226>>. Accessed: June 15th 2025.

ROGERS, M. et al. Player Profiling and Monitoring in Basketball: A Delphi Study of the Most Important Non-Game Performance Indicators from the Perspective of Elite Athlete Coaches. **Sports Medicine**, 5 nov. 2021.

RYAN, R. M.; DECI, E. L. Self-determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-being. **American Psychologist**, v. 55, n. 1, p. 68–78, jan. 2000.

SANTOS, A. J.; GONÇALVES, C. E. Tradução do Sources of enjoyment in youth sport questionnaire do development assents profile para jovens atletas portugueses. **Annals of Research in Sport and Physical Activity**, n. 3, p. 9–36, 2012.

DOS SANTOS, A. J. B.; GONÇALVES, C. E. B. Efeito da experiência desportiva e do grupo etário na satisfação e nos ativos de desenvolvimento de jovens futebolistas. **Revista Brasileira de Ciências do Esporte**, v. 38, n. 2, p. 139–148, abr. 2016.

SCANLAN, T. K. et al. Sources of Enjoyment for Youth Sport Athletes. **Pediatric Exercise Science**, v. 5, n. 3, p. 275–285, ago. 1993.

SCANLAN, T. K.; LEWTHWAITE, R. Social Psychological Aspects of Competition for Male Youth Sport Participants: IV. Predictors of Enjoyment. **Journal of Sport Psychology**, v. 8, n. 1, p. 25–35, mar. 1986.

SCANLAN, T. K.; RAVIZZA, K.; STEIN, G. L. An In-depth Study of Former Elite Figure Skaters: I. Introduction to the Project. **Journal of Sport and Exercise Psychology**, v. 11, n. 1, p. 54–64, mar. 1989.

SCHROEPF, B.; LAMES, M. Career patterns in German football youth national teams – A longitudinal study. **International Journal of Sports Science & Coaching**, v. 13, n. 3, p. 405–414, 30 ago. 2017.

SEDEAUD, A. et al. Talent Identification: Time to Move Forward on Estimation of Potentials? Proposed Explanations and Promising Methods. **Sports Medicine**, 15 jan. 2025.

SEMENICK, D. Tests and measurements: the Line Drill test. **Strength & Conditioning Journal**. 1990

SMALDINO, P. E.; MCELREATH, R. The natural selection of bad science. **Royal Society Open Science**, v. 3, n. 9, p. 160384, set. 2016.

SMITH, A. D. et al. Early Sports Specialization: An International Perspective. **Current Sports Medicine Reports**, v. 16, n. 6, p. 439–442, 2017.

SMITH, M. M. Early Sport Specialization: A Historical Perspective. **Kinesiology Review**, v. 4, n. 3, p. 220–229, ago. 2015.

SOARES, A. A. L. et al. Does early specialization provide an advantage in physical fitness development in youth basketball? **Frontiers in Sports and Active Living**, v. 4, 10 jan. 2023.

SOARES, A. L. A. et al. Determinants of drop-out in youth basketball: an interdisciplinary approach. **Research in Sports Medicine**, v. 28, n. 1, p. 84–98, 5 mar. 2019.

SOARES, A. L. A. et al. Variabilidade do desempenho no Line-Drill test em adolescentes jogadores de basquetebol. **Revista Brasileira de Medicina do Esporte**, v. 22, n. 6, p. 445–449, 1 dez. 2016.

SOARES, A. L. A. et al. Performance, motivation, and enjoyment in young female basketball players: An interdisciplinary approach. **Journal of Sports Sciences**, v. 38, n. 8, p. 873–885, 5 mar. 2020.

SPENCER, R. A.; REHMAN, L.; KIRK, S. F. Understanding gender norms, nutrition, and physical activity in adolescent girls: a scoping review. **International Journal of Behavioral Nutrition and Physical Activity**, v. 12, n. 1, 24 jan. 2015.

STEINGRÖVER, C. et al. Does Relative Age Affect Career Length in North American Professional Sports? **Sports Medicine - Open**, v. 2, n. 1, 15 jan. 2016.

TAYLOR, J.; COLLINS, D. Shoulda, Coulda, Didnae—Why Don't High-Potential Players Make it? **The Sport Psychologist**, v. 33, n. 2, p. 85–96, jun. 2019.

TE WIERIKE, S. C. M. et al. Development of Repeated Sprint Ability in Talented Youth Basketball Players. **Journal of Strength and Conditioning Research**, v. 28, n. 4, p. 928–934, abr. 2014.

R CORE TEAM. R: A language and environment for statistical computing. **R Foundation for Statistical Computing**, Vienna, Austria. 2018. Available online at <https://www.R-project.org/>.

TEAM, S. D. **Stan: A C++ library for probability and sampling**. 2014

TEAM, S. D. Stan modeling language user's guide and reference manual, version 2.19.2. **Interaction Flow Modeling Language**. 2020.

THOMIS, M. et al. Adolescent growth spurts in female gymnasts. **The Journal of Pediatrics**, v. 146, n. 2, p. 239–244, fev. 2005.

TORRES-UNDA, J. et al. Basketball Performance Is Related to Maturity and Relative Age in Elite Adolescent Players. **Journal of Strength and Conditioning Research**, v. 30, n. 5, p. 1325–1332, maio 2016.

TRICCO, A. C. et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. **Annals of Internal Medicine**, v. 169, n. 7, p. 467–473, 4 set. 2018.

TUDGE, J. R. H. et al. Uses and Misuses of Bronfenbrenner's Bioecological Theory of Human Development. **Journal of Family Theory & Review**, v. 1, n. 4, p. 198–210, 11 dez. 2009.

TUDGE, J. R. H. et al. Still Misused After All These Years? A Reevaluation of the Uses of Bronfenbrenner's Bioecological Theory of Human Development. **Journal of Family Theory & Review**, v. 8, n. 4, p. 427–445, dez. 2016.

VAEYENS, R. et al. Talent Identification and Development Programmes in Sport. **Sports Medicine**, v. 38, n. 9, p. 703–714, 2008.

VALLERAND, R. J.; LOSIER, G. F. An integrative analysis of intrinsic and extrinsic motivation in sport. **Journal of Applied Sport Psychology**, v. 11, n. 1, p. 142–169, mar. 1999.

VEHTARI, A.; GELMAN, A.; GABRY, J. Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. **Statistics and Computing**, v. 27, n. 5, p. 1413–1432, 30 ago. 2016.

VIGOTSKI, L. et al. **Pensée et langage. Suivi de Commentaire sur les remarques critiques de Vygotski**. Paris: La Dispute, 1997.

WALDRON, S. et al. The Costs and Benefits of Early Sport Specialization: A Critical Review of Literature. **Quest**, v. 72, n. 1, p. 1–18, 26 fev. 2019.

WELSMAN, J.; ARMSTRONG, N. Interpreting Aerobic Fitness in Youth: The Fallacy of Ratio Scaling. **Pediatric Exercise Science**, v. 31, n. 2, p. 184–190, 1 maio 2019.

WICKHAM, H. Data Analysis. **Use R!**, p. 189–201, 2016.

WIERSMA, L. D. Risks and Benefits of Youth Sport Specialization: Perspectives and Recommendations. **Pediatric Exercise Science**, v. 12, n. 1, p. 13–22, fev. 2000.

WIERSMA, L. D. Conceptualization and Development of the Sources of Enjoyment in Youth Sport Questionnaire. **Measurement in Physical Education and Exercise Science**, v. 5, n. 3, p. 153–177, set. 2001.

WILLIAMS, A. M.; FORD, P. R.; DRUST, B. Talent identification and development in soccer since the millennium. **Journal of Sports Sciences**, v. 38, n. 11-12, p. 1199–1210, 17 jun. 2020.

WILLIAMS, A. M.; REILLY, T. Talent identification and development in soccer. **Journal of sports sciences**, v. 18, n. 9, p. 657–67, 2000.

WORLD ASSOCIATION OF BASKETBALL COACHES. **Coaches' manual: Mini-basketball**: FIBA-World Association of Basketball Coaches. 2016.

ZARIĆ, I. et al. Association of mental toughness with competitive success of young female basketball players. **Human Sport Medicine**, v. 21, n. 1, p. 86–93, 22 abr. 2021.

APPENDIX A – SUPPLEMENTARY MATERIAL FOR THE MANUSCRIPT “DOES EARLY SPECIALIZATION PROVIDE AN ADVANTAGE IN PHYSICAL FITNESS DEVELOPMENT IN YOUTH BASKETBALL?”

List of figures in Appendix A

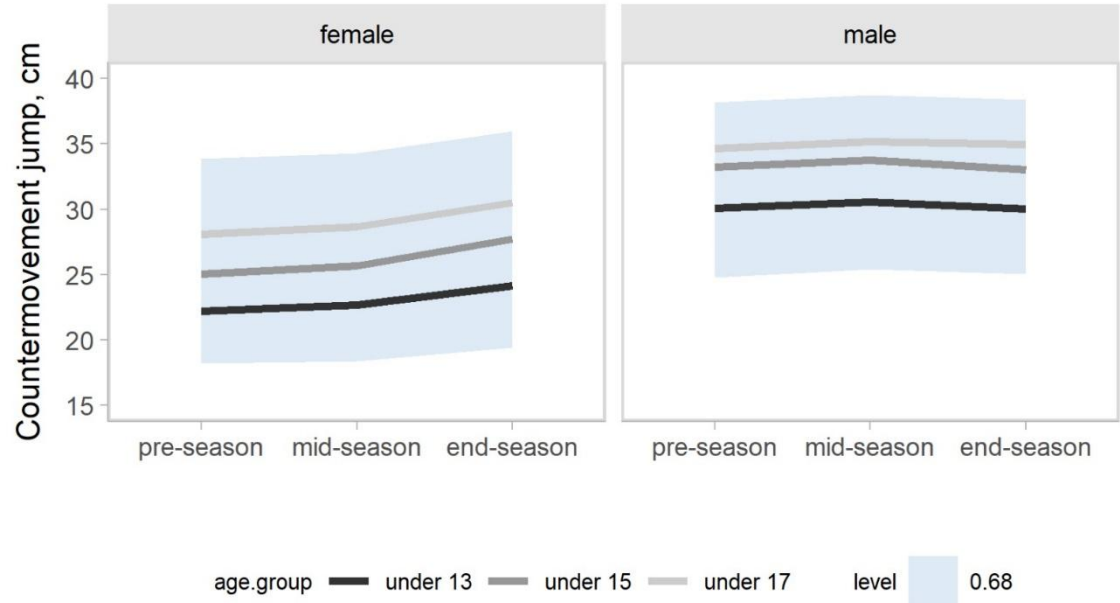
Supplementary Figure 1. Changes in countermovement jump performance for young females and male basketball players within a basketball season by age group. The shaded area represents the 68% credible interval, similar to a standard deviation. 156	156
Supplementary Figure 2. Changes in overall line-drill performance for young females and male basketball players within a basketball season by age group. The shaded area represents the 68% credible interval, similar to a standard deviation.....157	157
Supplementary Figure 3. Changes in Yo-yo intermittent recovery test level 1 performance for young females and male basketball players within a basketball season by age group. The shaded area represents the 68% credible interval, similar to a standard deviation.....157	157
Supplementary Figure 4. Changes in overall basketball-specific physical fitness index for young females and male basketball players within a basketball season by somatic maturity status. The shaded area represents the 68% credible interval, similar to a standard deviation. 158	158
Supplementary Figure 5. Changes in Countermovement jump for young females and male basketball players within a basketball season by somatic maturity status. The shaded area represents the 68% credible interval, similar to a standard deviation. 158	158
Supplementary Figure 6. Changes in line-drill performance for young females and male basketball players within a basketball season by somatic maturity status. The shaded area represents the 68% credible interval, similar to a standard deviation. 159	159
Supplementary Figure 7. Changes in Yo-yo intermittent recovery test level 1 performance for young females and male basketball players within a basketball season by somatic maturity status. The shaded area represents the 68% credible interval, similar to a standard deviation. 159	159
Supplementary Figure 8. Changes in overall basketball-specific physical fitness index for young females and male basketball players within a basketball season by somatic maturity status. The shaded area represents the 68% credible interval, similar to a standard deviation. 160	160

Supplementary Figure 9. Developmental changes in countermovement jump for young females and male basketball players within a basketball season. The shaded area represents the 68% credible interval, similar to a standard deviation.....161

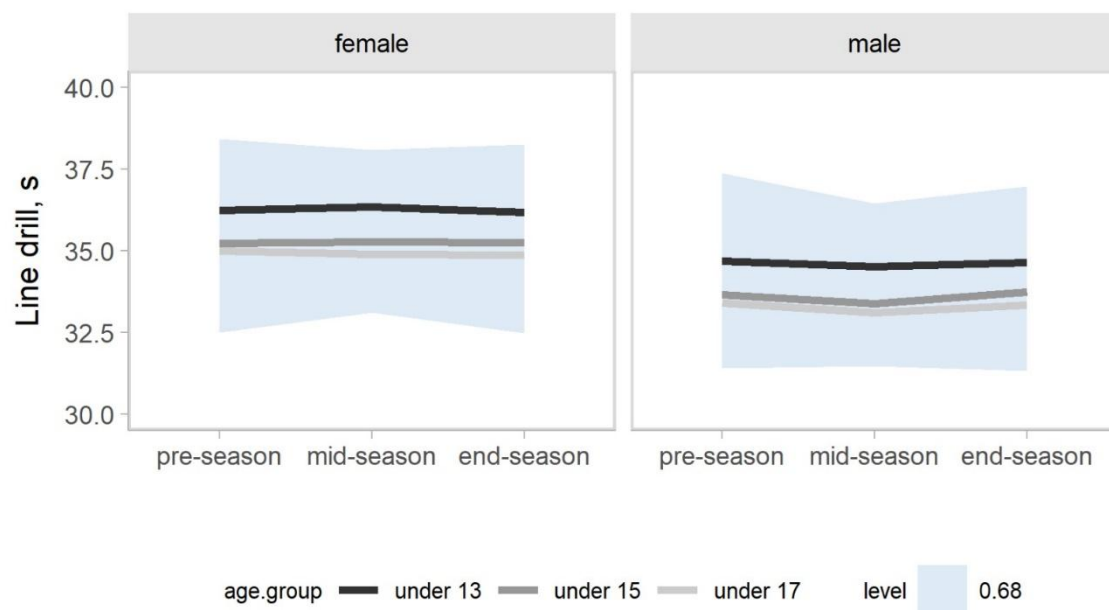
Supplementary Figure 10. Developmental changes in line-drill performance for young females and male basketball players within a basketball season. The shaded area represents the 68% credible interval, similar to a standard deviation.....162

Supplementary Figure 11. Developmental changes in Yo-yo intermittent recovery test level 1 performance for young females and male basketball players within a basketball season. The shaded area represents the 68% credible interval, similar to a standard deviation. 162

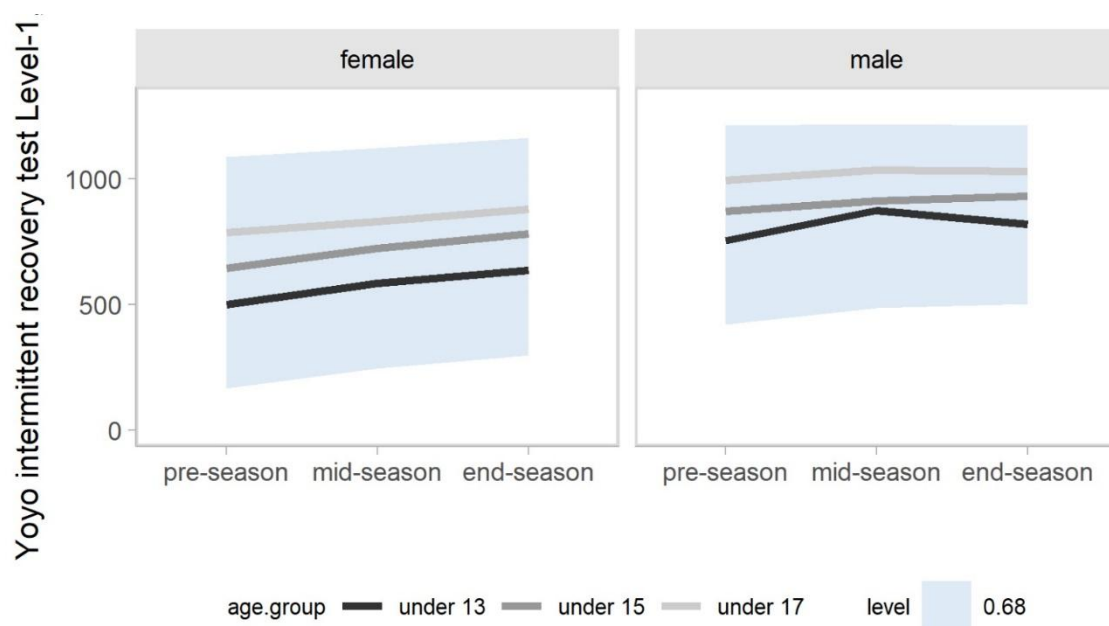
Supplementary Figure 12. Developmental changes in overall basketball-specific physical fitness index for young females and male basketball players within a basketball season. The shaded area represents the 68% credible interval, similar to a standard deviation. 163



