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Deliberate practice, biological maturation, functional performance, and psychosocial characteristics among young basketball players

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Dissertation submitted to the Post-Graduate Program in Physical Education of the Federal University of Santa Catarina to obtain a Master's Degree in Physical Education.
Supervisor: Prof. Dr. Humberto Moreira Carvalho

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Ahlan Benezar Lima

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O presente trabalho em nível de mestrado foi avaliado e aprovado por banca examinadora composta pelos seguintes membros:

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Prof. Dr. Humberto Moreira Carvalho
Orientador

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RESUMO

Os centros de esportes juvenis, com foco na identificação e desenvolvimento de talentos, promovem contextos altamente seletivos. A especialização precoce é frequentemente considerada indispensável para a expertise esportiva, e a prática deliberada tem papel fundamental na performance e na aquisição de habilidades. Porém, críticos da especialização precoce, apontam impactos negativos dessa exposição precoce, como altas taxas de lesões, perda de motivação e Burnout. Apesar do debate na literatura, as evidências empíricas sobre os benefícios e malefícios da especialização precoce, são limitadas. Principalmente pela falta de operacionalização de quando a especialização precoce ocorre. Dada a importância do crescimento e da maturação no desenvolvimento de jovens atletas, consideramos dois marcos biológicos (a idade de início do salto de crescimento pubertário e a idade do pico de velocidade de crescimento [PVC]) para propor uma operacionalização da especialização precoce. Contudo, o estudo do crescimento e da maturação em atletas não é tão investigado quanto na população geral, e as evidências precisam ser melhor sintetizadas. Nosso objetivo foi investigar a influência da prática deliberada, maturação biológica e dimensões corporais no desempenho funcional e características psicológicas em jovens atletas. Além disso, determinamos as curvas de crescimento e a estimativa da idade do PVC em atletas. Este trabalho é composto por dois estudos: o primeiro estudo investigou 321 jogadores de basquetebol de ambos os sexos (14,0 ± 1,7 anos). Nós agrupamos os atletas pela idade de início da prática deliberada no basquetebol, em relação aos marcos de maturação biológica (início antes, durante ou após a puberdade). No segundo estudo, realizamos uma busca eletrônica em quatro bases de dados e selecionamos estudos longitudinais que reportaram ao menos três medidas repetidas de estatura em jovens atletas do sexo masculino, entre 10 e 17 anos. Trinta e cinco artigos preencheram os critérios de elegibilidade e foram considerados para a meta-análise. Baseado nos resultados do primeiro estudo, não encontramos variação substancial entre atletas com diferentes períodos de início de prática deliberada, em nenhuma das variáveis investigadas. Ajustando por gênero, os meninos com início da prática após a puberdade apresentaram melhor desempenho funcional do que aqueles que iniciaram antes ou durante a puberdade. As meninas com início de prática após a puberdade, apresentaram desempenho funcional ligeiramente pior do que as jogadoras com início da prática antes e durante a puberdade. No segundo estudo, identificamos a idade média estimada do PVC em jovens atletas aos 12,9 anos. Determinamos a curva de crescimento da estatura em jovens atletas e comparamos com as curvas de referência da OMS. A estatura dos atletas por volta dos 11 anos é semelhante (50º percentil) à população de referência, mas a partir dos 13,5 anos, os atletas ficam mais altos do que a maioria da população (70º percentil). Neste estudo, não observamos evidência substancial de vantagens ou desvantagens de iniciar a prática esportiva, no basquetebol, mais cedo ou mais tarde. E a maturação no esporte juvenil deve ser abordada com base em evidências, para promover o desenvolvimento esportivo de todos, especialmente crianças com estados de maturação mais atrasados.

Palavras-chave: Esporte juvenil. Crescimento. Maturação. Motivação. Desenvolvimento de talentos. Especialização esportiva. Meta-Análise.

RESUMO EXPANDIDO

Introdução

A infância e a adolescência são períodos caracterizados pelo crescimento e maturação acompanhados de mudanças de comportamento e mudanças nas estruturas e funções corporais. A prática esportiva é essencial neste período, principalmente por trazer inúmeros benefícios para a coordenação motora e saúde física e mental, sendo esses benefícios notados inclusive na idade adulta. Por outro lado, o esporte de alta performance, que visa a identificação e o desenvolvimento de talentos, promove contextos altamente seletivos, em que a especialização precoce é, geralmente, considerada indispensável para a expertise esportiva. E a prática deliberada tem papel fundamental na performance e na aquisição de habilidades. Por outro lado, muitas críticas são feitas no que diz respeito a especialização precoce, os principais argumentos sobre os efeitos negativos, apontam o aumento das taxas de lesões relacionadas ao esporte, diminuição da motivação para a participação esportiva e aumento da desistência da prática esportiva (Burnout). Apesar da ampla discussão na literatura, a respeito dos benefícios e malefícios da especialização precoce, as evidências empíricas disponíveis são limitadas. Além disso, há falta de consenso e operacionalização do que é a especialização precoce e quando ela ocorre. A conquista da excelência no esporte é muito mais complexa do que o simples debate sobre especialização, sendo a performance de elite, provavelmente, o resultado da combinação de inúmeros aspectos, tais como biológicos, psicológicos e sociais. Por conta disso, as pesquisas que visam investigar e compreender o desenvolvimento de jovens atletas precisam ser feitas a partir de uma abordagem multidisciplinar, em uma tentativa de compreender o fenômeno como um todo. Outros fatores que influenciam fortemente o percurso do jovem atleta são o crescimento e a maturação. Crianças que participam em contextos esportivos de alto rendimento podem ter padrões de crescimento e maturação diferentes da população em geral, devido às caraterísticas de identificação de talentos e especialização em idades muito precoces. O foco na performance imediata pode favorecer atletas com estados de maturação mais avançados, uma vez que estes atletas tendem a apresentar uma melhor performance física. Contudo, o estudo do crescimento e da maturação em atletas não é tão investigado quanto na população em geral, e as evidências disponíveis precisam ser sintetizadas.

Objetivos

O objetivo do presente estudo foi investigar a influência da prática deliberada, maturação biológica e dimensões corporais no desempenho funcional e características psicológicas de jovens atletas. Os objetivos específicos incluem caracterizar a especialização esportiva precoce com base em estimativas de marcos biológicos (idade de início do salto de crescimento pubertário e idade do pico de velocidade de crescimento [PVC]) a partir de estudos na população em geral. Examinar a influência da idade de início da prática deliberada no basquetebol sobre o desempenho funcional e características psicológicas em jovens atletas. Por fim, com base em uma meta-análise de estudos longitudinais disponíveis na literatura, determinar as curvas de crescimento e estimar a idade média do pico de velocidade de crescimento em jovens atletas.

Métodos

Esta pesquisa foi composta por dois diferentes estudos. O estudo 1 é uma pesquisa original com design transversal. Neste estudo, foram considerados dados coletados de 2015 a 2019 no basquetebol juvenil de três estados diferentes: São Paulo, Santa Catarina e Rio Grande do Sul. A amostra total foi composta por 321 atletas adolescentes brasileiros de basquetebol, com idade média de 14,0 (1,7) anos. A amostra incluiu atletas de ambos os sexos (201 meninos e 120 meninas) que participavam de treinos e competições por seus respectivos clubes. Nós estimamos, para cada gênero, a idade de início do salto de crescimento pubertário, através de uma meta-análise, usando modelagem Bayesiana multinível. Da mesma forma, definimos as referências específicas de gênero para a idade do PVC. A idade de referência para o início do salto de crescimento pubertário foi de 9,4 e 11,1 anos para meninas e meninos, respectivamente. A idade de referência do PVC foi de 11,9 e 13,9 anos para meninas e meninos, respectivamente. Agrupamos os jogadores pelo início da prática deliberada no basquetebol, da seguinte forma: 1) início da prática deliberada no basquetebol antes da puberdade: atletas que iniciaram a prática antes da idade de referência para o início do salto de crescimento pubertário; 2) início da prática no basquete durante a puberdade: atletas que iniciaram a prática entre as idades de referência do início do estirão de crescimento e idade do PVC; 3) início da prática após a puberdade: atletas que iniciaram a prática após a idade de referência no PVC. Para avaliar a performance funcional nós usamos o teste de salto vertical com contramovimento, o teste específico do basquetebol *Line Drill*, o teste de resistência *Yo-Yo IR1*. Os aspectos psicológicos foram avaliados usando os questionários: Deliberate Practice Motivation Questionnaire, Work and Family Orientation Questionnaire e Sources of Enjoyment in Youth Sports Questionnaire. No estudo 2, nós realizamos uma meta-análise a partir de uma revisão sistemática. Nós realizamos uma busca eletrônica em quatro bases de dados: MEDLINE (via PubMed), SPORTDiscus (via EBSCOhost), SCOPUS (Elsevier), e Web of Science. A estratégia de busca foi desenvolvida para acessar estudos longitudinais que reportavam ao menos três medidas repetidas para a estatura, usando uma amostra de jovens atletas do sexo masculino, entre 10 e 17 anos. Nós seguimos as diretrizes do PRISMA para a conduzir e reportar os resultados desta meta-análise.