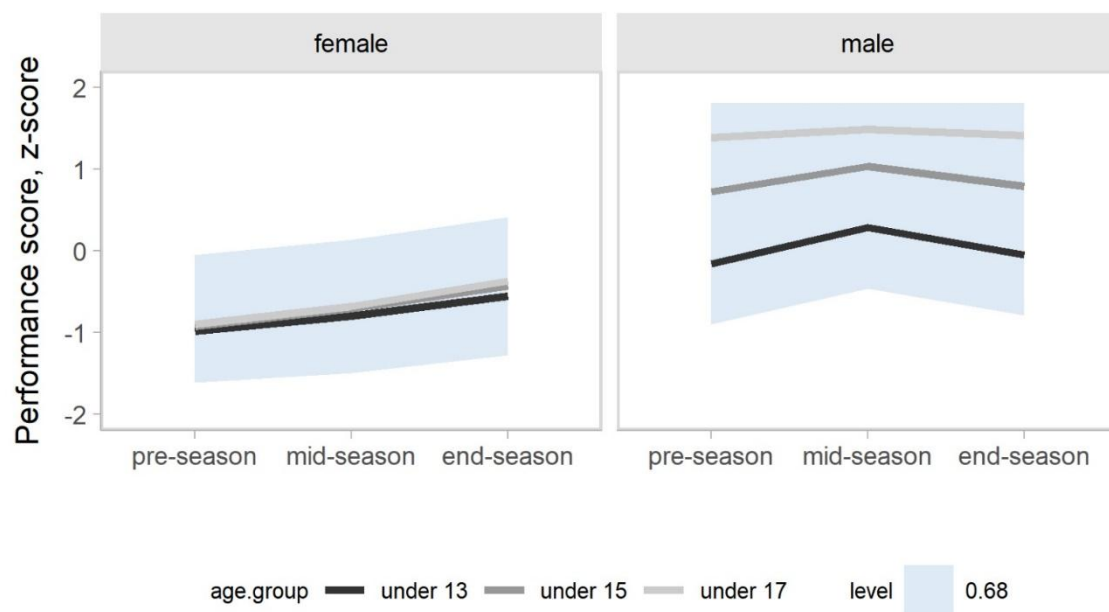
Supplementary Figure 1. Changes in countermovement jump performance for young females and male basketball players within a basketball season by age group. The shaded area represents the 68% credible interval, similar to a standard deviation.



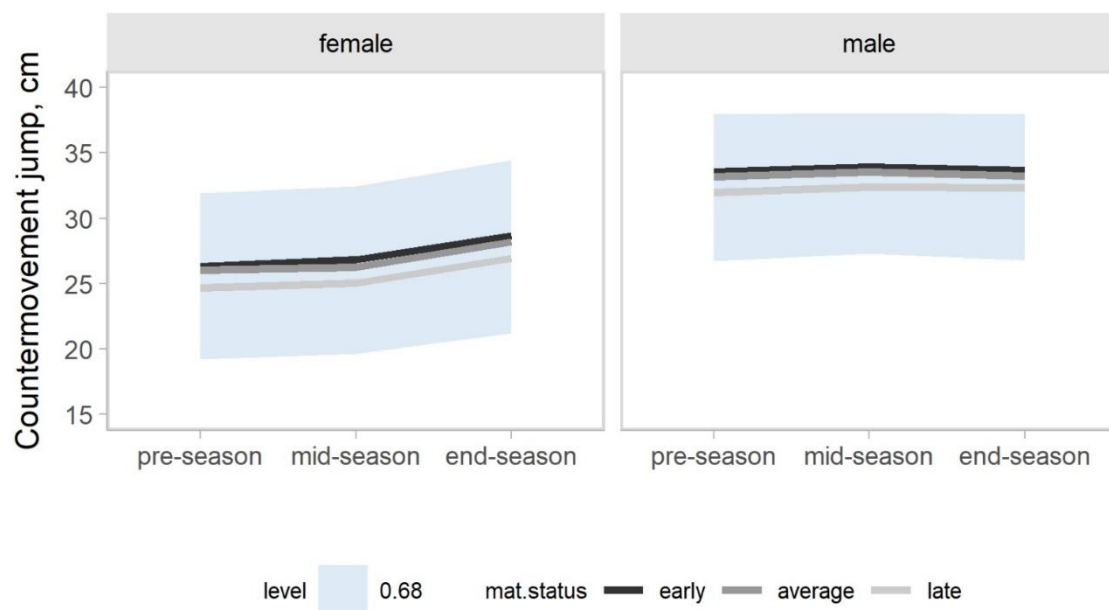
Supplementary Figure 2. Changes in overall line-drill performance for young females and male basketball players within a basketball season by age group. The shaded area represents the 68% credible interval, similar to a standard deviation.



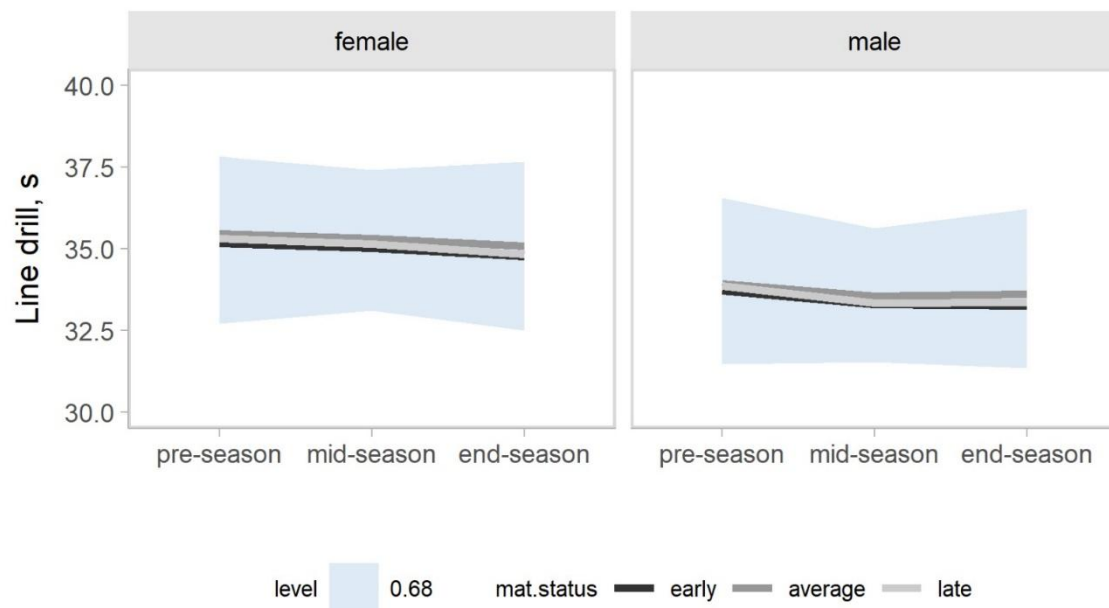
Supplementary Figure 3. Changes in Yo-yo intermittent recovery test level 1 performance for young females and male basketball players within a basketball season by age group. The shaded area represents the 68% credible interval, similar to a standard deviation.



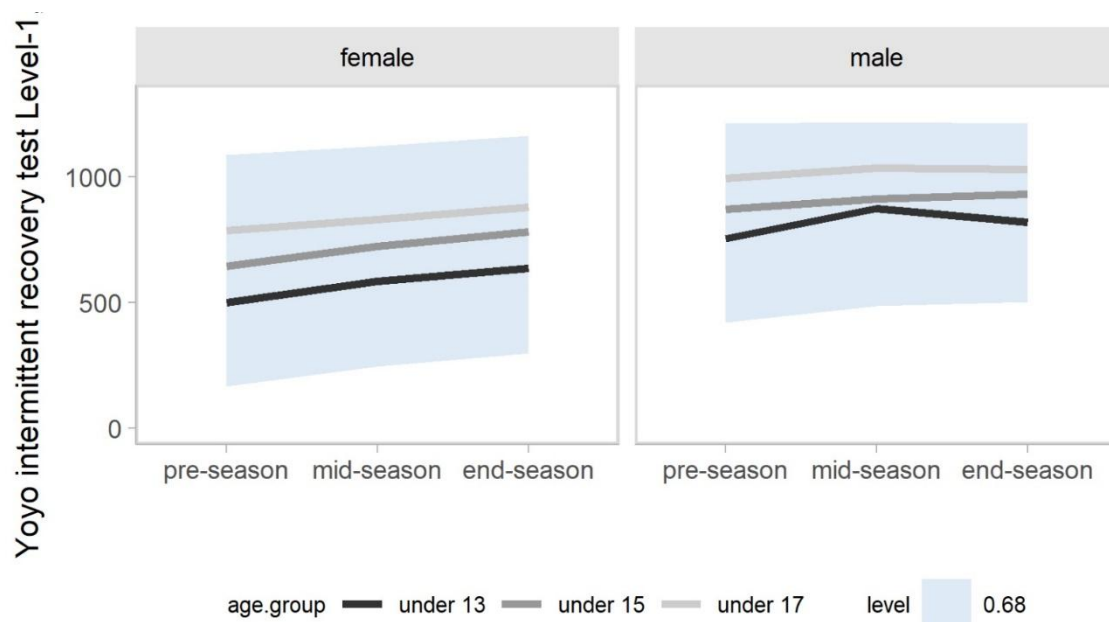
Supplementary Figure 4. Changes in overall basketball-specific physical fitness index for young females and male basketball players within a basketball season by somatic maturity status. The shaded area represents the 68% credible interval, similar to a standard deviation.



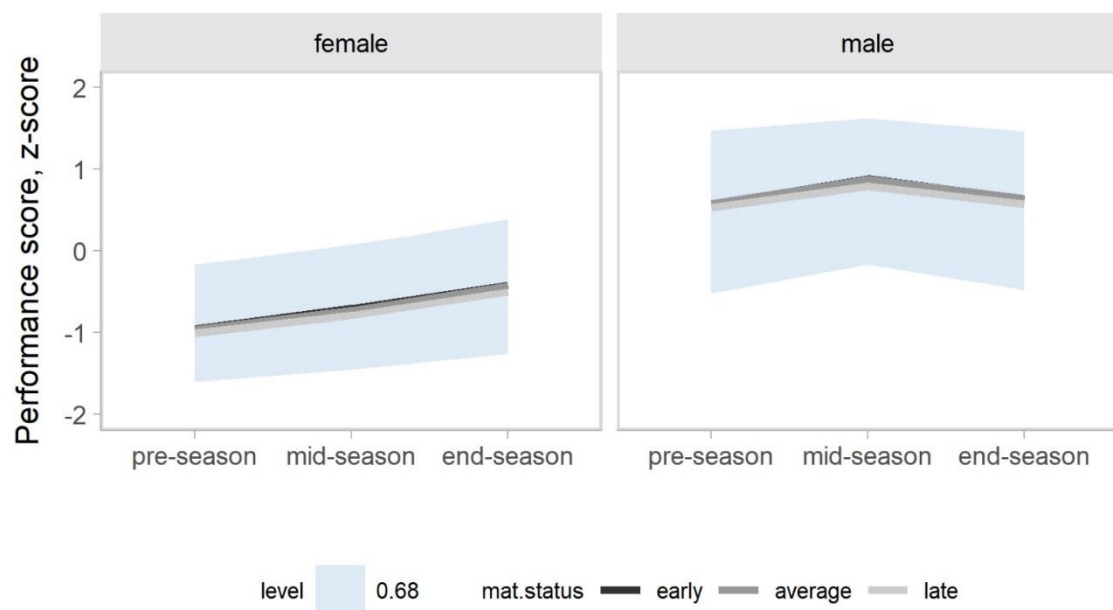
Supplementary Figure 5. Changes in Countermovement jump for young females and male basketball players within a basketball season by somatic maturity status. The shaded area represents the 68% credible interval, similar to a standard deviation.



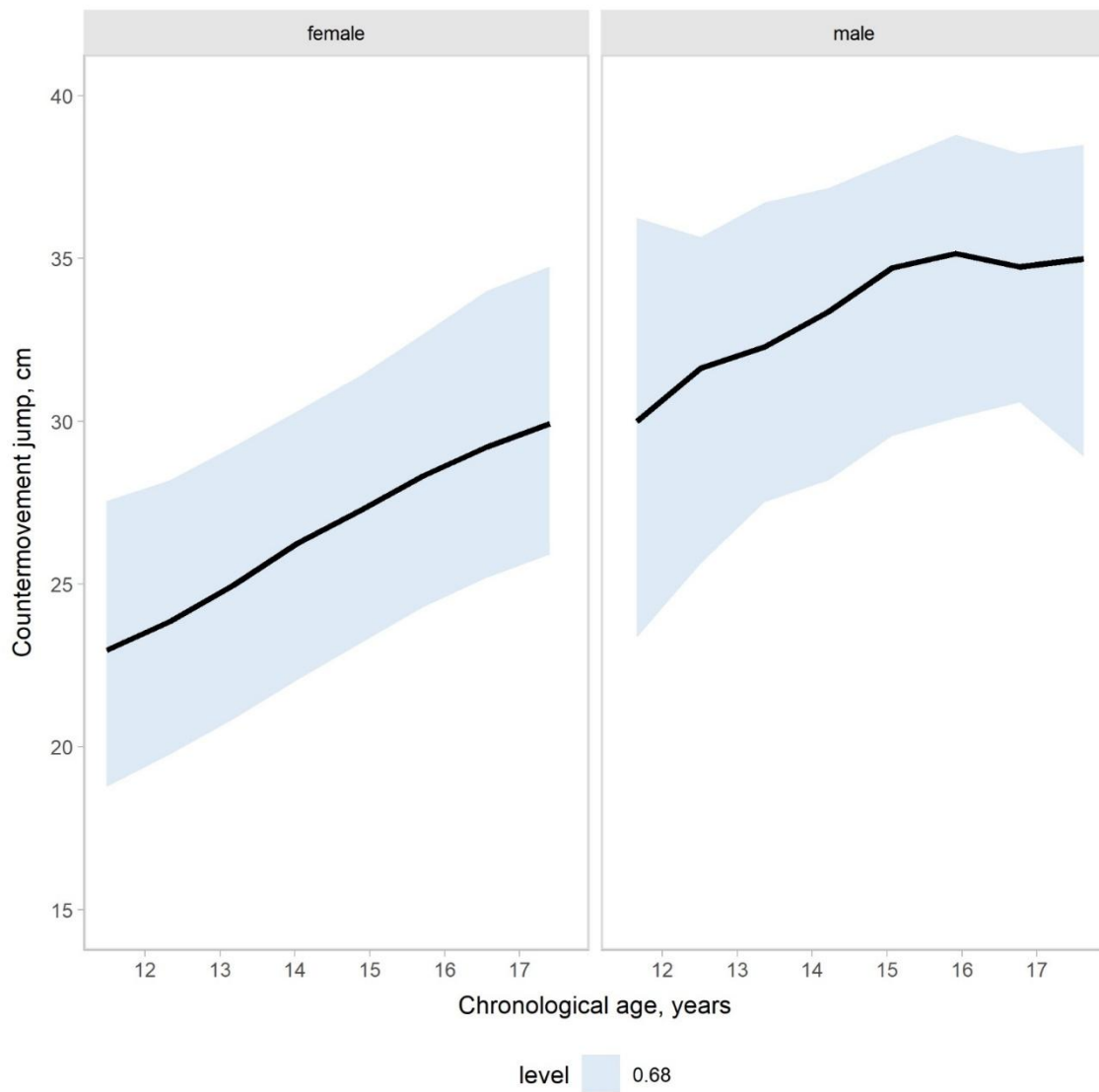
Supplementary Figure 6. Changes in line-drill performance for young females and male basketball players within a basketball season by somatic maturity status. The shaded area represents the 68% credible interval, similar to a standard deviation.