Resultados e Discussões

De acordo com os resultados do estudo 1, não houve variação substancial entre atletas com diferentes idades de início na prática deliberada em nenhuma das variáveis analisadas. Ajustando por gênero, atletas do sexo masculino com início da prática deliberada após a puberdade apresentaram melhor desempenho funcional do que aqueles que iniciaram a prática antes ou durante a puberdade. Atletas do sexo feminino que iniciaram a prática deliberada no basquetebol após a puberdade apresentaram um desempenho funcional ligeiramente pior do que aquelas que iniciaram a prática antes ou durante a puberdade. A prática deliberada precoce no basquetebol não parece fornecer uma vantagem para o desenvolvimento das funções fisiológicas. Da mesma forma, a motivação para a prática deliberada e a motivação para o sucesso e a competição não parecem ser influenciadas negativamente pelo início precoce na prática deliberada no basquetebol. O debate sobre a relação entre o tempo gasto na prática deliberada e o desenvolvimento da performance em jovens atletas precisa enfatizar a qualidade pedagógica e o ambiente de treino. Além de levar em consideração a prática informal e o jogo deliberado. No estudo 2, trinta e cinco artigos preencheram os critérios de elegibilidade e foram considerados para a meta-

análise. Neste estudo, nós identificamos que a idade média estimada do PVC em jovens atletas foi de 12,9 anos. Os estudos de crescimento humano com a população geral são mais abundantes quando comparados a estudos de crescimento de atletas. A maiorias dos estudos com a população geral apontam para a média de idade do PVC entre 13,8 e 14,2 anos para o sexo masculino. Nossas estimativas baseadas em estudo com atletas quando comparadas com estimativas da população geral, indicam que os atletas o PVC muito mais cedo do que a população em geral, com exatamente um ano de diferença. Nós determinamos a curva de crescimento de jovens atletas dos 11 aos 17 anos. Além da maturação precoce, os jovens atletas também são mais altos do que população geral. Essa diferença se destaca por volta dos 13,5 anos e se mantém ao longo da adolescência, período em que os atletas apresentam altura média maior do que 75% da população juvenil em geral.

Considerações Finais
Esta dissertação contribui para determinar as curvas de crescimento de jovens atletas e estimar a idade no PVC, na qual os atletas são mais altos do que a população em geral, e a idade média no PVC ocorre muito mais cedo do que os não-atletas. Com base nesses achados, concluímos que os esportes juvenis priorizam os atletas com estado de maturação mais adiantado. Em segundo lugar, esta pesquisa contribui para a literatura da especialização esportiva e propõe uma operacionalização da especialização precoce e especialização tardia. Este estudo ainda adiciona resultados empíricos sobre os benefícios e malefícios da especialização precoce, no entanto, com base em nossos achados, não observamos evidência substancial de vantagens ou desvantagens de iniciar a prática esportiva, no basquetebol, mais cedo ou mais tarde. Por fim, o crescimento e a maturação devem ser levados em consideração e tratados com base em evidências científicas em contextos de esportes juvenis, com o fim de promover o desenvolvimento esportivo de todos, especialmente aquelas crianças que possuem estados de maturação mais atrasados, que muitas vezes são excluídos do ambiente esportivo de alto rendimento.

Palavras-chave: Esporte juvenil. Crescimento. Maturação. Motivação. Desenvolvimento de talentos. Especialização esportiva. Meta-Análise.

ABSTRACT

Youth sports academies focused on talent identification and development often promote highly selective contexts. Early specialization is frequently considered imperative for sports expertise, and deliberate practice plays a key role in skill acquisition and performance. However, critics of early specialization argue for the negative impacts of this early exposure, such as high rates of sport-related injuries, lack of motivation, and burnout. Despite the discussion in the literature, empirical evidence on the benefits and harms of early specialization is limited, mainly because there is no consensus or operationalization on when early specialization occurs. Given the importance of growth and maturation in the development of young athletes, we consider the use of biological milestones to propose an operationalization of early specialization. However, growth and maturation of athletes are understudied compared to the general population. Hence, available evidence needs to be synthesized. Thus, this dissertation aimed to investigate the interacting influence of deliberate practice, biological maturation, and body dimensions on functional performance, and psychosocial characteristics, among young athletes. In addition, we determine growth curves and estimated age at PHV in young athletes. This dissertation is composed of two studies: study 1 is original cross-sectional research, and the sample included 120 female and 201 male adolescent basketball players (14.0±1.7 years). We grouped players by the age of onset of deliberate basketball practice as related to biologic maturation milestones (pre-puberty, mid-puberty, and late-puberty deliberate practice onset). The biological milestones used were the age of onset of the pubertal growth spurt and age at PHV. In study 2, we performed an electronic search in four databases and selected longitudinal studies that reported at least three repeated measures for stature, involving a sample of young male athletes aged between 10 and 17 years. Thirty-five articles met the eligibility criteria and were used for the meta-analysis. Based on findings of study 1, there was no substantial variation among contrasting players by the onset of deliberate practice in all of the outcomes. Adjusting for gender, male players with late-puberty deliberate practice onset had better functional performance than players with pre- and the mid-puberty onset of practice. Female players with late-puberty deliberate practice onset had slightly worst functional performance than players with pre- and the mid-puberty onset of practice. We identified in study 2 that the estimated average age at PHV in young athletes was 12.9 years. We determine the athlete's growth curve for stature and compared it with the WHO reference curves. Athletes' stature around 11 years old is similar (50th percentile) to the reference population, but from around 13.5 years, athletes are taller than most (70th percentile). In conclusion, we do not observe any substantial evidence on the advantages or disadvantages of early specialization. Growth and maturation must be addressed based on evidence in youth sport contexts to promote sports development for all children, especially athletes with a later maturation stage.

Keywords: Youth sports. Growth. Maturation. Motivation. Talent development. Specialization. Meta-Analysis.

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LIST OF ABBREVIATIONS AND ACRONYMS

aPHV – age at Peak Height Velocity

CA – Chronological Age

CMJ – Countermovement jump test

DMSP – Developmental Model of Sports Participation

DPMQ – Deliberate Practice Motivation Questionnaire

FIBA – International Basketball Federation

LD – Line drill test

TID – Talent Identification Development Programs

PHV – Peak Height Velocity

PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-Analysis

PRISMA-P – Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols

PROSPERO – The International Prospective Register of Systematic Reviews

SEYSQ – Sources of Enjoyment in Youth Sports Questionnaire

TITLE-ABS-KEY – Title, Abstract, and Key-words filter

TOYA Study – Training of Young Athletes Study

WFOQ – Work and Family Orientation Questionnaire

WHO – World Health Organization

YO-YO IR1 – Yo-yo Intermittent Recovery Level 1 test

DISSERTATION STRUCTURE

The present thesis is organized using the alternative format described on item 6 of the norm 02/2008 of the Post-Graduate Program in Physical Education of the Federal University of Santa Catarina. The present document has four chapters: 1) Introduction, composed of the rationale and justification for the research problem and its objectives; 2) Study I - Deliberate practice, functional performance and psychological characteristics in young basketball players: a bayesian multilevel analysis; 3) Study II - Peak height velocity curves in young athletes: a meta-analysis; and 4) Final considerations. The first study is an empirical investigation about deliberate practice and multidisciplinary factors of young athletes´ development in a sample of youth basketball athletes. Variation in functional performance, motivation, and enjoyment is investigated adjusting for starting deliberate basketball practice. This study is already published and is presented as study I. The second study corresponds to secondary research, where we will perform a meta-analysis of growth studies with young athletes focused on pubertal growth. The article is presented as study II, and its final version will be submitted in a scientific journal.

SUMMARY

1 INTRODUCTION

Childhood and adolescence are characterized by growth, maturation, and development, marked by changes in body structures, dimensions, functions, and behavior (1). Sports practice is an essential tool to increase physical activity (2, 3), motor competence (4), and mental health (5) during childhood and adolescence, likely bringing these benefits to adulthood (6).

Youth sports academies often promote highly selective contexts, focused on talent identification and development, assuming a deliberate practice framework (7). Consequently, early specialization of young athletes during childhood is often promoted (8). In the last decades, the identification and selection of talents have become of interest for sports science research and key for stakeholders in youth sports, mainly promoted by the increased importance of international competitions, such as the Olympic Games, which are profitable and offer political arguments (9-11). Thus, efforts are being devoted to developing evidence-based approaches to finding a competitive edge, fostering a greater quantity, quality, and structure of practice through an increase of talent identification and development programs (TID) (12, 13).

TIDs were developed on the premise that talent is made, not born (9). On the other hand, the nurture-nature debate is based on attempts to understand and cultivate expert performance (9, 14). Galton first proposed this nurture-nature distinction in 1874, and research in the field of Sports Genomics has advanced to the present day (15-17). Currently, research highlights a significant hereditary contribution to expert athletes and numerous genetic markers associated with elite status and predisposition to success in certain types of sports (16). Therefore, the simple genetic contribution is not enough to identify an elite athlete. For this reason, athletes are engaging at an earlier age in sports practice, focusing on ways and tasks that improve specific aspects of performance towards senior elite status (17, 18). Thus, research in sports science has focused on identifying, in addition to genetic factors, what types of environmental constraints are critical for the development of successful athletes (17, 19, 20).

Following the deliberate practice theory, it is often assumed that the expertise attainment in sport is positively related to the amount of practice (7, 19). Also, early sport specialization is generally and naively assumed as a premise for talent development (9, 21, 22). This premise emerged based on observations of monotonic deliberate practice and the acquisition of expert performance in musicians (7). Large amounts of deliberate practice were identified as critical in distinguishing those with an exceptional performance from those who were just good (7). Consequently, it was proposed a need to accumulate 10,000 hours of deliberate practice to promote expertise acquisition (7). In the sports context, deliberate practice can be defined as a sport-specific practice designed, instructed, and monitored by a coach with the primary purpose of attaining and improving skills (7, 22).

Early specialization popularity has increased primarily due to the influence of the deliberate practice theory (17, 21, 23). In this sense, parents and coaches attempt to expose children as early as possible to sport-specific deliberate practice to accelerate the development of athletes' performance and skill level looking for exceptional performance in adulthood (23-25). Early specialization is a complex process, and there is no consensus on its definition. However, some characteristics can be pointed out in this phenomenon, such as participation throughout the year in a single "signature" sport, limitation of participation in other sports and activities, the involvement of pre-pubertal children, and the pursuit of elite status (21, 26). Furthermore, within the chosen sport, sometimes there is specialization in a single game position or function, which further restricts the acquisition of new skills (27).

Despite being widespread as the principal way to achieve sports excellence (28), early specialization has been strongly criticized for an increase in the risk of injuries (29, 30), in addition to a lack of motivation and dropout (31-34). Data available is more abundant addressing the impact of musculoskeletal structures; on the other hand, research addressing the effects of early specialization on motivation and psychological characteristics is scarce and needs more understanding (21, 35). Given the lack of operationalization of early specialization and late specialization, it is not easy to interpret research to understand the impacts of this phenomenon. Thus, alternatives are needed to define in practical terms when early specialization occurs. Thus, an operationalization of early/late specialization was proposed in this study, using biological milestones of growth and human development (i.e., age of the pubertal growth spurt onset and age at PHV) to define this phenomenon.

Youth sport is an important research topic, and young athletes' development should be seen as a more complex process than the identification of genetic markers or the quantity and quality of practice. Despite the importance of understanding and investigating the contribution of each factor to the development of an athlete, sports success is more complex than the isolated contribution of these factors (36). Expert performance results from a successful combination of biological, psychological, and social constraints, so it is necessary to understand and investigate youth athletes' development in a holistic way (7, 37, 38). Physical performance is essential for most sports and has been extensively investigated in the literature, mainly because in team sports, physical performance is an essential part of the evaluation and development process of young athletes and, sometimes, serves as a criterion for the selection/deselection of players (9, 39-41).

Sports performance presents a complex problem with a myriad of interacting factors. Hence, it is not easy to highlight a single performance variable, or a set of variables, responsible for identifying and developing young athletes during pubertal years where performance is greatly influenced by growth and maturation (1, 9, 42, 43). Available data with children indicates a relation between physical performance and pubertal growth (44-49). Hence, growth and maturation changes must be considered in relation to physical capacities development in youth sports. There are several studies in youth sports addressing physical development (44-49). However, few studies attempt to control athletes' maturation when analyzing and interpreting the performance outcomes (41, 47, 49-51). Children participating in high-performance sports may show different patterns of growth and maturation due to the characteristics above, such as early talent identification and early specialization (28, 52). In addition, the focus on immediate performance can favor athletes with more advanced growth rates and maturation, leading to an overrepresentation of early-maturing athletes (53, 54). Although the importance of this topic for youth sports, little is known on specific characteristics of growth and maturation in athletic populations, and the evidence is diffuse. To the best of our knowledge, there is no available research synthesizing empirical data on young athletes' growth. Therefore, in this study, we performed a meta-analysis to characterize athletes' specific growth and maturation from individual studies.

On the other hand, psychological characteristics have been identified as determinants to coping within young athletes' development and expertise attainment (55, 56). In addition, motivation has been identified as an essential variable for success and distinguishing elite performance among young athletes (57-59). Also, contextual factors such as financial resources and parental support, the quality of the coach-athlete relationship, or birthplace effect are identified as determinants for youth athlete's development (38, 60-62). Therefore, research in youth sports must consider multidimensional approach, considering outcomes and levels of variation influencing young athletes' development and expertise attainment.

1.1 Purpose

To investigate the young athletes' growth patterns and the interacting influence of deliberate practice, biological maturation and body dimensions on functional performance, and psychological characteristics among young basketball players.

1.1.1 Specific purposes

To characterize early sport specialization based on estimates of biological milestones (age of the pubertal growth spurt onset and age at PHV) from studies in the general population.

To examine the influence of age starting deliberate basketball practice on functional performance and psychological characteristics in youth basketball.

Based on a meta-analysis of longitudinal studies available in the literature, determine growth curves and peak height velocity in young male athletes.

2 STUDY I: Deliberate Practice, Functional Performance and Psychological Characteristics in Young Basketball Players: A Bayesian Multilevel Analysis.

This manuscript is published in the *International Journal of Environmental Research and Public Health*[1] (Appendix A).

Deliberate Practice, Functional Performance and Psychological Characteristics in Young Basketball Players: A Bayesian Multilevel Analysis

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Abstract
Background: Early sport specialization has increased its popularity mostly based on the deliberate practice theory premises. In this study, we examined the influence of the age of onset of deliberate basketball practice on body size, functional performance (countermovement jump, line drill and yo-yo intermittent recovery level 1), motivation for achievement and competitiveness, motivation for deliberate practice and sources of enjoyment among young Brazilian basketball players. In addition, we adjusted for the influence of gender, age group, maturity status and state basketball federation on the outcomes. *Methods:* The sample included 120 female and 201 male adolescent basketball players aged 14.0 (1.7) years, on average. We grouped players by the age of onset of deliberate basketball practice as related to biologic maturation milestones (pre-puberty deliberate practice onset, mid-puberty deliberate practice onset and late-puberty deliberate practice onset). *Results:* There was no substantial variation among contrasting players by the onset of deliberate practice in all of the outcomes. Adjusting for gender, male players with late-puberty deliberate practice onset had better functional performance than players with pre- and mid-puberty onset of practice. Female players with late-puberty deliberate practice onset had slightly worst functional performance than players with pre- and mid-puberty onset of practice. *Conclusions:*

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Early deliberate basketball practice does not appear to provide an advantage for the development of physiological functions. Likewise, enjoyment, motivation for deliberate practice and motivation for achievement and competition do not appear to be negatively influenced by early deliberate basketball practice. The debate about the relationship between time spent in deliberate practice and performance development in young athletes will need to emphasize the coaching pedagogical quality and the training environment and account for informal practice and deliberate play.

Keywords: youth sports; maturation; motivation; talent development; specialization.

2.1 Introduction

In the context of talent development, early sport specialization is often assumed as a premise for expertise attainment (9, 25, 63). Early specialization popularity has increased mostly due to the influence of the deliberate practice theory (7, 63, 64). The conceptual framework postulates that the accumulated hours of training through the sports career imply extensive deliberate practice starting in childhood followed by continuous expansion in the specialization years (65). Promoters of early specialization often argue that early exposure to deliberate practice in a single sport will accelerate the development of athletes' performance and skill level (25), and it is imperative to develop expertise in adulthood (23, 63, 66).

However, there has been extensive criticism of early specialization. Early specialization is associated with high rates of sport-related injury, lack of motivation for participation, and increased sports withdrawal (burnout) (21, 23, 31-33, 35, 67-72). Data available is more abundant addressing the impact of early specialization on musculoskeletal structures (31, 32, 69, 70, 73, 74). When considering physiological function development or psychological determinants links with early specialization the available data are limited (21, 23, 24, 35, 75), at best. On the other hand, youth sports specialization research requires interdisciplinary approaches (75), as well as adjustments for confounding individuals (e.g., age, body size or gender) and contextual characteristics (e.g., sport context or socioeconomic environment) (21, 75).

Similar to other youth sports contexts, the International Basketball Federation (FIBA) and its affiliated World Association of Basketball Coaches advise coaches and youth basketball programs to promote the engagement and commitment to basketball practice in supervised contexts as early as 5 years of age (76). In basketball, body dimensions and specific functional capacities are important determinants of performance (77). Furthermore, basketball-specific functional capacities appear to have a substantial influence on the selection/promotion process (51). The emphasis—or probably overemphasis—on body size and functional capacities likely contributes to an overrepresentation of early maturing players at early age groups (51, 78). Hence, maturity-associated variation on body dimensions, functions, and behavioral characteristics should be considered in the interpretation of young players' performance and development.

On the other hand, in this study, we focus on two main psychological factors associated with deliberate practice and expertise attainment in sport (79-81). The first outcome of interest is motivation, in particular achievement and competitiveness motivation and deliberate practice motivation. The athlete's motivation has been highlighted as a relevant factor to distinguish those who progress through talent development programs (57, 59, 81). In particular, achievement motivation reflects the willingness to work hard and perform well, be challenged by difficult tasks, express high internal standards of excellence, and a desire to win in a competition against others (79). Furthermore, motivation relates to the athlete's engagement and willingness to be exposed to deliberate practice (79, 81), translated in the will to become an excellent performer (excel), and the will to improve in a competition. The second factor of interest is sport enjoyment. Enjoyment in youth sport has been noted to be a primary factor for initiating and maintain committed to long term involvement in sport (82-84). Enjoyment may be defined as pleasure, liking and fun for the sports practice (85). A negative impact of early specialization on enjoyment has been observed in young athletes (86).

There is a lack of consensus in the literature to define specialization (21). It may be conceptualized as year-round participation in a single "signature" sport, with limited participation in potential sport alternatives, and with a deliberate focus on training and development in the pursuit of elite status (21, 35, 87, 88). Also, youth sports participation and specialization can be conceptualized as a continuum. However, there are no clear references to define early specialization or late specialization. A solution is to interpret specialization relative to pubertal growth (64). Assuming the influence of deliberate practice framework on youth sports specialization, we may consider the start of a "signature" sport deliberate practice 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)]. Hence, we may consider the original operationalization of deliberate practice that defines it as any training activity undertaken with the specific purpose of increasing performance, requiring cognitive and/or physical effort and relevant to promoting positive skill development (7). The biological maturation milestones can be defined with available knowledge in the literature (89) and we can use Bayesian multilevel modeling to perform a meta-analysis to derive the estimates (90). Then players may be labeled as the pre-puberty onset of deliberate practice (i.e., before age of onset of pubertal growth), the mid-puberty onset of deliberate practice (i.e., between the onset of pubertal growth and age at PHV) or late-puberty onset of deliberate practice (i.e., after the age of PHV).