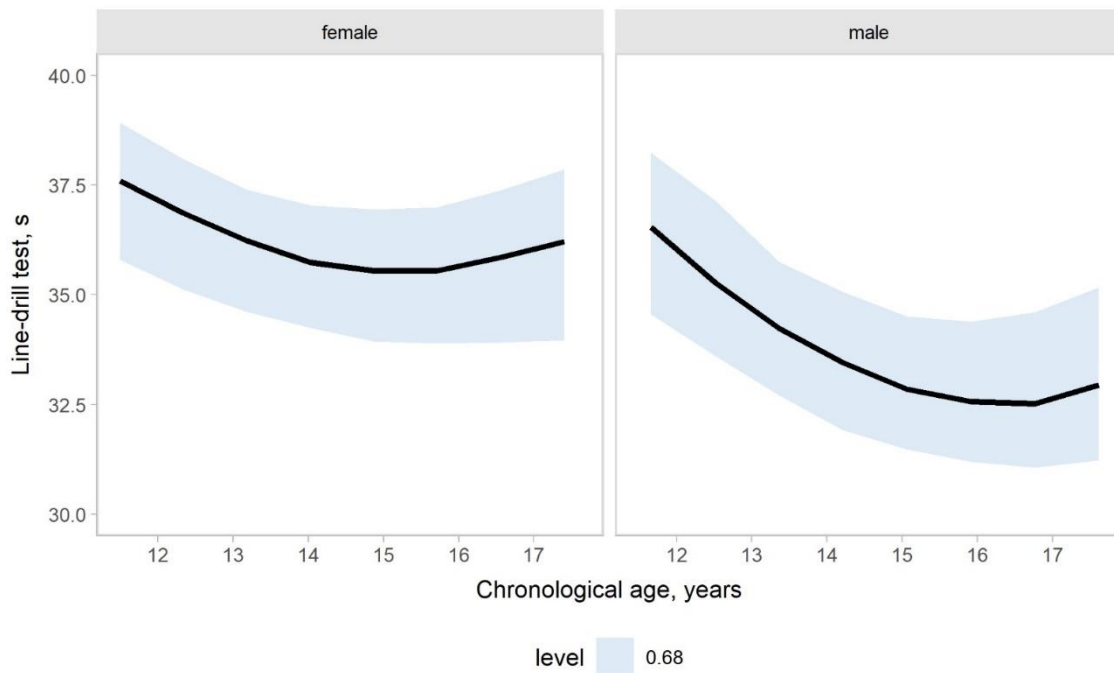
Supplementary Figure 7. Changes in Yo-yo intermittent recovery test level 1 performance for young females and male basketball players within a basketball season by somatic maturity status. The shaded area represents the 68% credible interval, similar to a standard deviation.



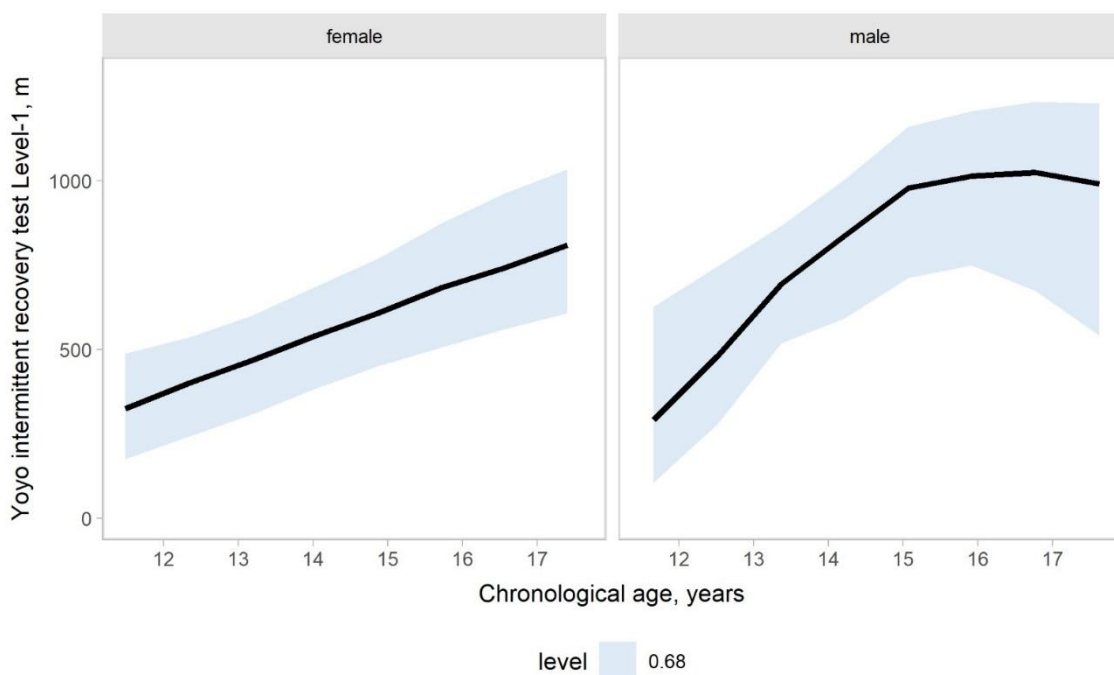
Supplementary Figure 8. Changes in overall basketball-specific physical fitness index for young females and male basketball players within a basketball season by somatic maturity status. The shaded area represents the 68% credible interval, similar to a standard deviation.



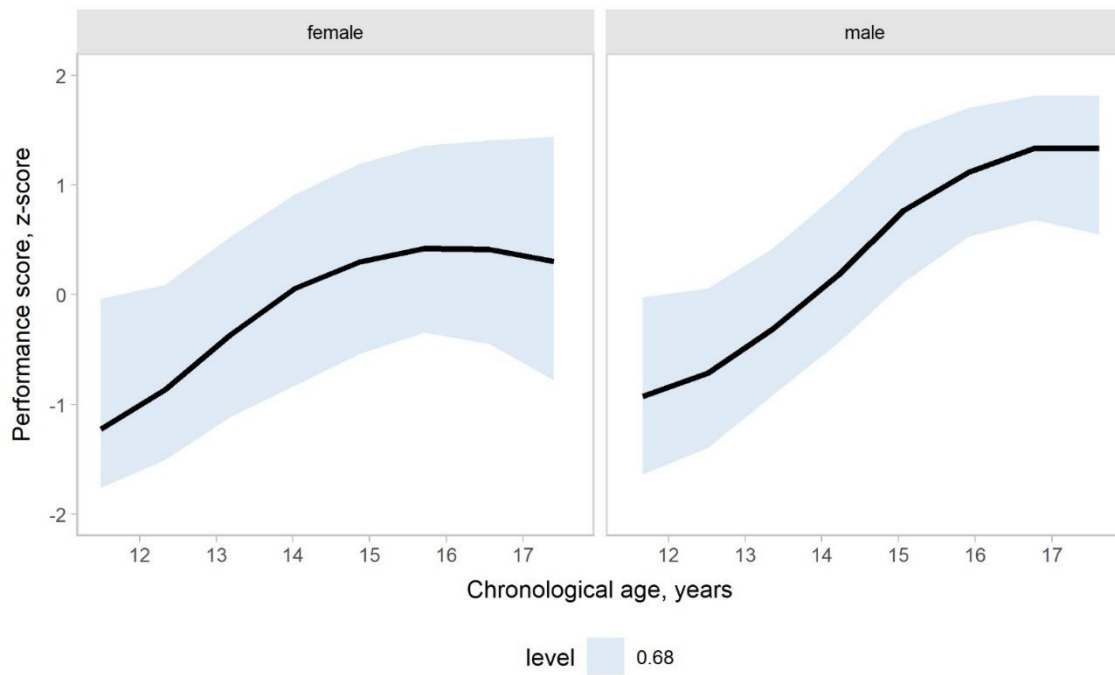
Supplementary Figure 9. Developmental changes in countermovement jump for young females and male basketball players within a basketball season. The shaded area represents the 68% credible interval, similar to a standard deviation.



Supplementary Figure 10. Developmental changes in line-drill performance for young females and male basketball players within a basketball season. The shaded area represents the 68% credible interval, similar to a standard deviation.



Supplementary Figure 11. Developmental changes in Yo-yo intermittent recovery test level 1 performance for young females and male basketball players within a basketball season. The shaded area represents the 68% credible interval, similar to a standard deviation.



Supplementary Figure 12. Developmental changes in overall basketball-specific physical fitness index for young females and male basketball players within a basketball season. The shaded area represents the 68% credible interval, similar to a standard deviation.

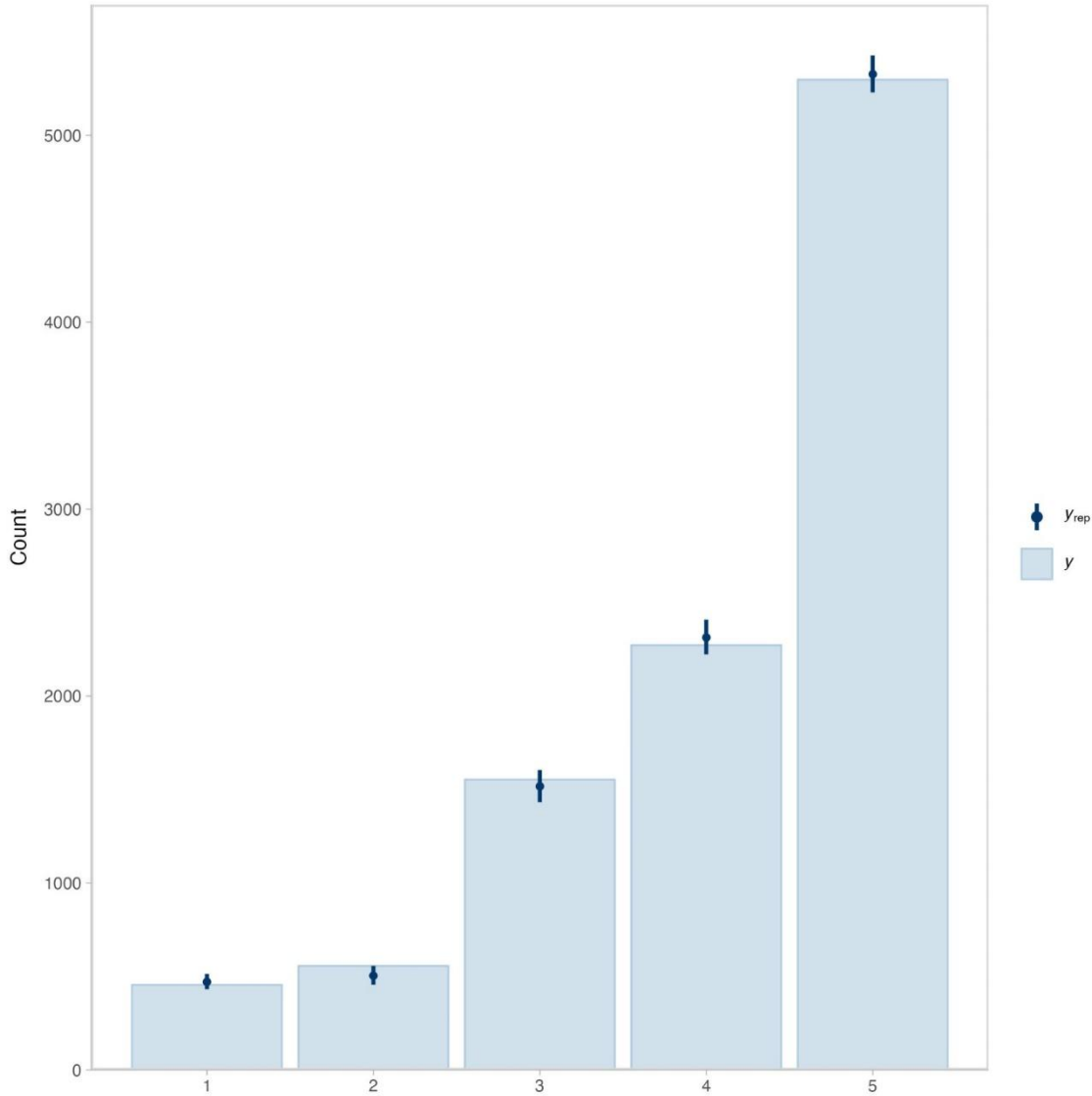
APPENDIX B – SUPPLEMENTARY MATERIAL FOR THE MANUSCRIPT “ACHIEVEMENT AND COMPETITIVENESS MOTIVATION IN YOUTH SPORT: A BAYESIAN HIERARCHICAL MODELING OF INDIVIDUAL- AND CONTEXTUAL-LEVEL DETERMINANTS”

List of figures in Appendix B

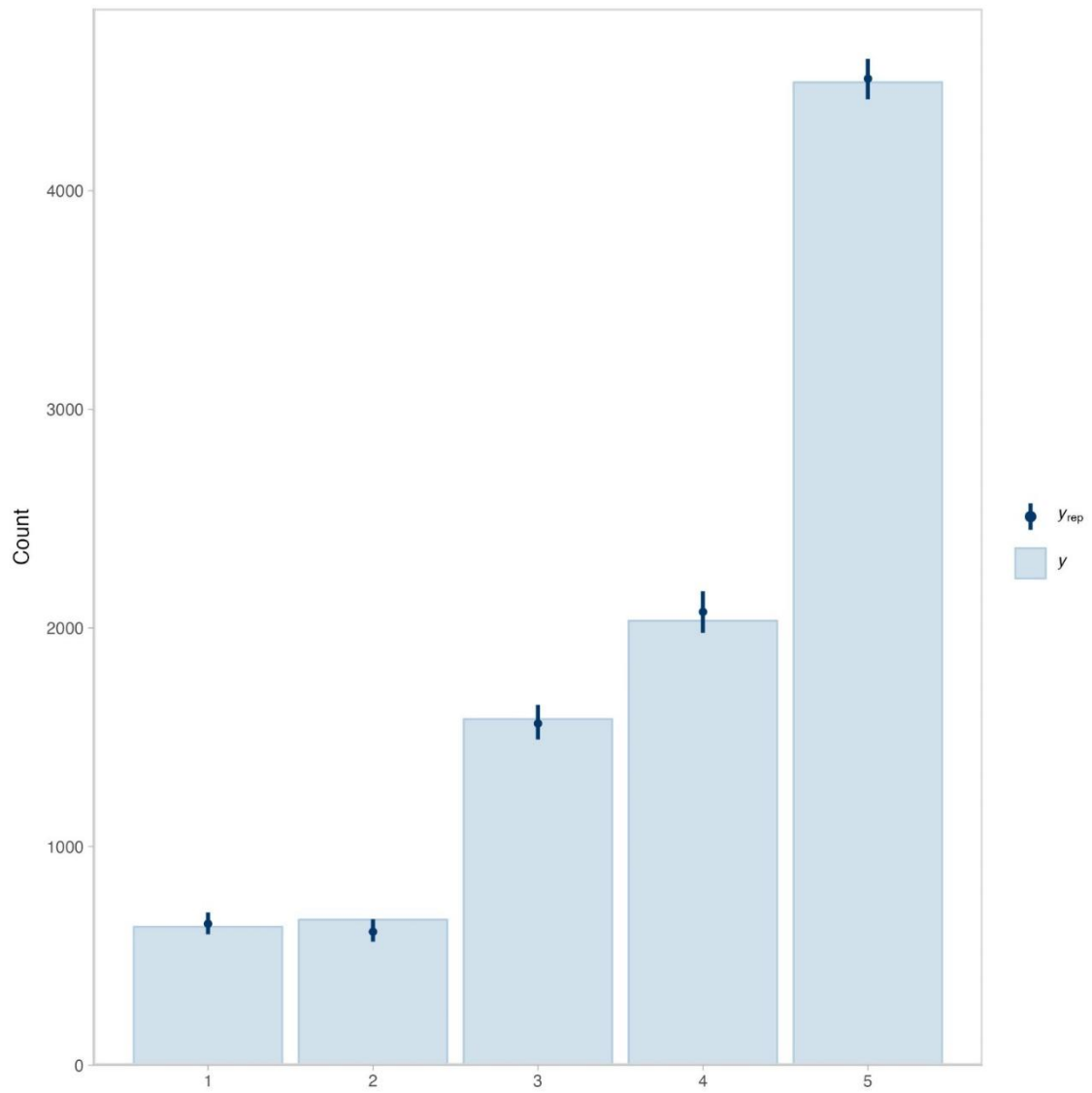
Supplementary Figure 13. Total Count for responses in WOFO	164
Supplementary Figure 14. Total Count for responses in DPMQ	165
Supplementary Figure 15. Posterior predictions of the probability of responses for Deliberate practice motivation questionnaire items in young Brazilian athletes grouped by competitive level. Uncertainty estimates represent the 68% credible intervals.	166
Supplementary Figure 16. Posterior predictions of the probability of responses for Deliberate practice motivation questionnaire items in young Brazilian athletes grouped by state. Uncertainty estimates represent the 68% credible intervals.	167
Supplementary Figure 17. Posterior predictions of the probability of responses for Work and family orientation questionnaire items in young Brazilian athletes grouped by age group. Uncertainty estimates represent the 68% credible intervals.	168
Supplementary Figure 18. Posterior predictions of the probability of responses for Deliberate practice motivation questionnaire items in young Brazilian athletes grouped by onset of specialization. Uncertainty estimates represent the 68% credible intervals.	169
Supplementary Figure 19. Posterior predictions of the probability of responses for Deliberate practice motivation questionnaire items in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 68% credible intervals.	170
Supplementary Figure 20. Posterior predictions of the probability of responses for Deliberate practice motivation questionnaire items in young Brazilian athletes grouped by age group. Uncertainty estimates represent the 68% credible intervals.	171
Supplementary Figure 21. Posterior predictions of the probability of responses for Work and family orientation questionnaire items in young Brazilian athletes grouped by state. Uncertainty estimates represent the 68% credible intervals.	172
Supplementary Figure 22. Posterior predictions of the probability of responses for Work and family orientation questionnaire items in young Brazilian athletes grouped by competitive level. Uncertainty estimates represent the 68% credible intervals.	173