Given the interdisciplinary nature of young players´ development (57, 91, 92), modeling approaches need to account for the potential influences of individual and contextual characteristics, as well as different levels and sources of variation on the outcomes (51, 93). In youth sports surveys, samples are often non-representative and imbalanced, with noisy data that can potentially lead to biased and unreliable inferences. As previously noted (93, 94), the Bayesian multilevel modeling approach offers a flexible approach that naturally considers the hierarchical data structure. Bayesian methods allow us to combine the information known before seeing the data (i.e., the prior uncertainty concerning a parameter or hypothesis expressed as a probability distribution) with what is learned from the observed data (i.e., the likelihood of the data conditioned on the parameter or hypothesis) to update our knowledge expressed as the posterior distribution (95). Hence, Bayesian methods provide a natural approach to account for different sources of inferential uncertainty (96).

In the present study, we examined the influence of the age starting basketball deliberate practice on functional performance and psychological characteristics in youth basketball. To allow a comprehensive interpretation, we illustrate the use of Bayesian multilevel modeling to estimate the variation in the outcomes accounting for cross-classified nesting, i.e., within and between variation by gender, competitive age group, estimated maturity status and state basketball federation (given the contrasts in organizational structures in Brazilian youth basketball across states).

2.2 Materials and Methods

2.2.1 Data

In this study, we considered data from surveys with cross-sectional data collected from 2015 to 2019 in youth basketball. The total sample comprised observations in 321 Brazilian adolescent basketball players aged 14.0 (1.7) years, on average, with a range between 9.5 and 17.9 years. The sample included 120 female and 201 male players. Players were engaged in clubs and competition from three state federations: São Paulo, Santa Catarina and Rio Grande do Sul. All federations are affiliated in the Confederação Brasileira de Basketball (Brazilian Basketball Confederation). Furthermore, all state federations have female and male youth basketball competitions each year. The São Paulo basketball federation (from the southeast part of Brazil) is the most representative in Brazil, as it has most of the teams in the highest professional championship. The Santa Catarina and the Rio Grande do Sul basketball federations have established traditions in youth basketball and organize a yearly state-level adult championship. Data were collected at each basketball club facility. All players participated in regular training sessions (3–5 sessions; 270–450 min per week) with their clubs. Clubs participated in a competitive season, which in Brazil typically runs between February/March until November/December comprising about 20–30 games per season. Given the variation between state federations for competitive age groups, we grouped players as under-11, under-13, under-15 and under-17, assuming a two-year range, which is the most common competitive age group in Brazilian youth sports. Distribution of players by gender and age group across the basketball federations is presented as **supplementary material** **(Appendix B)**.

We obtained ethical approval from the authors´ institutional ethics committee. The participants were informed about the nature of the survey, that participation was voluntary and that they could withdraw from the study at any time. All participants and their parents or legal guardians provided written informed consent.

2.2.2 Chronological Age and Anthropometry

We calculated chronological age by subtracting birth date from the day of testing to the nearest 0.1 year. Stature was measured with a portable stadiometer

(Seca model 206, Hanover, MD, USA) to the nearest 0.1 cm. Body mass was measured with a calibrated portable balance (Seca model 770, Hanover, MD, USA) to the nearest 0.1 kg. Reliability estimates for the observer are published elsewhere (57).

2.2.3 Maturity Status

Maturity status was determined based on the gender-specific maturity offset protocol (97). The offset equations predict time before or after PHV based on chronological age and stature. Based on maturity offset, the participants, ranging from −2.99 to +5.42 years from/to PHV, were grouped into three maturity status categories for analysis: pre-PHV (PHV ≤ −1.00 year; n = 33), circa-PHV (−1.00 < PHV < +1.00 year; n = 103) and post-PHV (PHV ≥ + 1.00; n = 185). 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 (98), assuming the limitations of the offset equation (97, 99).

2.2.4 Basketball Deliberate Practice

The age of deliberate practice onset in basketball was considered as the self-reported age when athletes started formal 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. However, deliberate play (63) and informal participation in other sports, previous or after the onset of deliberate basketball practice was not considered in this study. Hence, we assume the limits of our data to describe the continuum of sport participation of the sample and caution are advised to interpret the data. 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. The biologic milestones references were estimated considering data from longitudinal growth studies (89). We estimated the gender-specific age of pubertal growth spurt onset using Bayesian multilevel modeling to perform a meta-analysis (90). Similarly, we set the gender-specific references for the age at PHV based on a meta-analysis of 25 and 10 studies for female and male adolescents, respectively (89). 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 grouped the players by the onset of deliberate basketball practice as follows: pre-puberty deliberate basketball practice onset (n = 156), the players who started practice before the reference age of pubertal growth spurt onset; mid-puberty deliberate basketball practice onset (n = 125), the players starting practice between the reference ages of pubertal growth spurt onset age and at PHV; late-puberty deliberate basketball practice onset (n = 40), the players starting practice after the reference age at PHV.

2.2.5 Functional Performance

We used the vertical jump with countermovement (100), a short-term maximal running protocol, the line drill test (101, 102) and intermittent endurance test, the yo-yo intermittent recovery level 1 test (yo-yo IR1) (103) to examine functional performance. The tests were performed in two sessions separated by at least 48 h. The first session included the vertical jump and line drill test, and the second session the yo-yo IR1. A standardized warm-up was taken by all athletes before testing. Details about the functional performance procedures and reliability estimates are available elsewhere (44, 57, 91).

2.2.6 Psychological Measures

The psychological factors were assessed using the deliberate practice motivation questionnaire (80), the work and family orientation questionnaire (104) and the Sources of Enjoyment in Youth Sports (84). The deliberate practice motivation questionnaire was originally designed for chess (79, 80). The questionnaire is composed of 18 items, rated similarly on a 5-point Likert scale, considering two dimensions of deliberate practice: will to compete and will to excel. We used an adapted version for basketball, translated and validated to Portuguese (81). The adapted version to basketball included both long term goals (“I want to be a professional Basketball player”), and basketball-specific changing situations (“I like tough drills in practice because they help me to improve my skills” or “I prefer to play 3 on 3 with friends rather than practicing hard”) (81). The reliability of the adapted

Portuguese version has been reported with data in youth basketball from the same age range of the present study elsewhere (81). The work and family orientation questionnaire is composed of 19 items, rated on a 5-point Likert scale (1 = completely disagree to 5 = completely agree), assessing four dimensions of achievement: personal unconcern (lack of concern with others' opinions), work (the desire to face challenging tasks the desire to practice and perform well), mastery (the desire to face challenging tasks) and competitiveness (the desire to be better when compared to others). For the present study, we only used the last three subscales in the present study, consistent with previous observations with similar samples of youth basketball (42, 57, 81). The players from the São Paulo Basketball Federation completed a study-and-pencil questionnaire, while the remaining completed an online form of the questionnaires. All questionnaires were completed under the supervision of a researcher during the data collection at the clubs training facilities. We used the 28-item Portuguese version of the sources of enjoyment in youth sport questionnaire (105). The questionnaire examines five dimensions: self-referenced competencies, others-referenced competencies, effort expenditure, affiliation with peers and positive parental involvement. Each questionnaire item is rated on a 5-point Likert scale (1 = completely disagree to 5 = completely agree). The questionnaire showed good reliability (105).

2.2.7 Data Analysis

We used Bayesian multilevel models to examine variation by the onset of deliberate basketball practice, gender, age group, maturity status and state basketball federation on adolescent Brazilian basketball players´ body dimensions, functional performance and psychological characteristics. For interpretative convenience and computational efficiency, we standardized the outcomes. Each player´s outcome was estimated as a function of his/her characteristics, i.e., onset of deliberate basketball practice, gender, age group, maturity status and state (for player i, with indexes j, k, l, m and n for the onset of deliberate basketball practice, gender, age group, maturity status, and state, respectively), and we allowed female and male players to vary when grouped by the onset of deliberate basketball practice:

$$y_i = \beta^0 + \alpha_{j[i]}^{basketball\ practice} + \alpha_{k[i]}^{gender} + \alpha_{l[i]}^{age\ group} + \alpha_{m[i]}^{maturity\ status} + \alpha_{n[i]}^{state} + \alpha_{j[i],k[i]}^{basketball\ practice.gender} \quad (1)$$

The terms after the intercept are modeled as group effects (also referred to as random effects) drawn from normal distributions with variances to be estimated from the data:

$\alpha_{j[i]}^{basketball\ practice} \sim N\ (0, \sigma^2_{basketball\ practice})$, *for* j = *1, 2, 3.*

$\alpha_{k[i]}^{gender} \sim N\ (0, \sigma^2_{gender})$, *for* k = *1, 2.*

$\alpha_{l[i]}^{age\ group} \sim N\ (0, \sigma^2_{age\ group})$, *for* l = *1, 2, 3 and 4.*

$\alpha_{m[i]}^{maturity\ status} \sim N\ (0, \sigma^2_{maturity\ status})$, *for* m = *1, 2, 3.*

$\alpha_{n[i]}^{state} \sim N\ (0, \sigma^2_{state})$, *for* n = *1, 2, 3.*

$\alpha_{j[i],k[i]}^{basketball\ practice.gender} \sim N\ (0, \sigma^2_{basketball\ practice,gender})$, *for* j = *1, 2, 3 and* k = *1, 2.*

An important step of the Bayesian methods is the selection of priors. Given that human behavior and performance tends to be heterogenous, particularly in youth sports contexts, we were intentionally conservative with our interpretations. Hence, we used weakly informative priors to regularize our estimates. We used normal priors (0,1) for the population-level parameter (i.e., intercept) and the group-level parameters. By standardizing the outcomes and using a normal (0,1) prior for the parameters, we state that effects among group-level estimates are unlikely to be greater than one standard deviation of the outcome. We run four chains for 2000 iterations with a warm-up length of 1000 iterations for each model. The models were inspected and validated using posterior predictive checks (93). The Bayesian estimations were implemented using R statistical language (106), with the “brms” package (107) which call Stan (108).

2.3 Results

Characteristics of the youth basketball players adjusted for gender are shown in Table 1. All but nine maturity offset values were positive for the female players. A total of 138 of maturity offset values were positive for male players. In general, most of the players in the present sample were beyond the age at PHV. The range of onset of deliberate basketball practice was between 5 and 17 years for female players, and between 5 and 16 for male players.