Supplementary Figure 23. Posterior predictions of the probability of responses for Work and family orientation questionnaire items in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 68% credible intervals.....174

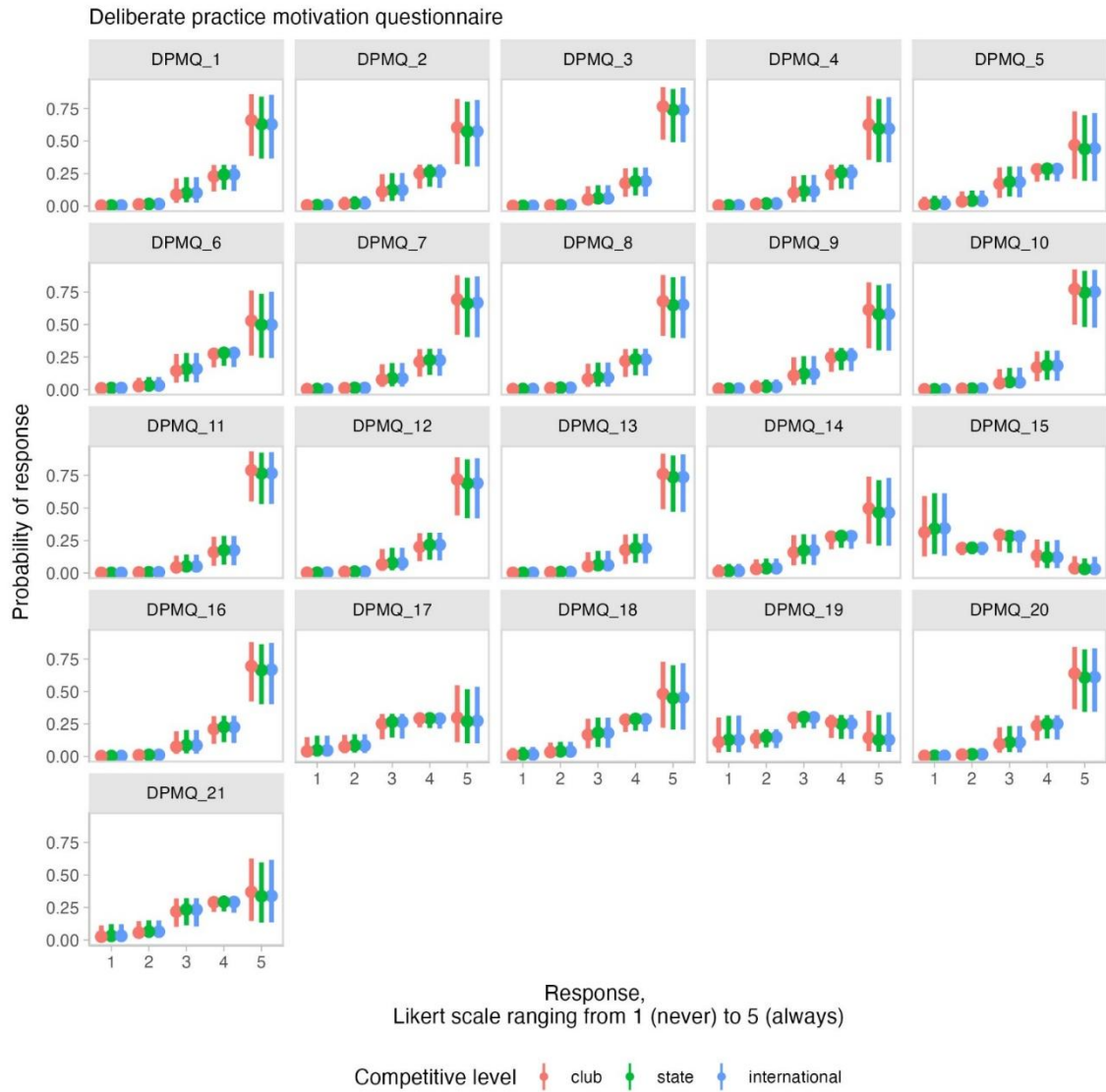
Supplementary Figure 24. Posterior predictions of the probability of responses for Work and family orientation questionnaire items in young Brazilian athletes grouped by onset of specialization. Uncertainty estimates represent the 68% credible intervals.....175



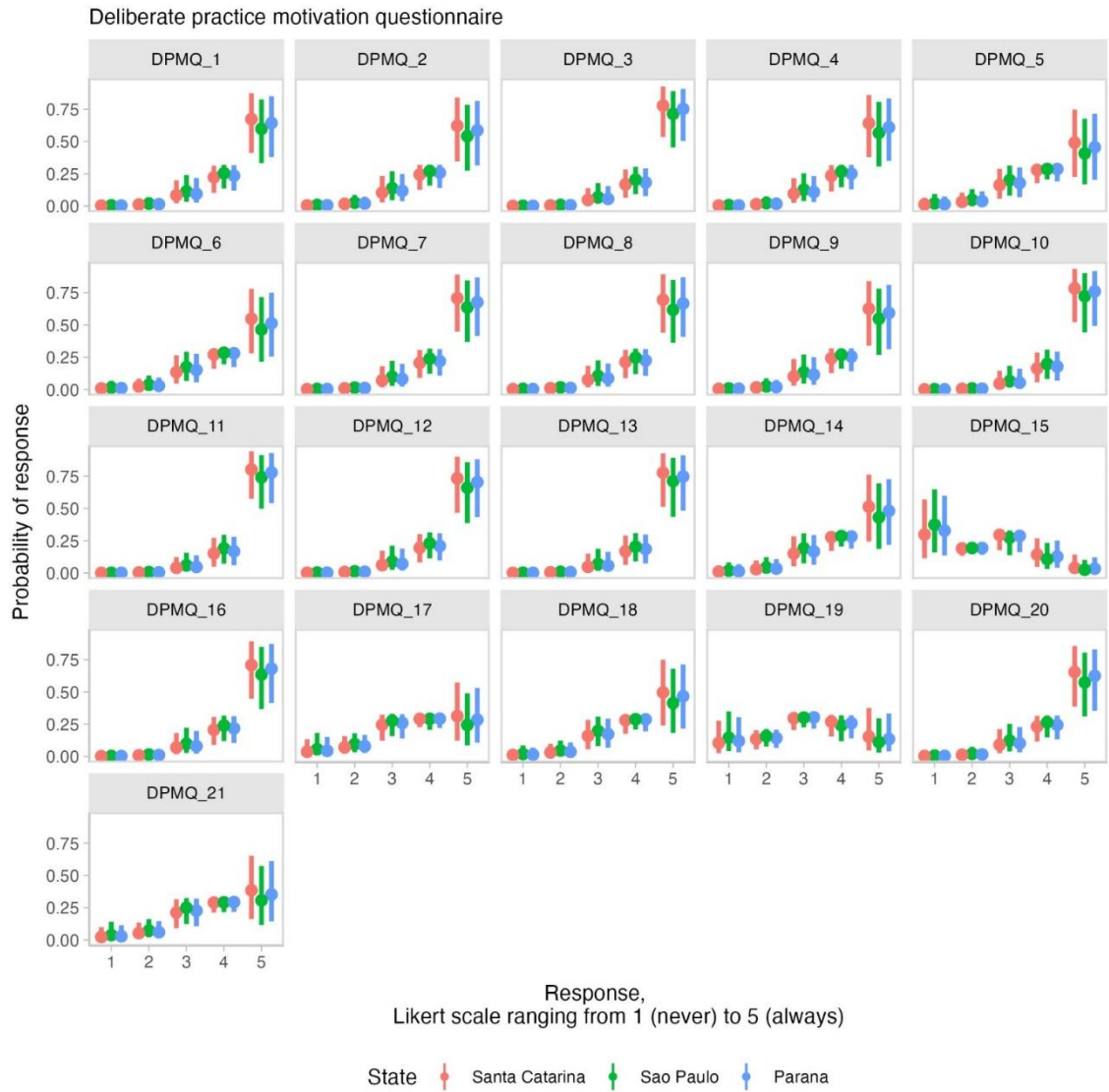
Supplementary Figure 13. Total Count for responses in WOFO



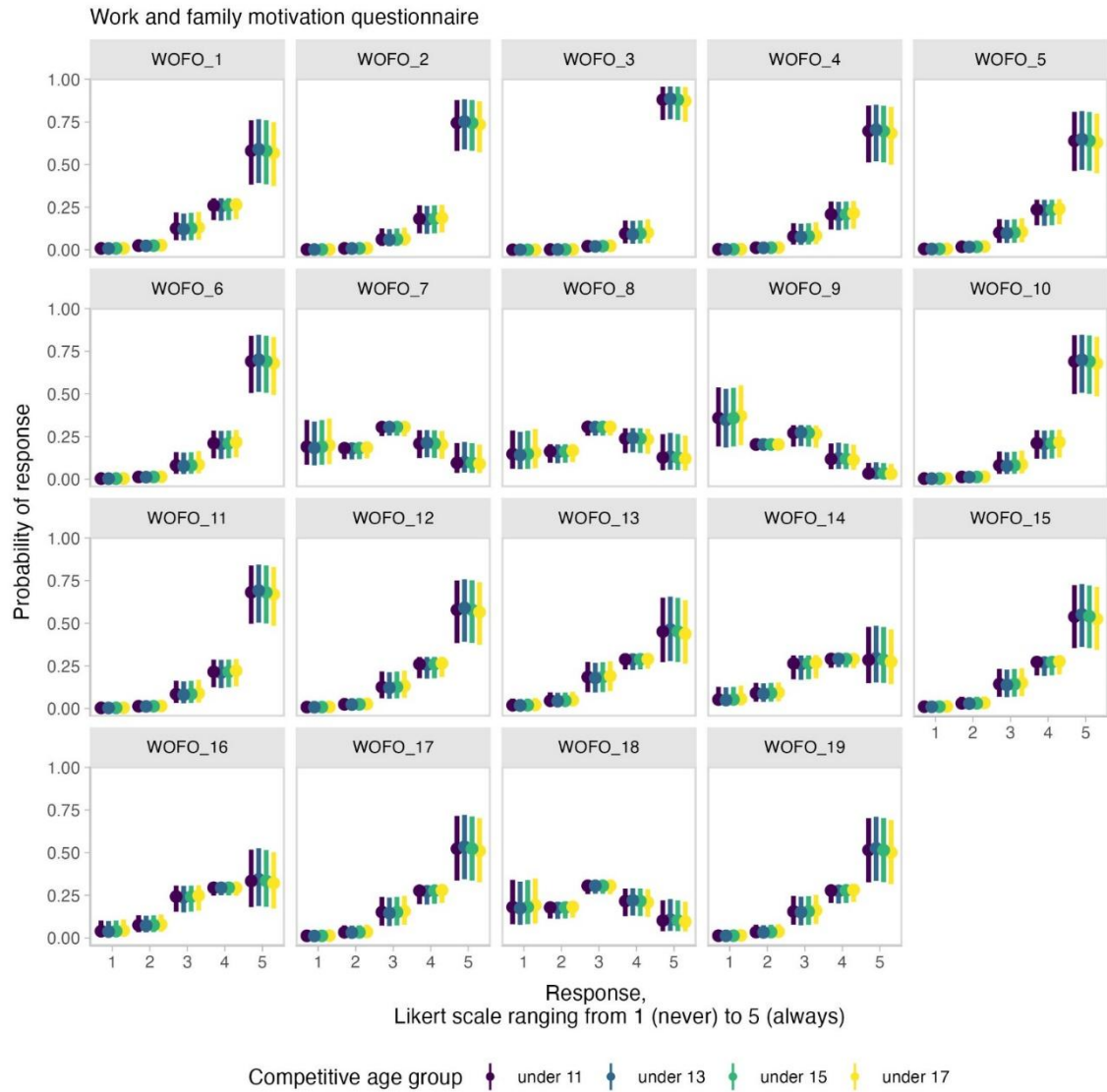
Supplementary Figure 14. Total Count for responses in DPMQ



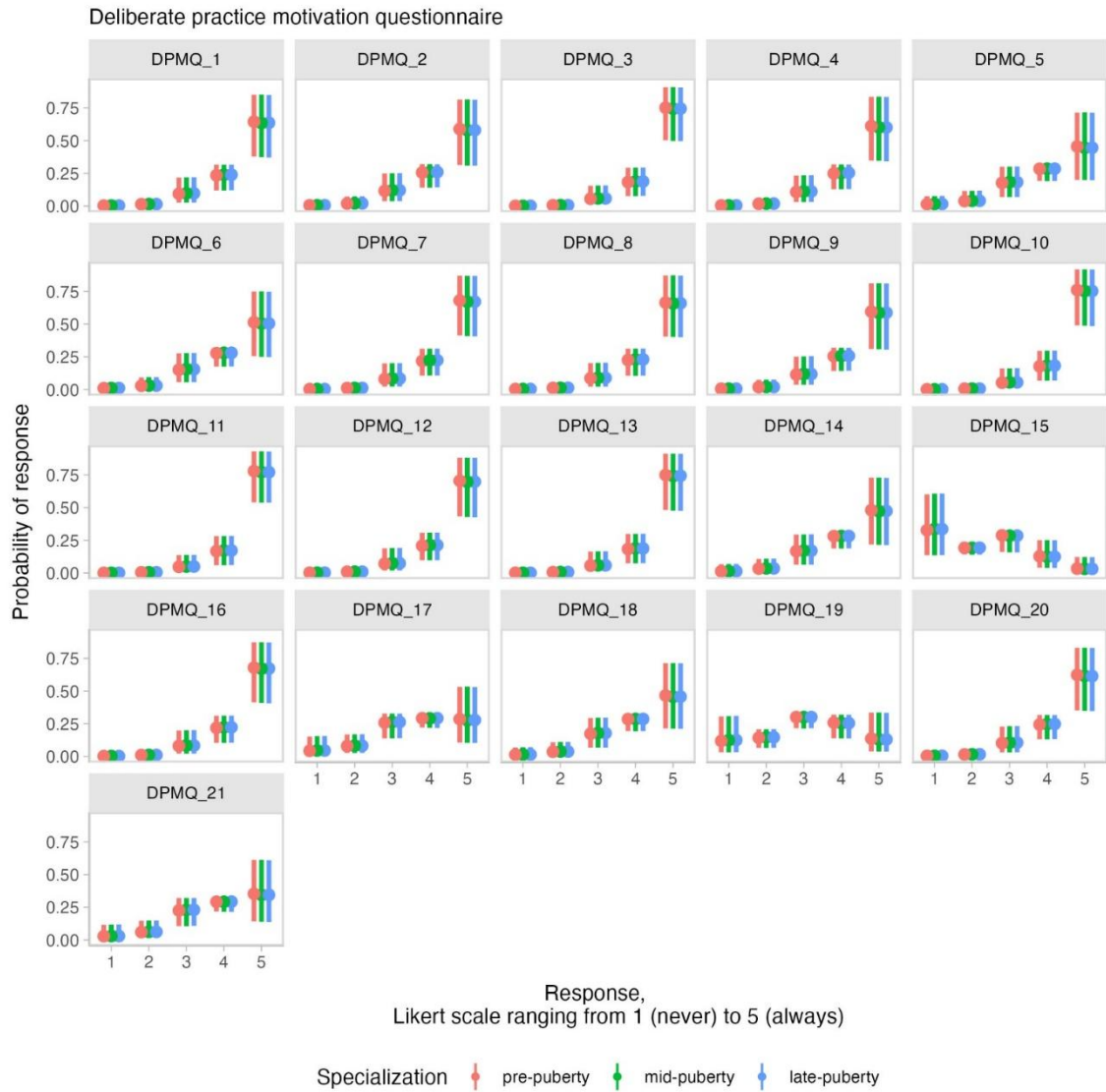
Supplementary Figure 15. Posterior predictions of the probability of responses for Deliberate practice motivation questionnaire items in young Brazilian athletes grouped by competitive level. Uncertainty estimates represent the 68% credible intervals.