Table 1. Marginal estimates and 80% credible intervals of young Brazilian basketball players adjusted by gender.

	All sample (n = 321)	**Female (n = 120)**	**Male (n = 201)**
Chronological age, yrs	14.1 (13.6 to 14.6)	14.2 (14.0 to 14.4)	13.9 (13.8 to 14.1)
Maturity offset, yrs	1.46 (0.44 to 2.46)	2.17 (1.99 to 2.35)	0.71 (0.57 to 0.84)
Onset of deliberate basketball practice, years	10.4 (9.6 to 11.1)	10.1 (9.8 to 10.4)	10.6 (10.4 to 10.9)
Stature, cm	168.1 (165.9 to 170.3)	165.0 (163.0 to 166.0)	171.0 (170.0 to 172.0)
Body mass, kg	63.2 (61.1 to 65.3)	60.5 (58.7 to 62.3)	65.9 (64.6 to 67.3)
Countermovement jump, cm	28.7 (26.8 to 30.6)	25.8 (25.1 to 26.4)	31.5 (31.0 to 32.1)
Line drill test, s	34.7 (33.7 to 35.7)	35.4 (35.1 to 35.7)	34.0 (33.7 to 34.3)
Yo-yo IR1, m	673 (391 to 956)	543 (497 to 590)	815 (781 to 851)
Deliberate practice motivation			
Will to excel, 1-5	4.09 (3.59 to 4.59)	3.88 (3.78 to 3.98)	4.27 (4.20 to 4.35)
Will to compete, 1-5	4.31 (3.96 to 4.63)	4.25 (4.18 to 4.33)	4.41 (4.36 to 4.47)
Achievement and competitiveness motivation			
Mastery, 1-5	4.14 (3.74 to 4.52)	4.06 (3.99 to 4.13)	4.27 (4.21 to 4.32)
Work, 1-5	4.36 (3.94 to 4.74)	4.27 (4.21 to 4.33)	4.54 (4.49 to 4.59)
Competitiveness, 1-5	3.76 (3.40 to 4.19)	3.58 (3.50 to 3.67)	3.84 (3.77 to 3.90)
Sources of enjoyments in youth sports			
Self-referenced competencies, 1-5	4.41 (4.07 to 4.71)	4.38 (4.31 to 4.45)	4.53 (4.48 to 4.58)
Others-referenced competencies, 1-5	3.79 (3.43 to 4.19)	3.63 (3.51 to 3.74)	3.84 (3.76 to 3.92)
Effort expenditure, 1-5	4.69 (4.45 to 4.87)	4.73 (4.68 to 4.79)	4.72 (4.68 to 4.76)
Affiliation with peers, 1-5	4.45 (4.21 to 4.66)	4.46 (4.39 to 4.54)	4.48 (4.43 to 4.54)
Positive parental involvement, 1-5	4.35 (4.04 to 4.63)	4.45 (4.36 to 4.55)	4.35 (4.28 to 4.42)

Given the extensive results of our modeling approach, the estimates and uncertainty (80% credible intervals) grouped by the onset of deliberate basketball practice for female and male young basketball players are shown in Table 2 and Table 3, respectively. Although the results are shown separately, the marginal estimates are based on joint models, as described previously, after back-transformation from the standardized model-based estimates. The standardized outcomes plotted by the onset of deliberate basketball practice adjusted for by gender are available as supplementary material. There was no substantial variation between players grouped by the onset of deliberate basketball practice for body size, functional performance, motivation for deliberate practice, motivation for achievement and competitiveness and sources of enjoyment (Supplementary Figures S1–S5). However, when adjusting for gender, female players with a late-puberty onset of deliberate basketball practice had slightly worst functional performance values than players with a pre- and mid-puberty onset of practice (Table 2). Male players with a late-puberty onset of deliberate basketball practice had better functional performance values than players with a pre- and mid-puberty onset of deliberate basketball practice (Table 3). As for the motivation for deliberate practice, motivation for achievement and competitiveness and sources of enjoyment, there was no variation between players grouped by the onset of deliberate basketball practice, both for female and male players.

Table 2. Marginal estimates and 80% credible intervals of female young Brazilian basketball players by the onset of deliberate basketball practice.

	Onset of Deliberate Basketball Practice		
	Early starters	Starters during pubertal growth	Late starters
Stature, cm	153.3 (151.0 to 155.6)	153.2 (151.0 to 166.0)	153.6 (151.1 to 156.1)
Body mass, kg	55.0 (51.4 to 58.6)	54.2 (50.8 to 57.6)	57.6 (53.6 to 61.6)
Countermovement jump, cm	24.1 (22.0 to 26.2)	23.8 (21.8 to 25.8)	22.3 (20.0 to 24.6)
Line drill test, s	35.5 (34.5 to 36.4)	36.6 (35.7 to 37.5)	36.9 (35.9 to 37.8)
Yo-yo IR1, m	402.3 (274.2 to 529.8)	378.9 (261.8 to 497.4)	342.8 (208.0 to 478.2)
Deliberate practice motivation			
Will to excel, 1-5	3.89 (3.65 to 4.12)	3.77 (3.54 to 3.99)	3.89 (3.64 to 4.13)
Will to compete, 1-5	4.20 (4.03 to 4.36)	4.24 (4.08 to 4.40)	4.23 (4.05 to 4.40)
Achievement and competitiveness motivation			
Mastery, 1-5	4.07 (3.91 to 4.22)	4.04 (3.89 to 4.19)	4.04 (3.87 to 4.20)
Work, 1-5	4.23 (4.06 to 4.39)	4.26 (4.10 to 4.41)	4.27 (4.10 to 4.43)
Competitiveness, 1-5	3.53 (3.28 to 3.79)	3.43 (3.18 to 3.67)	3.43 (3.17 to 3.69)
Sources of enjoyments in youth sports			
Self-referenced competencies, 1-5	4.30 (4.14 to 4.46)	4.33 (4.18 to 4.54)	4.37 (4.19 to 4.54)
Others-referenced competencies, 1-5	3.47 (3.17 to 4.77)	3.42 (3.13 to 3.70)	3.33 (3.01 to 3.64)
Effort expenditure, 1-5	4.69 (4.54 to 4.82)	4.72 (4.57 to 4.86)	4.70 (4.54 to 4.85)
Affiliation with peers, 1-5	4.60 (4.41 to 4.79)	4.59 (4.41 to 4.77)	4.48 (4.26 to 4.69)
Positive parental involvement, 1-5	4.53 (4.31 to 4.72)	4.51 (4.31 to 4.72)	4.39 (4.13 to 4.63)

The posterior predictions and uncertainty (80% and 50% credible intervals) plotted by age group, maturity status, gender and state basketball federation are also presented as supplementary material. Overall, the present predictions are consistent with our previous reports accounting for the age- and maturity-related variation on functional performance and psychological characteristics (51, 91, 109). In addition, there was considerable variation by gender for body dimensions, as expected (Supplementary Figure S8), for functional performance outcomes (Supplementary Figure S12). There was no apparent variation associated with the context of training and competition for body dimensions and functional performance. As for deliberate practice motivation, adolescent female players likely have slightly lower values for both will to excel and will to compete (Supplementary Figure S16). Furthermore, for achievement and competitiveness motivation adolescent female players likely have somewhat lower values for all dimensions than adolescent male players (Supplementary Figure S20). As for sources of enjoyment, scores appear to vary by gender only for others-referenced competencies (Supplementary Figure S24). The context of training and competition appeared to influence players´ psychological characteristics, in particular sources of enjoyment dimensions.

Table 3. Marginal estimates and 80% credible intervals of male young Brazilian basketball players by the onset of deliberate basketball practice.

	Onset of Deliberate Basketball Practice		
	Early starters	Starters during pubertal growth	Late starters
Stature, cm	167.2 (165.3 to 169.2)	168.9 (166.9 to 171.1)	167.9 (165.4 to 170.4)
Body mass, kg	66.7 (63.6 to 69.8)	66.4 (63.2 to 69.7)	68.1 (64.1 to 72.1)
Countermovement jump, cm	30.6 (28.8 to 32.5)	30.6 (28.6 to 32.5)	32.6 (30.1 to 35.1)
Line drill test, s	34.6 (33.8 to 35.4)	34.4 (33.6 to 35.2)	33.7 (32.7 to 34.8)
Yo-yo IR1, m	687.3 (583.7 to 794.1)	772.5 (663.0 to 884.6)	1142.1 (989.8.0 to 1294.0)
Deliberate practice motivation			
Will to excel, 1-5	4.31 (4.11 to 4.52)	4.19 (3.97 to 4.42)	4.31 (4.07 to 4.56)
Will to compete, 1-5	4.32 (4.17 to 4.47)	4.37 (4.20 to 4.52)	4.35 (4.18 to 4.51)
Achievement and competitiveness motivation			
Mastery, 1-5	4.29 (4.15 to 4.42)	4.27 (4.12 to 4.41)	4.26 (4.10 to 4.41)
Work, 1-5	4.40 (4.26 to 4.55)	4.43 (4.28 to 4.58)	4.44 (4.28 to 4.60)
Competitiveness, 1-5	3.84 (3.62 to 4.07)	3.74 (3.50 to 3.97)	3.74 (3.48 to 3.99)
Sources of enjoyments in youth sports			
Self-referenced competencies, 1-5	4.27 (4.12 to 4.42)	4.30 (4.15 to 4.45)	4.34 (4.17 to 4.52)
Others-referenced competencies, 1-5	3.94 (3.66 to 4.20)	3.88 (3.60 to 4.15)	3.79 (3.46 to 4.10)
Effort expenditure, 1-5	4.70 (4.56 to 4.83)	4.73 (4.60 to 4.87)	4.71 (4.56 to 4.86)
Affiliation with peers, 1-5	4.50 (4.34 to 4.67)	4.49 (4.31 to 4.66)	4.38 (4.16 to 4.59)
Positive parental involvement, 1-5	4.41 (4.22 to 4.60)	4.39 (4.20 to 4.59)	4.27 (4.01 to 4.51)

2.4 Discussion

In this study, our primary interest was to examine the influence of the onset of deliberate basketball practice on functional performance and psychological characteristics in youth basketball. Considering the need to adopt interdisciplinary approaches to interpret young players´ performance and development (28, 51, 91, 92), we accounted for the confounding influence of players´ characteristics (gender, age and maturity status) and contextual characteristics (state basketball federations) on body dimensions, functional performance and psychological characteristics.

The delivery of youth sports programs in the last decades has changed substantially (88). Youth sports programs often create a highly targeted, athlete-centered environment generally focused on early specialization. Youth sports programs often create a highly targeted, athlete-centered environment generally focused on early specialization (28). Consequently, early specialization appears to be promoted as a mainstream path for talent development in team sports, as those who achieve professional status in adult sports may need to be engaged in youth sports academies at early pre-pubertal ages (110, 111). However, caution is warranted with this interpretation. Data have shown that to achieve a professional adult level, it may not be necessary—and even detrimental—to be included in talent development programs such as youth academies at a particularly young age (112). Nevertheless, children and adolescents engaged in multi-sports developmental programs may have limited opportunities for later entry in talent development programs. This may be the case, at least, in youth sports that promote early engagement in their programs such as basketball.

Conditional on our data, there was no substantial variation on functional characteristics between players when group by the onset of deliberate basketball practice. Furthermore, players with a later onset of deliberate basketball practice appear to have slightly better functional performance, adjusting for age group, maturity status and state basketball federation. From a physiological performance perspective, early exposure to deliberate practice in basketball does not seem to accelerate the development of athletes' performance, as argued by early specialization advocates (25, 113). Our data imply that there is no reason to narrow the opportunities for players with later onset of deliberate practice, likely late maturing boys in youth basketball. Inadvertently, by early targeting children and promoting early development and selection, youth basketball programs and coaches are selecting/promoting and reducing the pool of available players after pubertal growth to mostly early maturing players.

Our predictions suggest the need to be cautious—and to consider gender differences when interpreting players´ functional performance. Albeit the large uncertainty in our prediction, it was apparent that female players with a later onset of deliberate basketball practice had worst performance than their peers with an earlier onset of deliberate practice. Pubertal changes and sexual maturation in girls is accompanied by smaller gains in muscle mass, a widening of the hips relative to shoulders and an increase in body fat percentage (1). Likely, earlier sports participation/practice may be important for a better adjustment of young female players´ athletic performance to pubertal changes. Hence, coaches, parents, youth basketball organizers and ultimately, athletes should be aware of the need to promote young girls' participation in sports, either early specialization or sampling in different sports, not only to increase their chances to achieve expertise in basketball, but to promote girls a positive development through basketball practice (114).

Criticism of early specialization has been based mostly on the negative impacts the rates of sport-related injury, increased sports withdrawal and decreased motivation for participation, along with other health problems including burnout, overuse injuries and overtraining (68, 70). Conditional on the data, early onset of deliberate basketball practice had no negative influence on young players´ motivation and scores for sources of enjoyment, adjusting for individual and contextual factors. Furthermore, the scores in all motivation dimensions and sources of enjoyment scores were consistently high in both female and male athletes. Considering the deliberate practice framework, our observations appear to concur with athletes’ retrospective ratings of deliberate practice being perceived as enjoyable. These observations do not fit well with the original definition of deliberate practice for musicians (35). Overall, our results lead us to agree with suggestions to shift the focus of the debate about specialization. Emphasis should be placed on the quality of sports instruction, regardless of the level of performance or accumulated hours of practice (25, 115). Conditional on the data, the training environments in Brazilian youth basketball programs appear to be sufficient to motivate players to be committed with deliberate practice. Young basketball players are likely willing to perform well and be challenged by difficult tasks and with a desire to compete. Furthermore, players seem to enjoy their training environments and deliberate practice. In these two relevant psychological outcomes, there was no apparent negative effect of early onset of deliberate basketball practice. These observations suggest that at least some of the negative consequences of early sport specialization may be avoided with appropriate coaching and sport skill instruction (25). Hence, youth basketball programs and interested stakeholders should invest in the promotion of the quality of coaching, adequate training and competitive environment for the athletes.

The use of Bayesian multilevel models allowed us to explore the interacting influences of individual and contextual factors on functional capacities and psychological characteristics. The present results considering age- and maturity-related variation are consistent with our previous observations in female and male young basketball players (51, 57, 91). Mainly, these results give us confidence in our models’ validity to replicate previous observations when combining and including more participants and other sources of variation. As noted previously, caution is warranted when interpreting maturity-associated variation on the outcomes, given the limitations of the maturity offset equations. On the other hand, several dimensions of motivation and enjoyment varied across the state basketball federations (see supplementary material). These results highlight the need to consider the influence of the training environments (35). In addition, it highlights a limitation in our analysis, which is the lack of information about coaching.

In general, youth sports specialization discussion is dichotomized as “early specialization” versus “early diversification” (35). In our study, we used the onset of deliberate basketball practice as a left censor of the data. This indicator may be insufficiently sensitive to mark the beginning of the athletes´ specialization in basketball. Nevertheless, we assumed that our indicator marked year-round participation in a single sport (basketball), potentially limiting participation in potential sport alternatives. As stated in the methods section, information about players´ deliberate play and informal participation in other sports, previous or after the onset of deliberate basketball practice, was not retained in our surveys. Hence, we assume the limitations of our data and highlight the need for caution when generalizing our data and interpretations. Considering the influence of nature (genes) or nurture (environment) on players’ performance development, the decision about the start and type of engagement in specific-sport training programs (early specialization, sampling or late specialization) is probably the most significant in the hands of children/adolescent and their parents. Nevertheless, future research into the patterns of children and adolescents in youth sports should consider a multidimensional continuum that is reflected by several continuous variables including chronological age, the onset of deliberate practice, growth and maturation patterns, amount of main-sport coach-led practice, amount of main-sport youth-led play, amount of other-sports coach-led practice, amount of other-sports youth-led play and perhaps the number of sports in which an athlete engages (112, 116).

2.5 Conclusions

Assuming an interdisciplinary perspective with the present sample of adolescent basketball players, there was no substantial variation on body size, functional characteristics and psychological characteristics between players when group by the onset of deliberate basketball interpreted as related to puberty. Hence, there was no apparent advantage of the early accumulation of deliberate basketball practice for the development of specific physiological functions. Likewise, there was no negative effect of early onset of deliberate basketball practice on enjoyment, motivation for deliberate practice or motivation for achievement and competition. Furthermore, all psychological scores were consistently high across the players in the present study. Based on our data and models, it was apparent the need to consider gender differences and the context of the youth basketball programs when interpreting the relevance of deliberate basketball practice and specialization. Given an appropriate environment and pedagogical approach, structured youth basketball may potentially provide a positive environment for players´ development and commitment to training and excellence attainment. Coaches should refine their pedagogical strategies, adjusting for the importance of the interactions among physical growth, biologic maturity status, and accumulation of deliberate practice and its influence on functional performance and psychological characteristics. Furthermore, researchers and coaches should consider the potential contributions of deliberate play and informal practice on players´ development. Hence, further interdisciplinary research about youth sports developmental paths is warranted. Overall, we concur with the need to focus the debate about specialization in youth sports and developmental paths on the pedagogical quality of the coach and the training environment (25).

2.6 Supplementary Materials

The following are available as appendices (Appendix B) and online at https://www.mdpi.com/1660-4601/17/11/4078/s1, Table S1. Distribution of observations by gender and age group across the basketball state federations, Table S2. Posterior estimations of youth basketball players by gender and age group, Figure S1. Posterior predictions for stature (a) and body mass (b) by onset of deliberate basketball practice in young female and male basketball players (80% and 50% credible intervals), Figure S2. Posterior predictions for countermovement jump (a), line drill test (b) and yo-yo intermittent recovery test level-1 (c) by onset of deliberate basketball practice in young female and male basketball players (80% and 50% credible intervals)., Figure S3. Posterior predictions for will to excel (a) and will to compete (b) by onset of deliberate basketball practice in young female and male basketball players (80% and 50% credible intervals), Figure S4. Posterior predictions for mastery (a), work (b) and competitiveness (c) by onset of deliberate basketball practice in young female and male basketball players (80% and 50% credible intervals), Figure S5. Posterior predictions for self-referenced competences (a), others-referenced competences (b), effort expenditure (c), positive parental involvement (d) and affiliation with peers (e) by onset of deliberate basketball practice in young female and male basketball players (80% and 50% credible intervals), Figure S6. Posterior predictions for body dimensions by age group in young female and male basketball players, controlling for maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S7. Posterior predictions for body dimensions by maturity status in young female and male basketball players, controlling for age group, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S8. Posterior predictions for body dimensions in young female and male basketball players, controlling for age group, maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S9. Posterior predictions for body dimensions by state basketball federation in young female and male basketball players, controlling for age group, maturity status and age starting basketball practice (80% and 50% credible intervals), Figure S10. Posterior predictions for functional capacities by age group in young female and male basketball players, controlling for maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S11. Posterior predictions for functional capacities by maturity status in young female and male basketball players, controlling for age group, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S12. Posterior predictions for functional capacities in young female and male basketball players, controlling for age group, maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S13. Posterior predictions for functional capacities by state basketball federation in young female and male basketball players, controlling for age group, maturity status and age starting basketball practice (80% and 50% credible intervals), Figure S14. Posterior predictions for deliberate practice motivation dimensions by age group in young female and male basketball players, controlling for maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S15. Posterior predictions for deliberate practice motivation dimensions by maturity status in young female and male basketball players, controlling for age group, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S16. Posterior predictions for deliberate practice motivation dimensions in young female and male basketball players, controlling for age group, maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S17. Posterior predictions for deliberate practice motivation dimensions by state basketball federation in young female and male basketball players, controlling for age group, maturity status and age starting basketball practice (80% and 50% credible intervals), Figure S18. Posterior predictions for achievement and competitiveness motivation dimensions by age group in young female and male basketball players, controlling for maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S19. Posterior predictions for achievement and competitiveness motivation dimensions by maturity status in young female and male basketball players, controlling for age group, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S20. Posterior predictions for achievement and competitiveness motivation dimensions in young female and male basketball players, controlling for age group, maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S21. Posterior predictions for achievement and competitiveness motivation dimensions by state basketball federation in young female and male basketball players, controlling for age group, maturity status and age starting basketball practice (80% and 50% credible intervals), Figure S22. Posterior predictions for sources of enjoyment dimensions by age group in young female and male basketball players, controlling for maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S23. Posterior predictions for sources of enjoyment dimensions by maturity status in young female and male basketball players, controlling for age group, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S24. Posterior predictions for sources of enjoyment dimensions in young female and male basketball players, controlling for age group, maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals), Figure S25. Posterior predictions for sources of enjoyment dimensions by state basketball federation in young female and male basketball players, controlling for age group maturity status and age starting basketball practice (80% and 50% credible intervals).