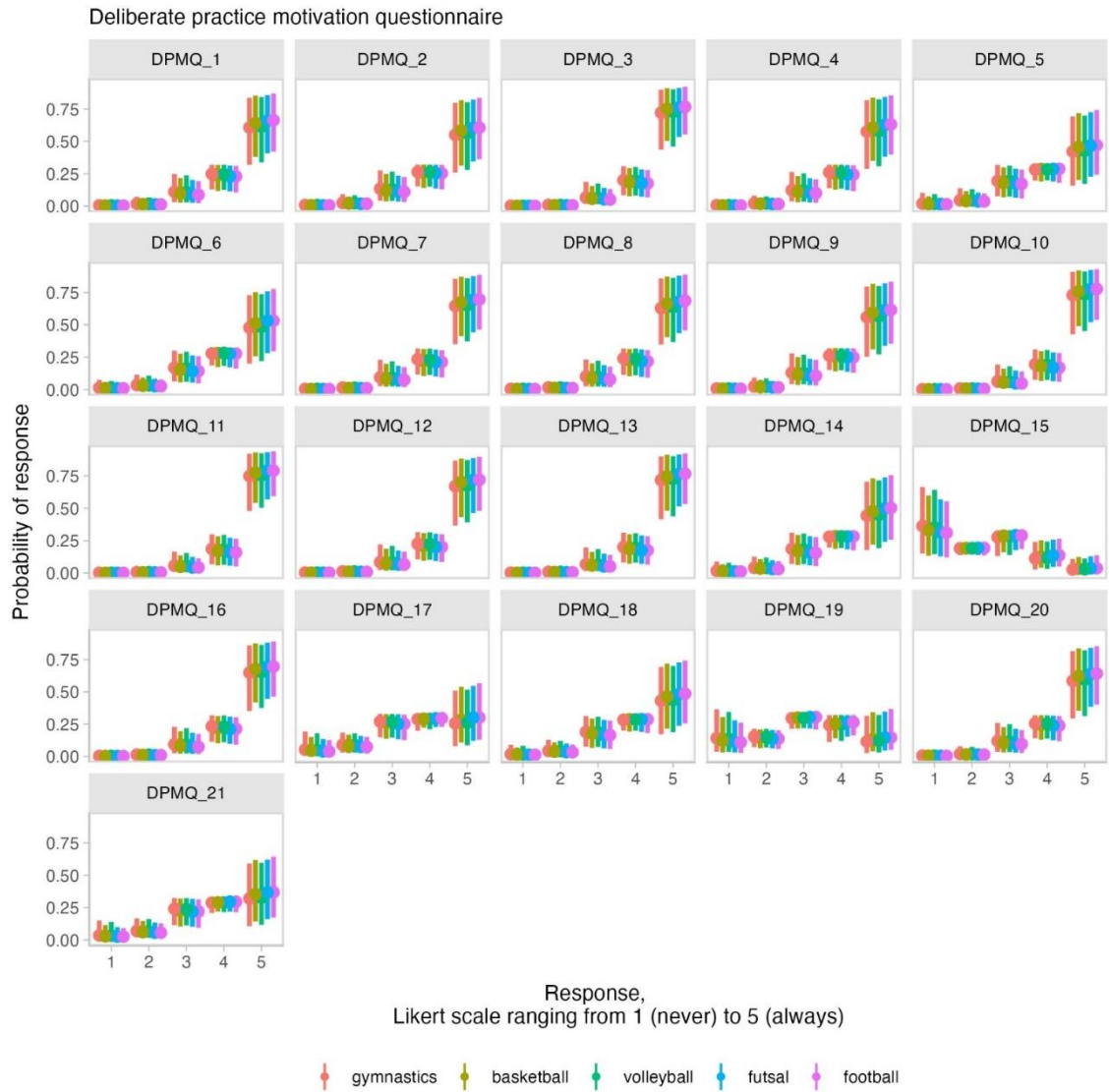
Supplementary Figure 16. Posterior predictions of the probability of responses for Deliberate practice motivation questionnaire items in young Brazilian athletes grouped by state. Uncertainty estimates represent the 68% credible intervals.



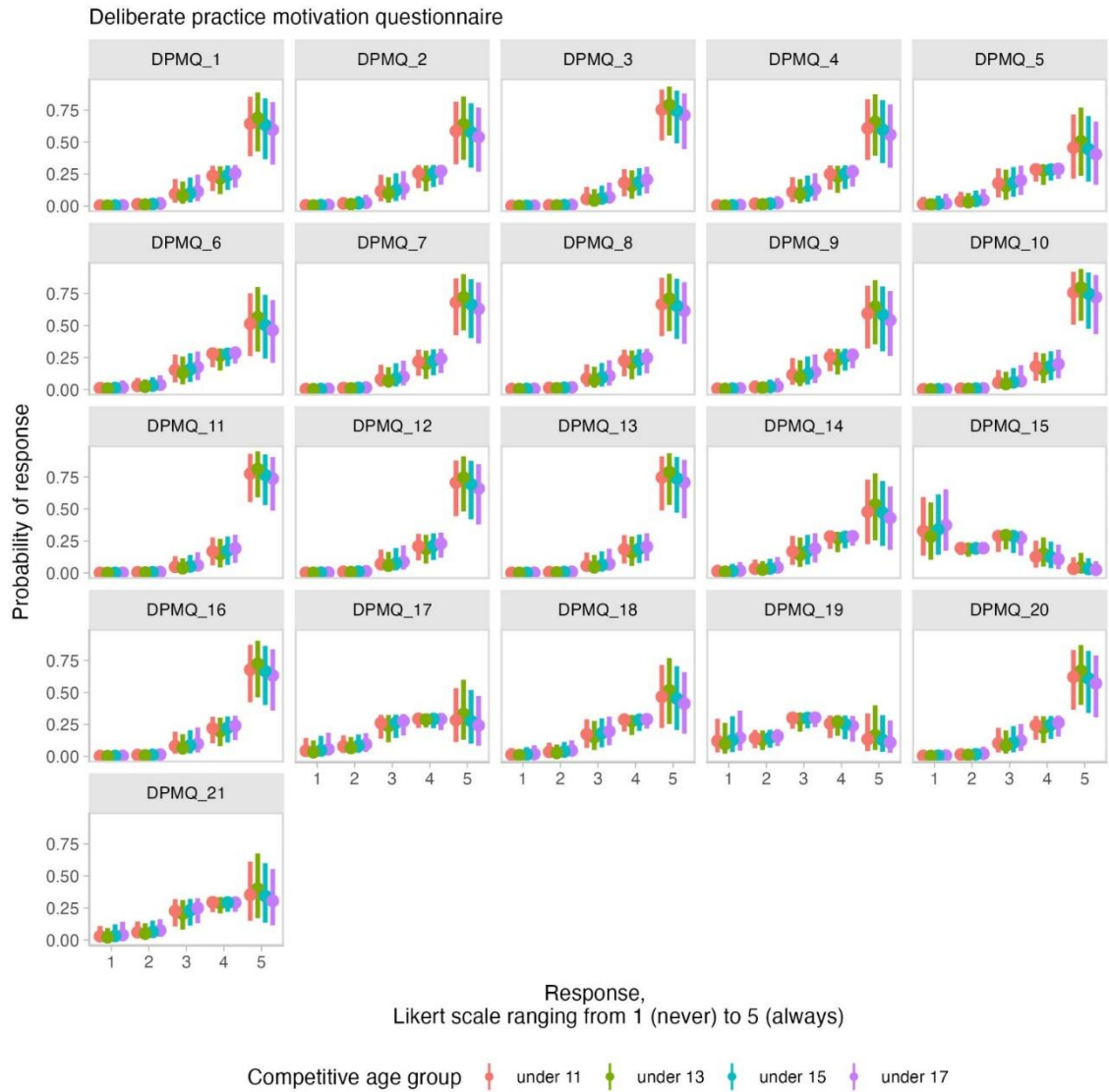
Supplementary Figure 17. Posterior predictions of the probability of responses for Work and family orientation questionnaire items in young Brazilian athletes grouped by age group. Uncertainty estimates represent the 68% credible intervals.



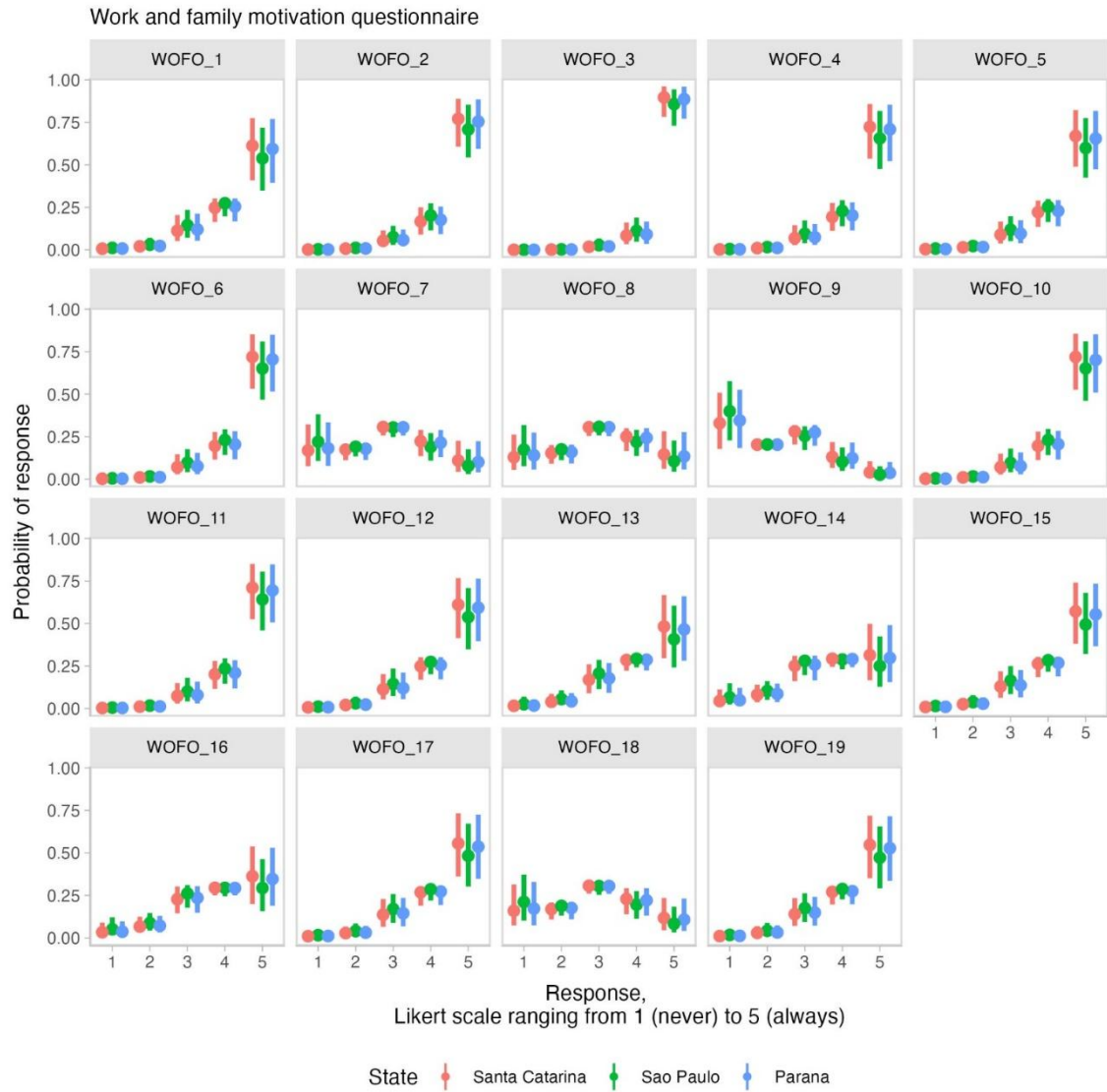
Supplementary Figure 18. Posterior predictions of the probability of responses for Deliberate practice motivation questionnaire items in young Brazilian athletes grouped by onset of specialization. Uncertainty estimates represent the 68% credible intervals.



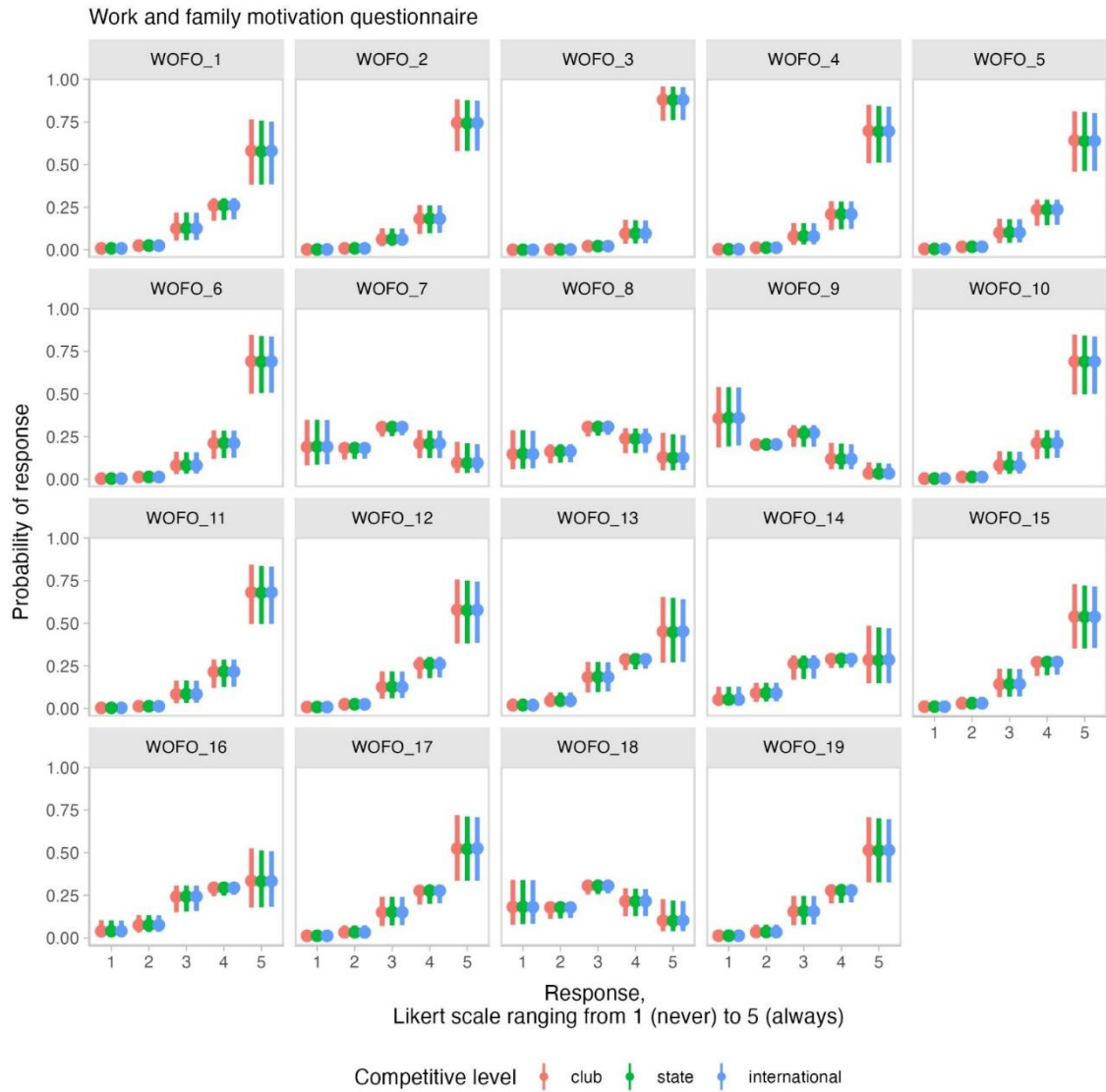
Supplementary Figure 19. Posterior predictions of the probability of responses for Deliberate practice motivation questionnaire items in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 68% credible intervals.