Author Contributions

Conceptualization, R.R.P., C.E.G., J.V.N. and H.M.C.; investigation, L.A.S., T.J.L., A.L.S., H.M.C.; methodology, A.B.L., T.J.L. and A.L.S.; formal analysis, H.M.C.; data curation, A.B.L., T.J.L. and A.L.S.; writing—original draft preparation, H.M.C.;

writing—review and editing, A.B.L., T.J.L., A.L.S., R.R.P., C.E.G., J.V.N. and H.M.C.; supervision, H.M.C. All authors have read and agree to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

3 STUDY II: Peak Height Velocity Curves in Young Athletes: A Meta-Analysis

Peak Height Velocity in Young Athletes: A Meta-Analysis

3.1 Introduction

Regular participation in sports provides several benefits for children and adolescents' healthy growth and development (6). These advantages can be noted in the motor competence, physical fitness, psychological and social domains (2, 4, 5). In addition to specific sport development, the young athlete goes through the growth and maturation phase during pubertal years, influencing physical fitness and performance (1, 52, 91, 115). While growth refers to measurable increases in body size, maturation refers to biological progress towards the mature state (1, 52).

Chronological age (CA) is commonly used to characterize anthropometric and performance development throughout childhood and adolescence to align athletes into groups (89). However, athletes of the same age group are often heterogeneous in growth and maturity status (1, 53). When compared athletes' maturation to their respective CA, early maturers are advanced in maturity status, whereas late maturers showed a delay (52). Because of this interindividual variability, late-maturing athletes may momentarily have a larger body size, better physical performance, and potential success than athletes with different maturation timing (53, 117, 118). Therefore, scientific research must make an attempt to control athletes' maturity.

Peak height velocity (PHV), which refers to the maximum growth rate in height during the adolescent spurt, is a valuable and non-invasive method to assess somatic maturation in children and adolescents (118, 119). The age at which PHV occurs is an important biological milestone and provides more specific information than CA when analyzing young athletes' sports development and performance (120). The most recommended way to estimate the PHV is measuring stature repeatedly over pubertal years, such as in longitudinal studies (89). Although the longitudinal study is the best way to investigate changes in growth and development, the challenges that this type of research imposes (e.g., time, financial resources, and adherence to subjects) make it scarce in the literature (121).

Most of the data available in the literature with young athletes use prediction equations to estimate PHV, such as maturity offset protocol (50, 97, 122-124). Maturity offset prediction equations needed only a cross-sectional measure of anthropometric variables to estimate age at PHV (97, 122). Although prediction equations are an alternative when longitudinal data are not possible, their limitations are recognized (118). The highly selected characteristic of sports makes adherence of subjects in longitudinal studies even more complicated. However, longitudinal data with young athletes are relatively scarce, especially when addressing growth and performance, and a few studies consider repeated measures to estimate PHV (121, 125).

Considering the lack of longitudinal studies describing athletes' growth curves and maturation, there is a need to synthesize better the available evidence to understand the young athlete's development. Furthermore, studies that propose to use anthropometric data to control maturation to explain physical performance are also rare. Thus, in this meta-analysis, we aimed to determine the growth curves and estimate the PHV and the average age at PHV in young male athletes based on the anthropometric data from longitudinal studies available in the literature.

3.2 Methods

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA and PRISMA-P) (126, 127) guidelines to examine and report the data. The study protocol was registered in The International Prospective Register of Systematic Reviews - PROSPERO (registration number: CRD42020175084). To meet the aim of the present study, we adapted the protocol for screening only longitudinal studies reporting repeated measures for young athletes' stature.

3.2.1 Search Strategy

An electronic search was conducted from inception to March 13, 2020, in four databases: MEDLINE (via PubMed, 1946-present), SPORTDiscus (with Full Text via EBSCOhost, 1985-present), SCOPUS (Elsevier), and Web of Science (Core Collection, 1945-present). The search was updated on April 30, 2021. The search strategy was designed to access longitudinal studies that report anthropometric characteristics in young athletes. Articles should be written in English and published in peer-reviewed journals. No limits for publication dates were applied. The search strategy was developed using PICOS (Patients, Intervention, Comparator, Outcomes, and Study Type) method (except by the comparator item), and search terms were organized by clusters: 1) Population (e.g., “athlete”, “player”); 2) Population age (e.g., “youth”, “adolescent”); 3) Intervention (e.g., “sports”, “soccer”, “basketball”); 4) Outcomes (e.g., “height”, “stature”) and 5) Study type (e.g., “longitudinal”, “repeated measures”). The search was first run by cluster, searching terms within each cluster using Boolean operator ‘OR’, finally, the clusters were combined with the Boolean operator ‘AND’. The search for keywords in electronic databases was run considering “All fields”, except for SCOPUS, where the TITLE-ABS-KEY (title, abstract, and key-words) filter was applied (**Appendix C**).

3.2.2 Selection Criteria

Studies were included in the meta-analysis if they (1) had longitudinal designs, following individuals over at least six months; (2) reported at least three repeated measures for stature; (3) involved a sample of young male athletes aged between 10 and 17 years; (4) were original articles, written in the English language and published in peer-review journals. Conversely, studies were excluded from the meta-analysis if they: (a) did not have available at least three repeated measures between 10 and 17 years old; (b) had a mixed sample and did not report data separately by gender; (c) were case studies or conference proceedings with incomplete reporting; (d) the data were not reported correctly for analysis (e.g., the study did not report the sample by assessment points or chronological age).

Two authors (ABL and RTQ) independently selected articles based on the eligibility criteria. The authors screened the titles and abstracts, and the studies were selected for the full-text analysis if they met the eligibility criteria or the aims and methods were unclear. The full-text versions of the remaining studies were then retrieved, and the authors applied the selection criteria independently. Studies considered to meet the inclusion criteria were obtained for data synthesis (meta-analysis). Disagreements arising between the two reviewers were resolved through discussion and with the assistance of a third reviewer (HMC) when necessary. *EndNote* software (version X9.0, Clarivate Analytics, Philadelphia, PA, USA) was used to manage the results of electronic databases, and duplicated documents were removed. *Rayyan* website (128) was used to peer-review screening and checking the eligibility criteria for titles, abstracts, and full-texts.

3.2.3 Data Extraction

We used the WebPlotDigitizer tool to extract the data when the data was only available in plots or figures. During this meta-analysis, finding more than one article using the same or similar sample derived from major research was common. Therefore, to avoid duplicate data, we adopted only the article that best described and represented the study and the others were excluded for large studies with more than one article.

A standardized form was used to extract the relevant data by two reviewers (ABL and RTQ). The data extracted from each study included the following details: first author, year, title, journal, objective, country, sport, gender, sample size, setting/context of recruitment, study duration, times of assessments, and assessment intervals. In addition, the outcomes of interest were extracted: chronological age, stature, and respective standard deviations. Finally, the standard error for stature was calculated for each study (129).

3.2.4 Data Synthesis

We used longitudinal meta-analysis models to describe the growth patterns of young athletes based on the extracted data by fitting a Bayesian multilevel model. We considered each study´s outcome (y_{ts}), i.e., stature, at time point t (i.e., chronological age) in study s, with an error variance of the within-study sampling errors, assumed to be normally distributed, $\epsilon_{ts} \sim Normal(0, \sigma_{ts})$. To capture pubertal growth, we fitted a non-linear multilevel model on each study maximum stature velocity of growth at puberty, considering at least growth coefficients up to the cubic. We determined stature velocity curves, maximum velocity, and age at PHV by calculating the first derivative of the multilevel polynomial growth model curve based on the population level parameters (130). For interpretative convenience and computational efficiency, we standardized the outcomes. We extended our model by considering study characteristics as a group-level effect (also referred to as random effects). In particular, we explored whether age at peak height velocity varied by sport.

In Bayesian methods, there is a conjugation of prior knowledge and the information available on the data. Hence we need to select priors for the model parameters. We used weakly informative priors to regularize our estimates, furthermore after standardization of the outcomes. We used normal priors (0,10) for the population-level parameter and normal priors (0,1) the group-level parameters. We run four chains for 2000 iterations with a warm-up length of 1000 iterations for each model. The models were inspected and validated using posterior predictive checks *(93)*. The Bayesian estimations were implemented using R statistical language *(106)*, with the “brms” package *(107)*, which call Stan *(108)*.