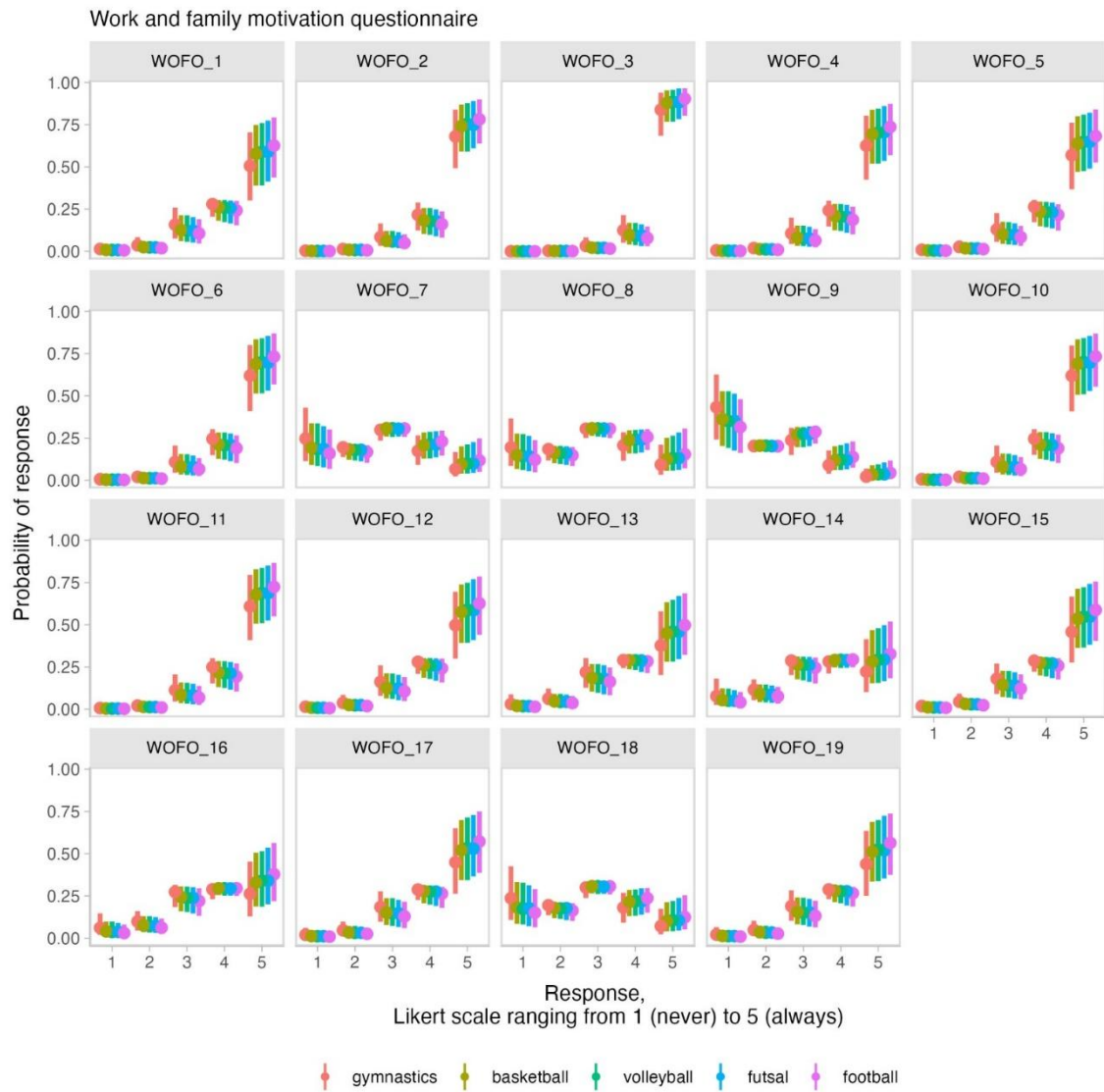
Supplementary Figure 20. Posterior predictions of the probability of responses for Deliberate practice motivation questionnaire items in young Brazilian athletes grouped by age group. Uncertainty estimates represent the 68% credible intervals.



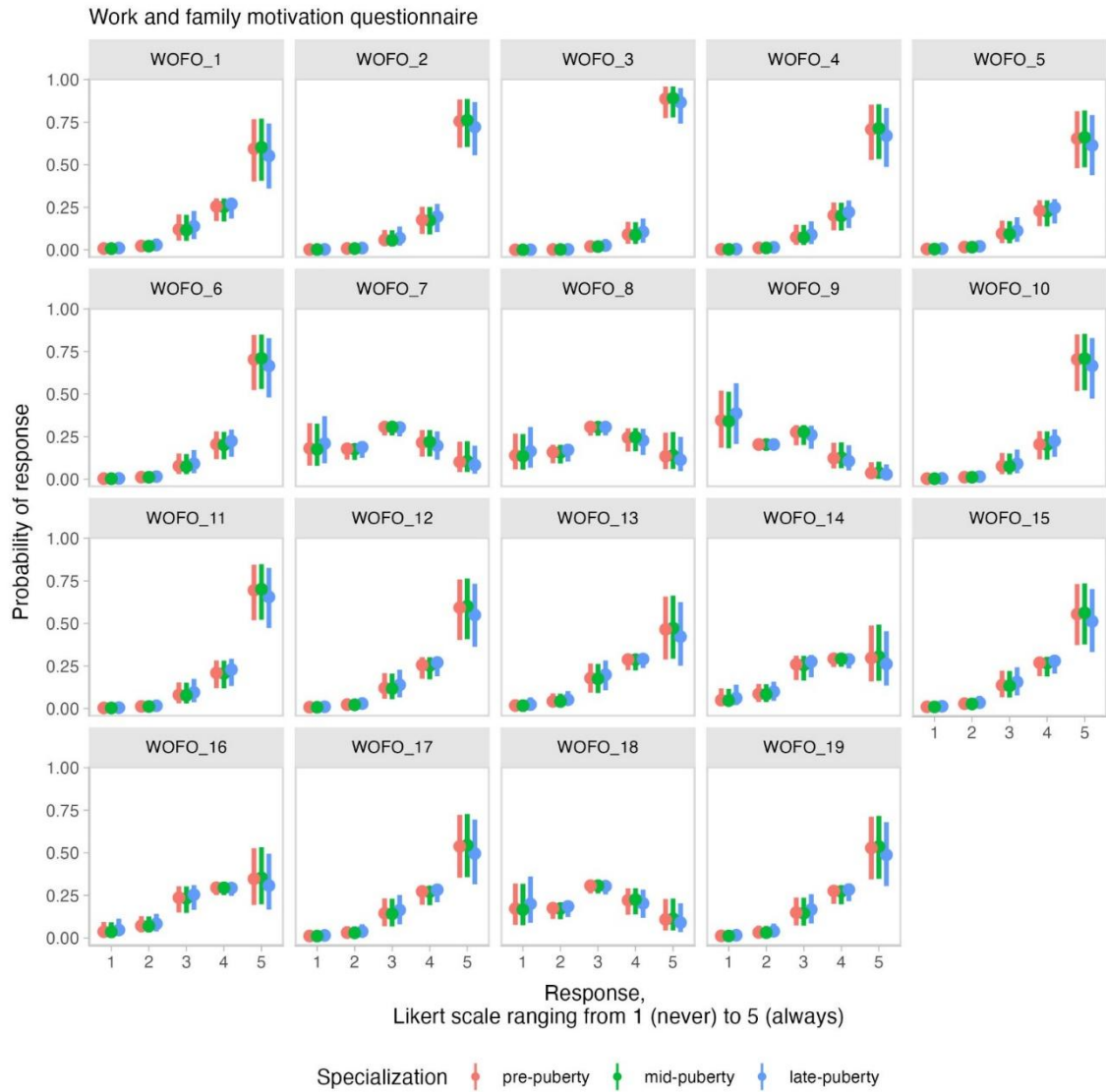
Supplementary Figure 21. Posterior predictions of the probability of responses for Work and family orientation questionnaire items in young Brazilian athletes grouped by state. Uncertainty estimates represent the 68% credible intervals.



Supplementary Figure 22. Posterior predictions of the probability of responses for Work and family orientation questionnaire items in young Brazilian athletes grouped by competitive level. Uncertainty estimates represent the 68% credible intervals.



Supplementary Figure 23. Posterior predictions of the probability of responses for Work and family orientation questionnaire items in young Brazilian athletes grouped by sport. Uncertainty estimates represent the 68% credible intervals.



Supplementary Figure 24. Posterior predictions of the probability of responses for Work and family orientation questionnaire items in young Brazilian athletes grouped by onset of specialization. Uncertainty estimates represent the 68% credible intervals.

APPENDIX C – SUPPLEMENTARY MATERIAL FOR THE MANUSCRIPT “AN ECOLOGICAL APPROACH TO SOURCES OF ENJOYMENT IN YOUNG FEMALE ATHLETES”

List of figures in Appendix C

Supplementary Figure 25. Posterior predictive checks for the hierarchical model fitting the cross-sectional data.....	178
Supplementary Figure 26. Posterior predictive checks for the hierarchical model fitting the repeated-measures data.....	179
Supplementary Figure 27. Posterior predictions of the probability of responses for Other-referenced competency and recognition by specialization onset. Uncertainty estimates represent the 50% credible intervals.	180
Supplementary Figure 28. Posterior predictions of the probability of responses for Other-referenced competency and recognition by menarche status. Uncertainty estimates represent the 50% credible intervals.	181
Supplementary Figure 29. Posterior predictions of the probability of responses for Other-referenced competency and recognition by age group. Uncertainty estimates represent the 50% credible intervals.....	182
Supplementary Figure 30. Posterior predictions of the probability of responses for Other-referenced competency and recognition by sport. Uncertainty estimates represent the 50% credible intervals.....	183
Supplementary Figure 31. Posterior predictions of the probability of responses for Other-referenced competency and recognition by competitive level. Uncertainty estimates represent the 50% credible intervals.	184
Supplementary Figure 32. Posterior predictions of the probability of responses for Other-referenced competency and recognition by state. Uncertainty estimates represent the 50% credible intervals.	185

The present supplementary material details: (i) the confirmatory factor analysis of the Sources of Enjoyment in Youth Sport Questionnaire applied in the sample of young female Brazilian athletes; (ii) posterior prediction checks of the Bayesian hierarchical models; (iii) plots of the posterior predictions of the probability of responses for the SEYSQ factors by person (menarcheal status), process (onset of specialization), and context characteristics (mesosystem: age group, competitive level; exosystem: sport; macrosystem: state).

CONFIRMATORY FACTOR ANALYSIS

Methods

To guarantee evidence of construct validity of the questionnaire to the Brazilian culture, we conducted a Confirmatory Factor Analysis (CFA). Considering that the questionnaire was first validated based on the frequentist approach, we also first tested the questionnaire structure using the same approach and then using the Bayesian approach. We run the CFA following the original structure of the questionnaire (28 items distributed in six factors)(WIERSMA, 2001). To perform this analysis, the “lavaan” package (Rosseel, 2012) in the R statistical language (TEAM, 2018) was used. Factor loadings above 0.5 were used as cutoff points to retain items (KLINE, 2016). The covariances between measure error items and between latent variable (factor) and item were also analyzed. In the case of high covariances between measure errors that could disturb the model, the item with lower factor loading was excluded. Lastly, model adequacy was tested through the most recommended fit indices (JACKSON et al., 2009): Chi-square (X^2), Degrees of Freedom (DF), Chi-square Ratio (X^2/df), Tucker Lewis Index (TLI), Relative Noncentrality Index (RNI), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Standardized Root Mean Square (SRMS), and Expected Cross-validation Index (ECVI).

After finding a satisfactory factor structure based on the frequentist approach, we tested the final structure with the Bayesian approach. Thus, a Bayesian Confirmatory Factor Analysis (BCFA) was applied to examine the model factorial structure. A posterior latent variable closer to 0.5 (MERKLE & ROSSEEL, 2018) was set as a satisfactory value to retain an item based on the literature. Moreover, Bayesian root mean square error of approximation (BRMSEA), Bayesian Gamma Hat (BGamma-Hat), Adjusted Bayesian Gamma Hat (adjBgammaHat), and Bayesian McDonald's centrality index (BMc) were also applied to confirm the model fit (MONTENEGRO-MONTENEGRO, 2020). Two chains for 10,000 iterations with 2,000 used as warm-up, using probabilistic programming language Stan (Stan Development Team, 2020). The model estimations were regularized using normal prior (0, 10) for the manifest variable (intercept) and normal prior (0, 1) for the latent variable were set. The BCFA was conducted using the “blavaan” package (MERKLE & ROSSEEL, 2018) in the R software (TEAM, 2018).

Results

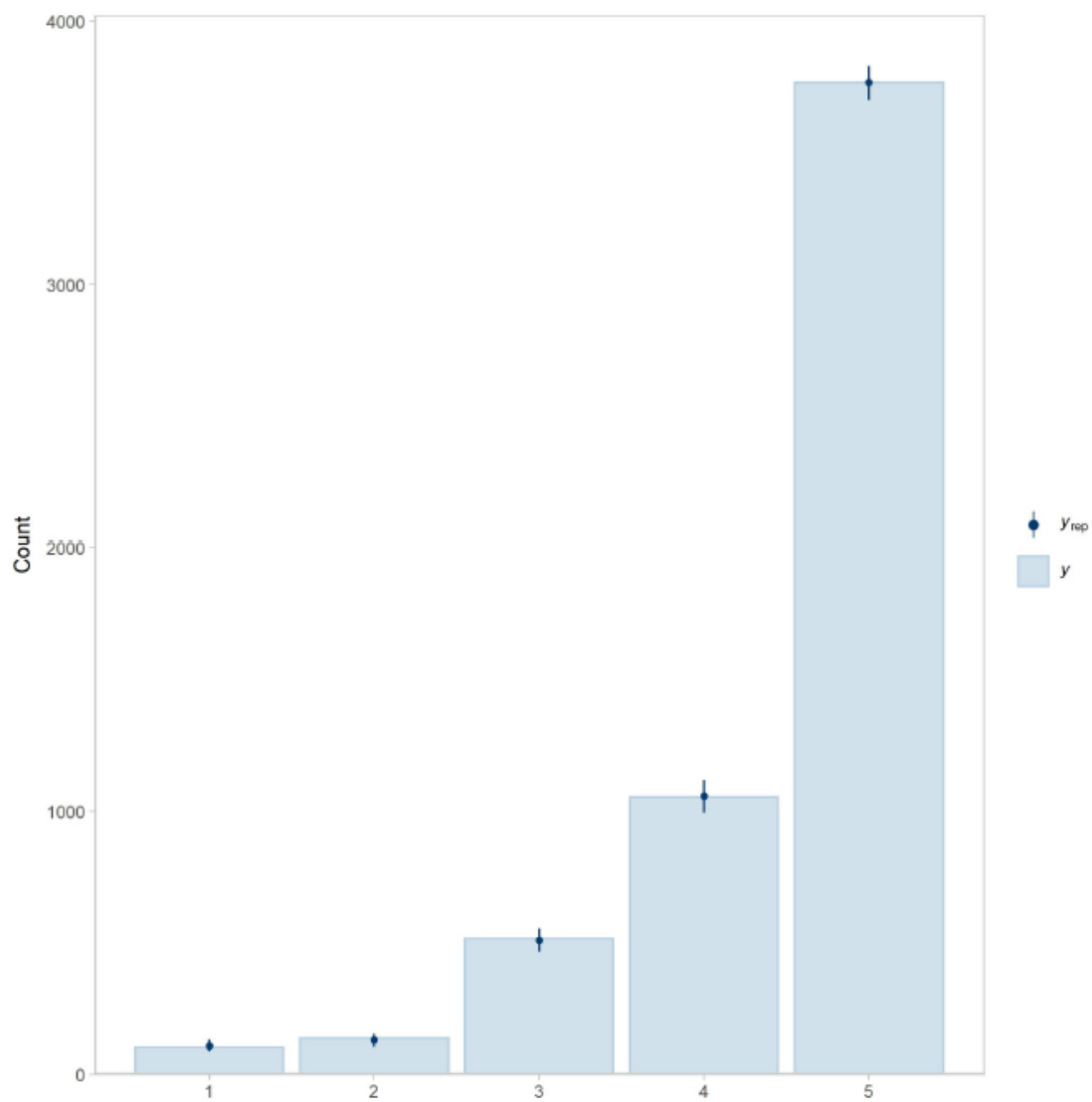
The first step consisted of testing the original 28 items distributed in the six factors. The first model (M1) presented items 1 (0.34), 20 (0.23) and 15 (0.40) with low factor loadings.

Thus, those three items were excluded. Additionally, there was a high covariance (157.85) between measure errors of item 12 and item 19. In this case, item 12 (0.51) was excluded due to present lower factor loading compared to item 19 (0.62). M1 also did not present adequacy of most fit indexes (Supplementary table 1). Thus, a new model was tested (M2). M2 presented almost all items with a factor loading above 0.5. Item 8 presented a factor loading of 0.48. However, the value was close to our cutoff point and we decided to retain the item. Fit indexes presented a better fit, but were not totally satisfactory. Lastly, there was a medium covariance between measure errors (36.12) of item 19 and a latent variable. This kind of covariance could disturb the model severally. Thus, item 19 was excluded and a third model was tested (M3). In M3, item 8 is still the only item with factor loading lower than 0.5 (0.48), but there was no high or medium covariance between items or latent variables and fit indexes were presented as satisfactory. Thus, M3 was considered the final structure to be tested using the Bayesian approach.

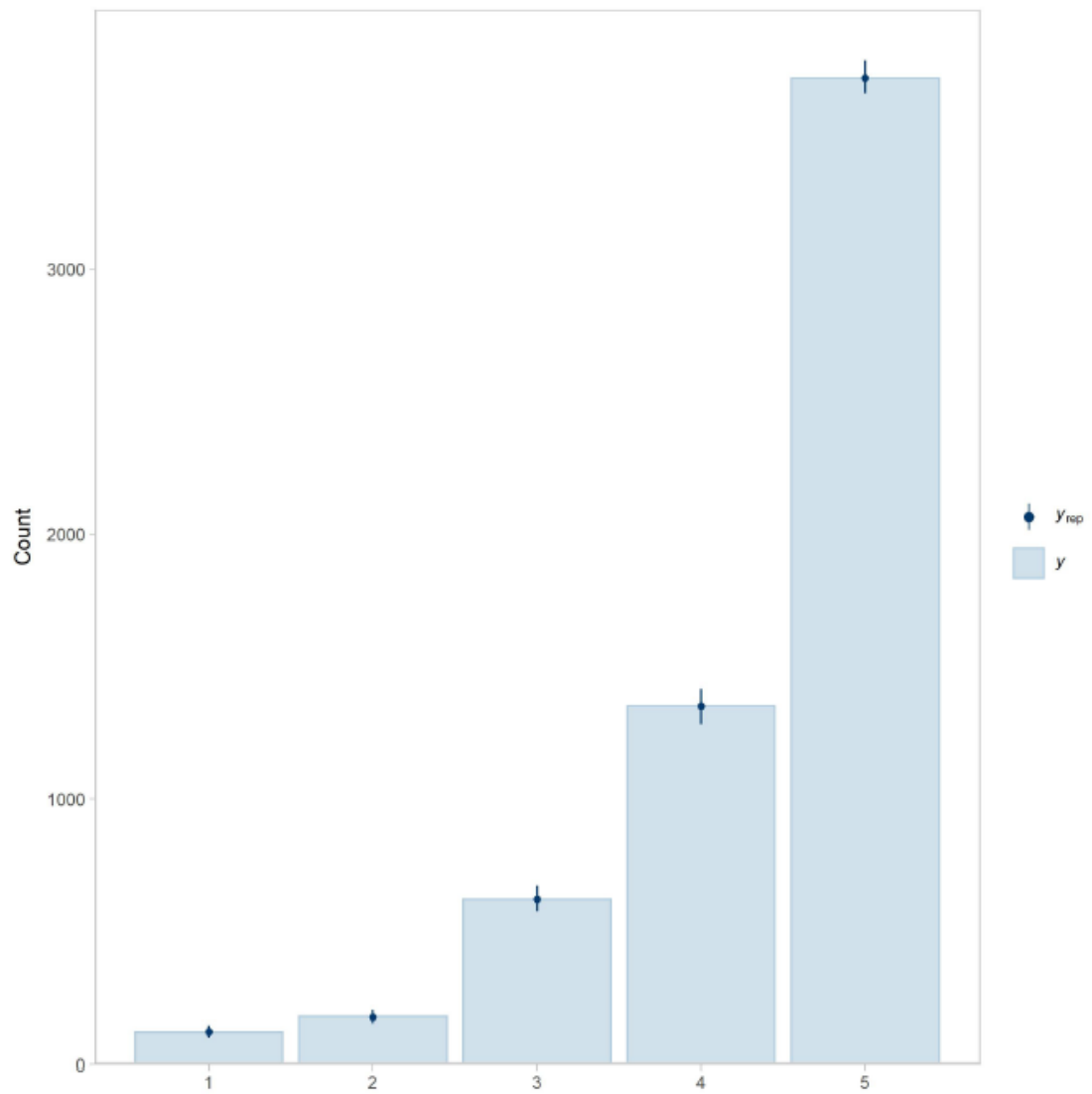
In the BCFA, item 8 (0.47) was the only one presenting a posterior value lower than 0.5. However, again it was close to the cutoff point and the item was retained. Additionally, the model presented a satisfactory model fit, although not the best values (BRMSEA = 0.07; BGammaHat D 0.95; adjBgammaHat = 0.89; BMc = 0.75). This structure was considered suitable to conduct future analysis.

Supplementary Table 1. Indices of model fit

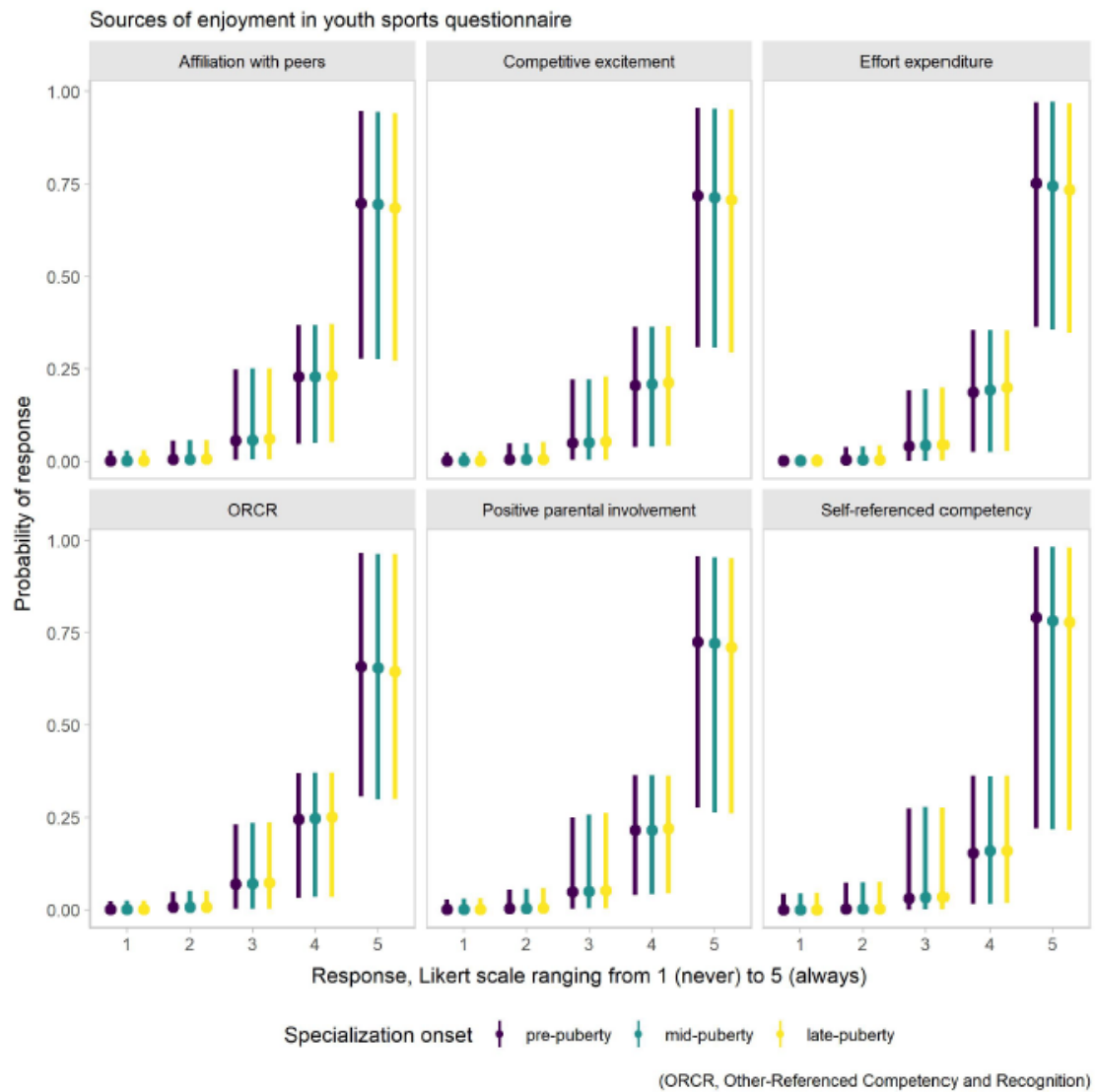
	X^2	df	X^2/df	CFI	TLI	RNI	$RMSEA$	$ECVI$	$SRMR$
M1	1005.6	335	3.00	0.88	0.79	0.81	0.07	2.97	0.07
M2	553.0	237	2.33	0.90	0.88	0.90	0.06	1.75	0.06
M3	462.8	215	2.15	0.92	0.90	0.92	0.05	1.51	0.06



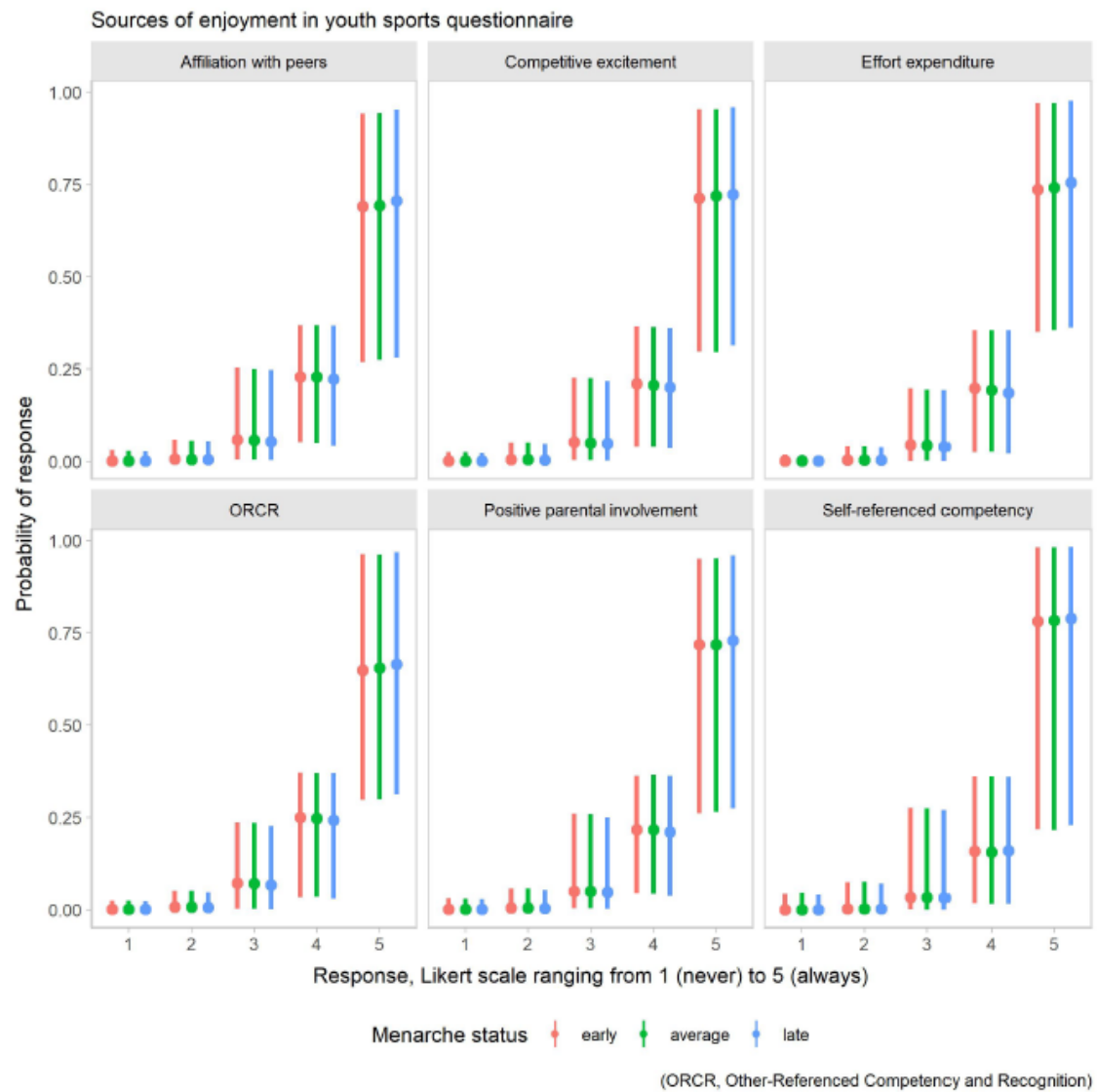
Supplementary Figure 25. Posterior predictive checks for the hierarchical model fitting the cross-sectional data



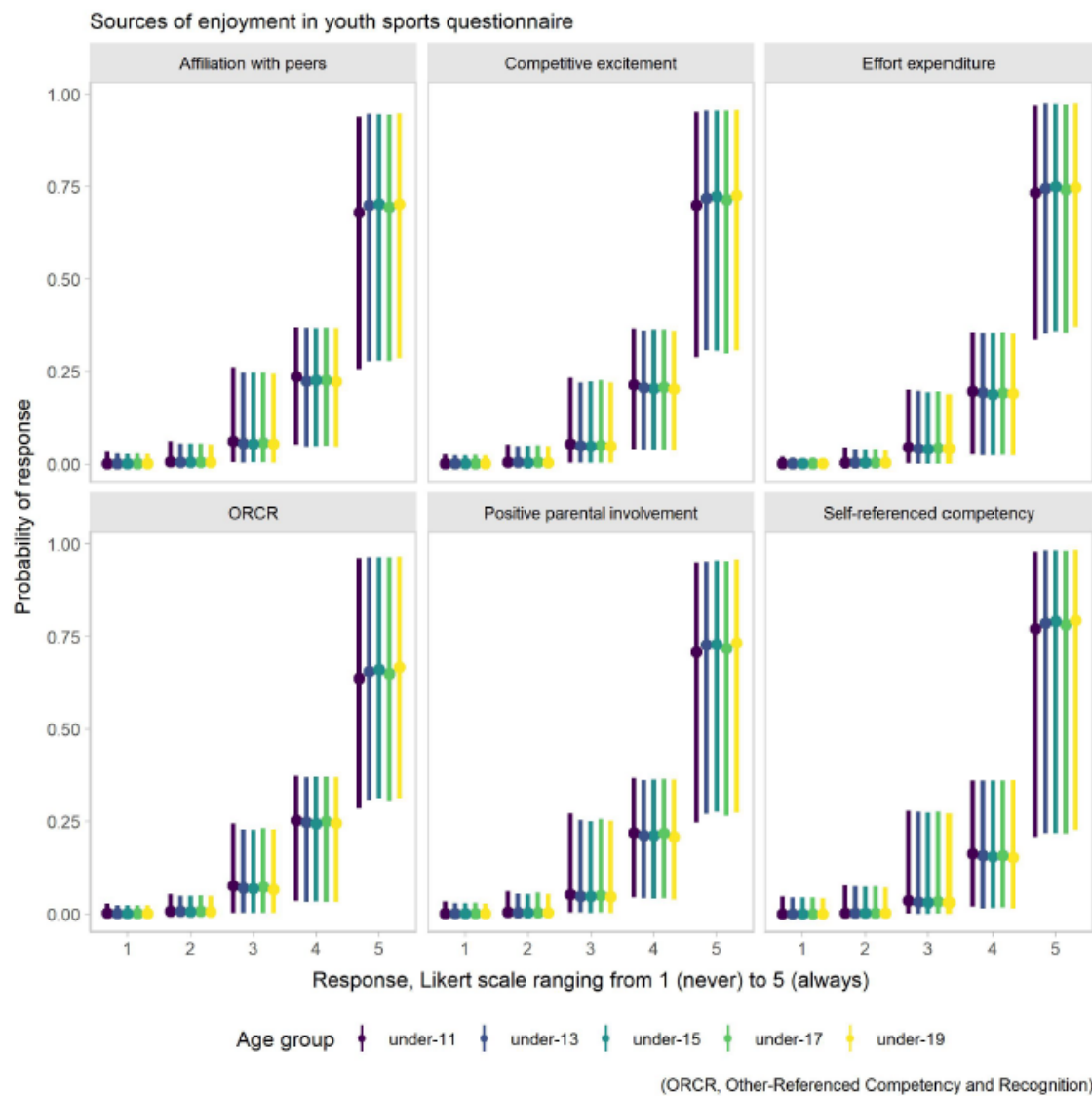
Supplementary Figure 26. Posterior predictive checks for the hierarchical model fitting the repeated-measures data



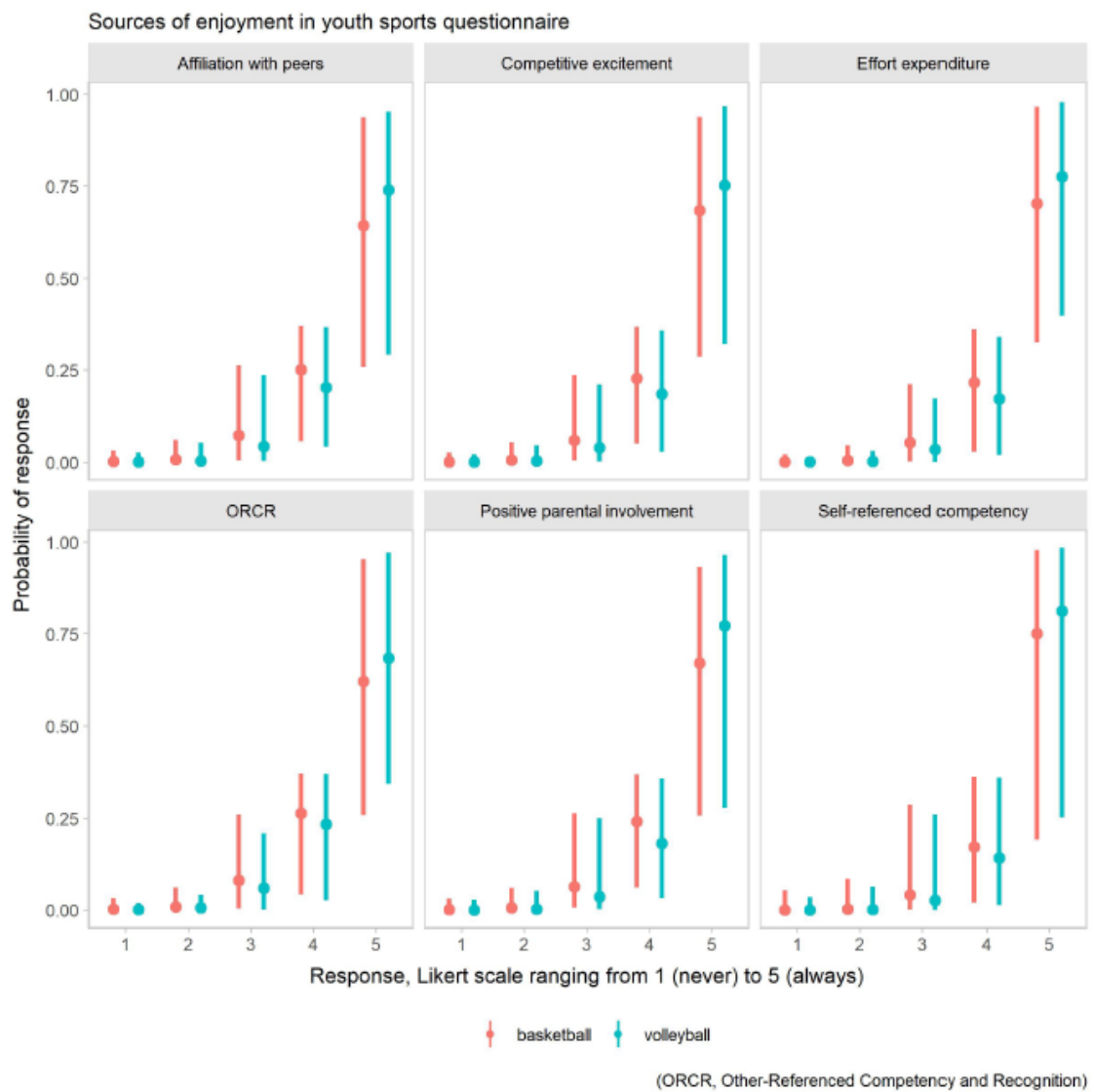
Supplementary Figure 27. Posterior predictions of the probability of responses for Other-referenced competency and recognition by specialization onset. Uncertainty estimates represent the 50% credible intervals.



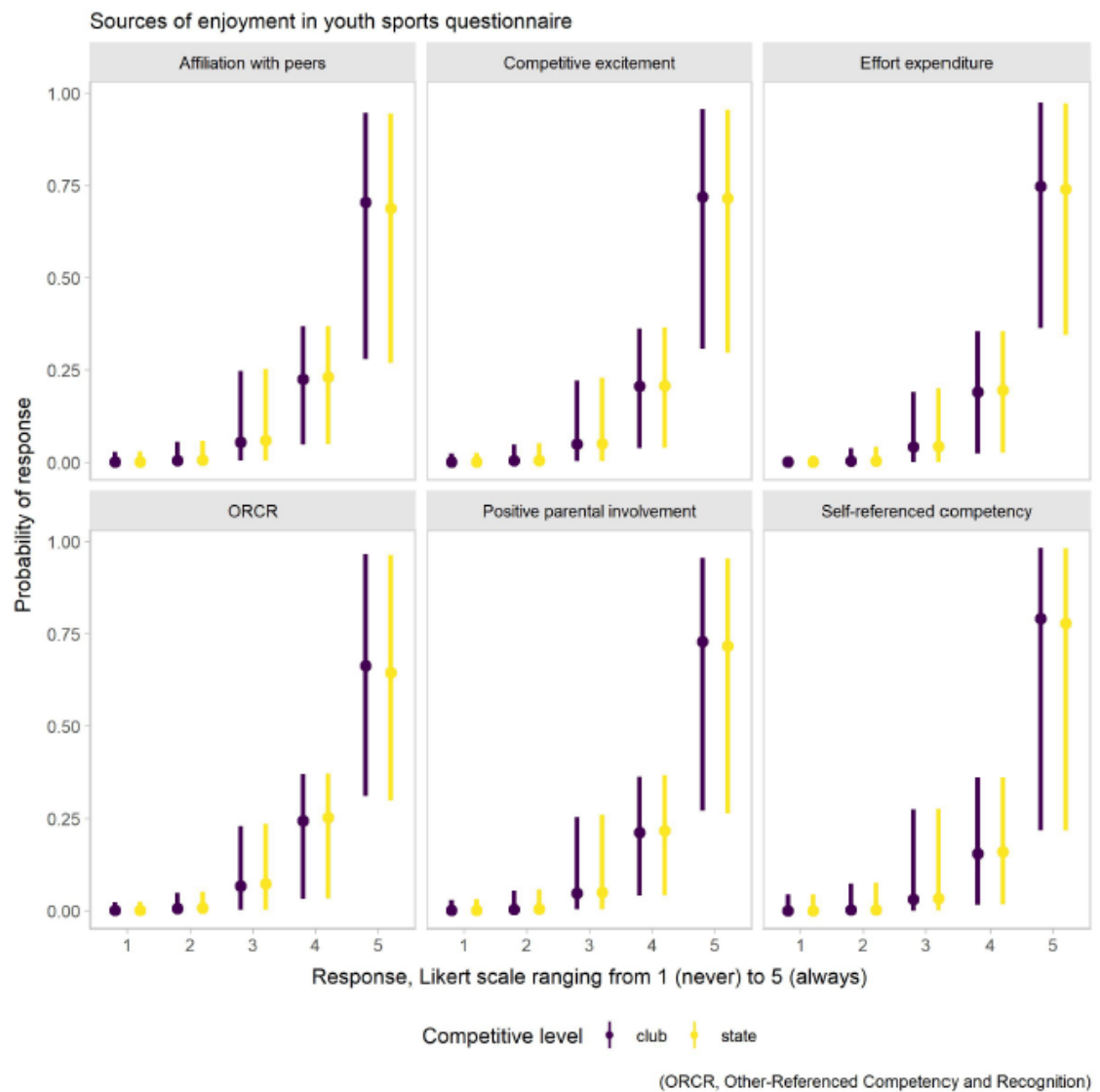
Supplementary Figure 28. Posterior predictions of the probability of responses for Other-referenced competency and recognition by menarche status. Uncertainty estimates represent the 50% credible intervals.



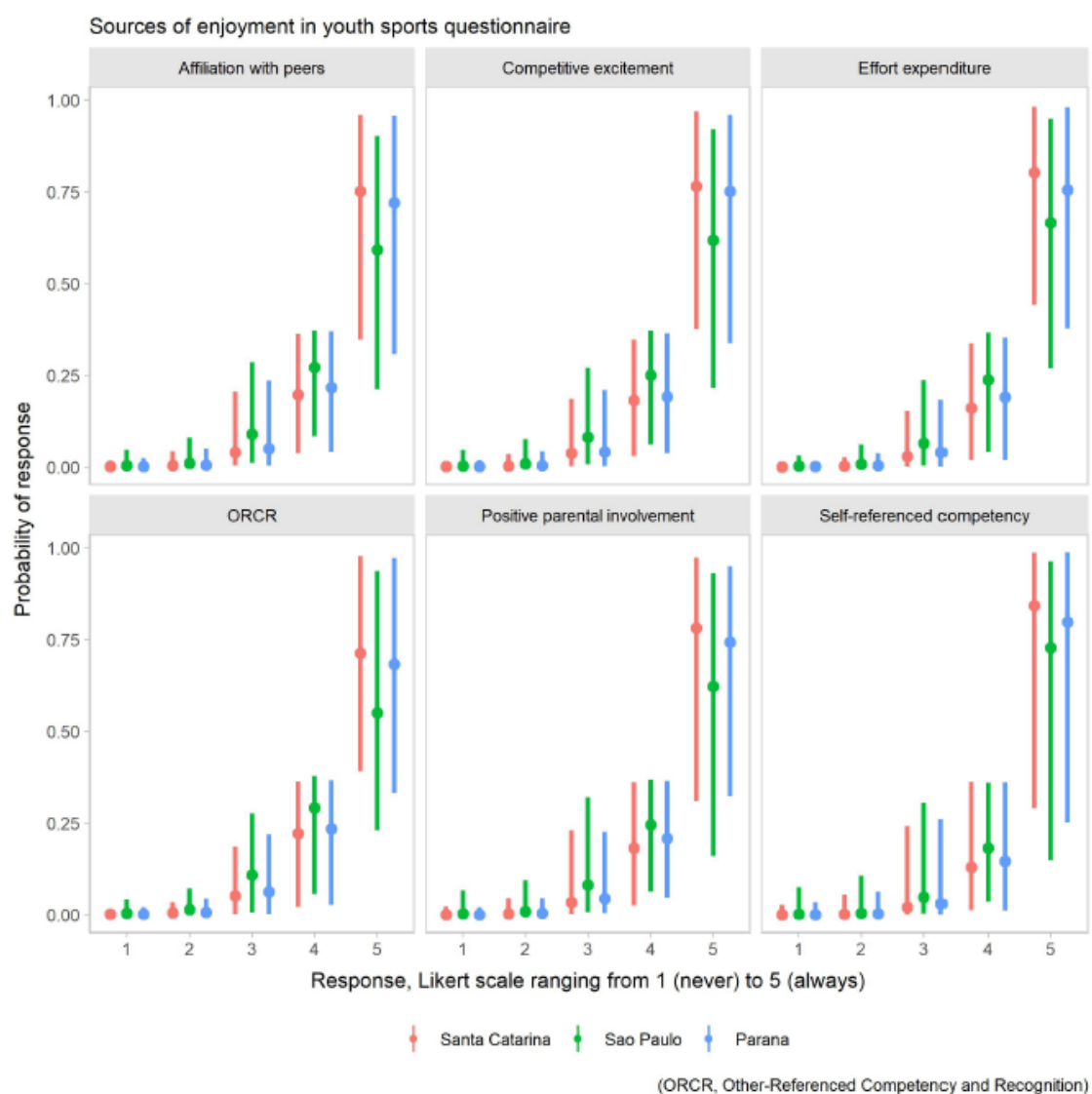
Supplementary Figure 29. Posterior predictions of the probability of responses for Other-referenced competency and recognition by age group. Uncertainty estimates represent the 50% credible intervals.



Supplementary Figure 30. Posterior predictions of the probability of responses for Other-referenced competency and recognition by sport. Uncertainty estimates represent the 50% credible intervals.



Supplementary Figure 31. Posterior predictions of the probability of responses for Other-referenced competency and recognition by competitive level. Uncertainty estimates represent the 50% credible intervals.



Supplementary Figure 32. Posterior predictions of the probability of responses for Other-referenced competency and recognition by state. Uncertainty estimates represent the 50% credible intervals.

References

JACKSON, D. L.; GILLASPY, J. A.; PURC-STEPHENSON, R. Reporting practices in confirmatory factor analysis: An overview and some recommendations. **Psychological Methods**, v. 14, n. 1, p. 6–23, mar. 2009.

MERKLE, E. C.; ROSSEEL, Y. blavaan: Bayesian Structural Equation Models via Parameter Expansion. **Journal of Statistical Software**, v. 85, n. 4, 2018.

MONTENEGRO-MONTENEGRO, E. **Improving the guidelines to conduct multigroup invariance test in Bayesian SEM**. Disponível em: <<https://ttu-ir.tdl.org/handle/2346/85814>>. Acesso em: 1 set. 2025.

R CORE TEAM. R: A language and environment for statistical computing. **R Foundation for Statistical Computing**, Vienna, Austria. 2018. Available online at <https://www.R-project.org/>.

ROSSEEL, Y. lavaan: An R Package for Structural Equation Modeling. **Journal of Statistical Software**, v. 48, n. 2, p. 1–36, 2012.

TEAM, S. D. Stan modeling language user's guide and reference manual, version 2.19.2. **Interaction Flow Modeling Language**. 2020.

WIERSMA, L. D. Conceptualization and Development of the Sources of Enjoyment in Youth Sport Questionnaire. **Measurement in Physical Education and Exercise Science**, v. 5, n. 3, p. 153–177, set. 2001.