3.3 Results

Based on the search strategy, a total of 2,892 published articles were identified. After removing the duplicated studies, 1,843 studies were eligible for initial screening on titles and abstracts. After the initial screening, 1,552 records were removed. Thus, 291 articles were fully screened following the defined eligibility criteria. After the full-text screening, 35 articles met the eligibility criteria and were used for meta-analysis. **Figure 1** shows the PRISMA flowchart.

The main reason for study exclusion (n= 116) was the *wrong study design*, in which either studies had cross-sectional designs or only one measure of follow-up between 10 and 17 years old. Papers were excluded because of the *repeated sample* (n = 27) because we identified articles based on the same study sample. In these cases, we chose just one article that better described the sample. Finally, articles were considered *unsuitable* (n= 22) when they did not adequately report chronological age, sample size, and stature.

Ten out of 35 studies included in this meta-analysis used mixed-longitudinal designs, of which nineteen remained with the same sample size during the whole study. The sample sizes ranged between 8 and 2270 young athletes, and 60% of the studies were at least three years long, ranging from 30 weeks to 12 years. Only four studies were from non-European countries, in which two were conducted in the USA and the others in Canada and China. The majority of the studies (n= 31) were conducted in European countries, such as the United Kingdom (n= 7), Belgium (n= 4), Netherlands (n= 4), Denmark, and Italy (n= 2). In addition, single studies were conducted in Estonia, Finland, France, Germany, Hungary, Ireland, Norway, Poland, Portugal, Serbia, and Spain.

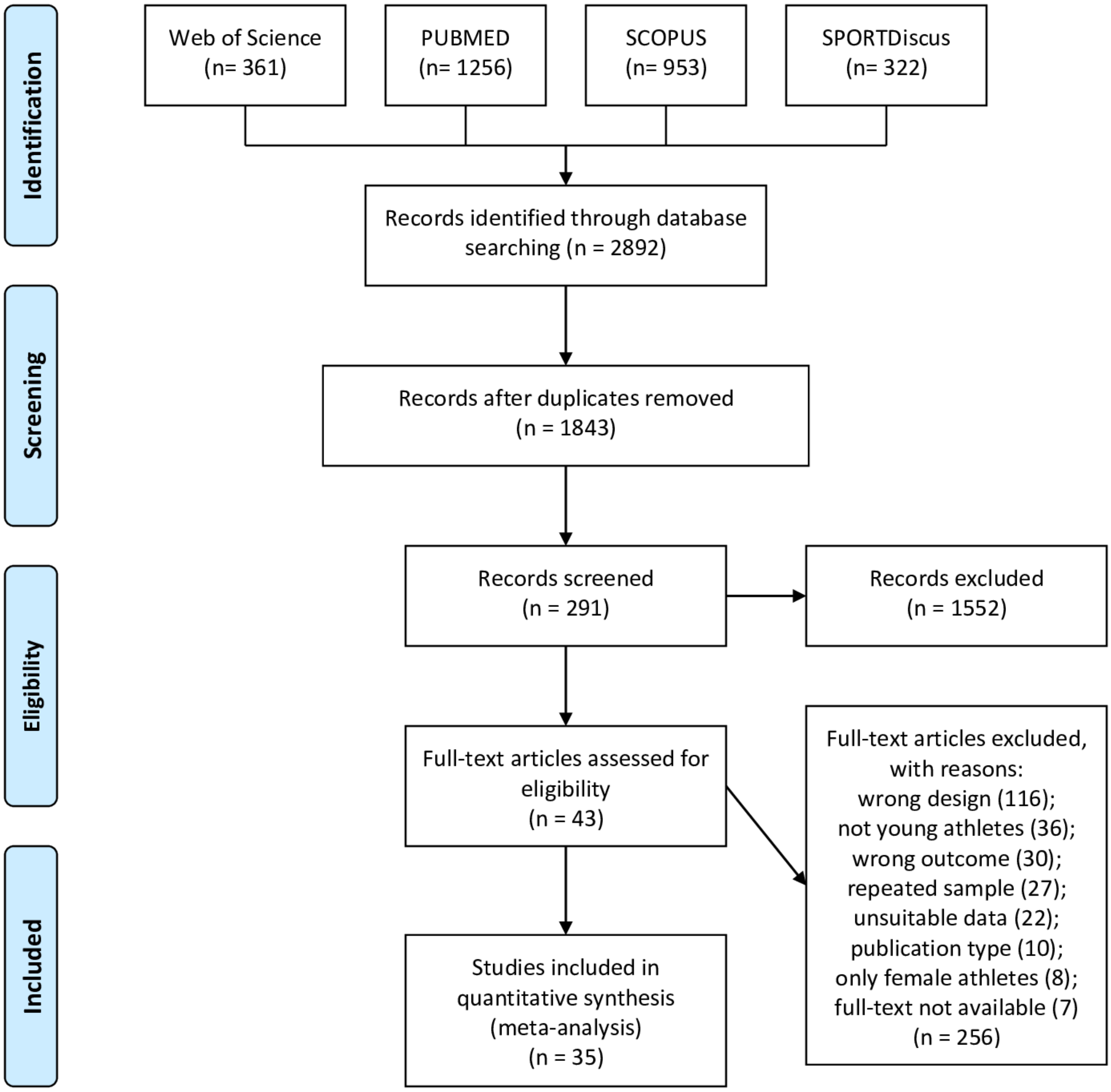

Figure 1. Flowchart including literature search and selection steps following the PRISMA statement.

Thirty-one studies used a single sports sample; two studies used two subsamples, in which study of Landgraff et al. (131) was taken with cross-country skiing, and team sports (they did not specify the team sports) and study of Zhao et al.. (132) were taken with swimming and racket sports (badminton and table tennis were presented together). The TOYA study (133) used four subsamples (soccer, gymnastics, swimming, tennis), and the study of Holden et al. (134) did not report the sport in the sample. In total, thirty-five studies were investigated in this meta-analysis; 15 out of 35 studies used a sample from soccer (45, 133, 135-147), four from swimming (132, 133, 148, 149) and ice hockey (150-153), three from rugby (49, 154, 155), and two from athletics (156, 157), tennis (48, 133) and badminton (132, 158) (table tennis were included in badminton because they were presented together). In addition, single studies were conducted in basketball (159), cross-country skiing (160), field hockey (161), gymnastics (162), handball (163), and wrestling (164). Most of the studies were conducted with athletes who belonged to youth sports academies (91%), and the other studies were conducted with athletes that played in high school.

Figure 2 shows the meta-analysis' growth curve of the 35 selected studies and the World Health Organization (165) reference growth curves**.** We can observe that athletes' stature around 11 years old is similar to the 50th percentile of the reference population. However, around 13.5 years, athletes are taller than most of the population and stay close to the 70th percentile, at least up to 17years. Therefore, we estimated the average age at peak height velocity for the total sample of studies from the meta-analysis, which occurs at 12.9 years in young athletes. The mean and standard deviation for age at PHV is presented by study (**Figure 3**) and sport (**Figure 4**).

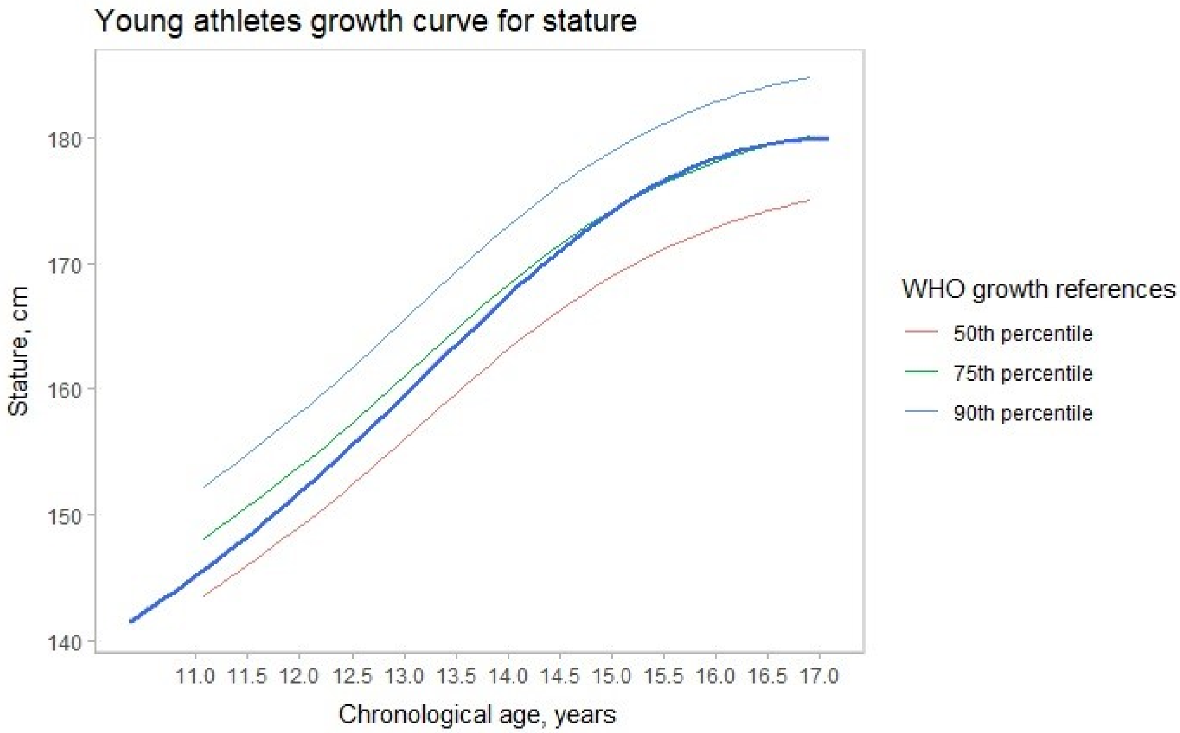

Figure 2. Growth curve of young athletes (stature by chronological age) compared by WHO growth references.

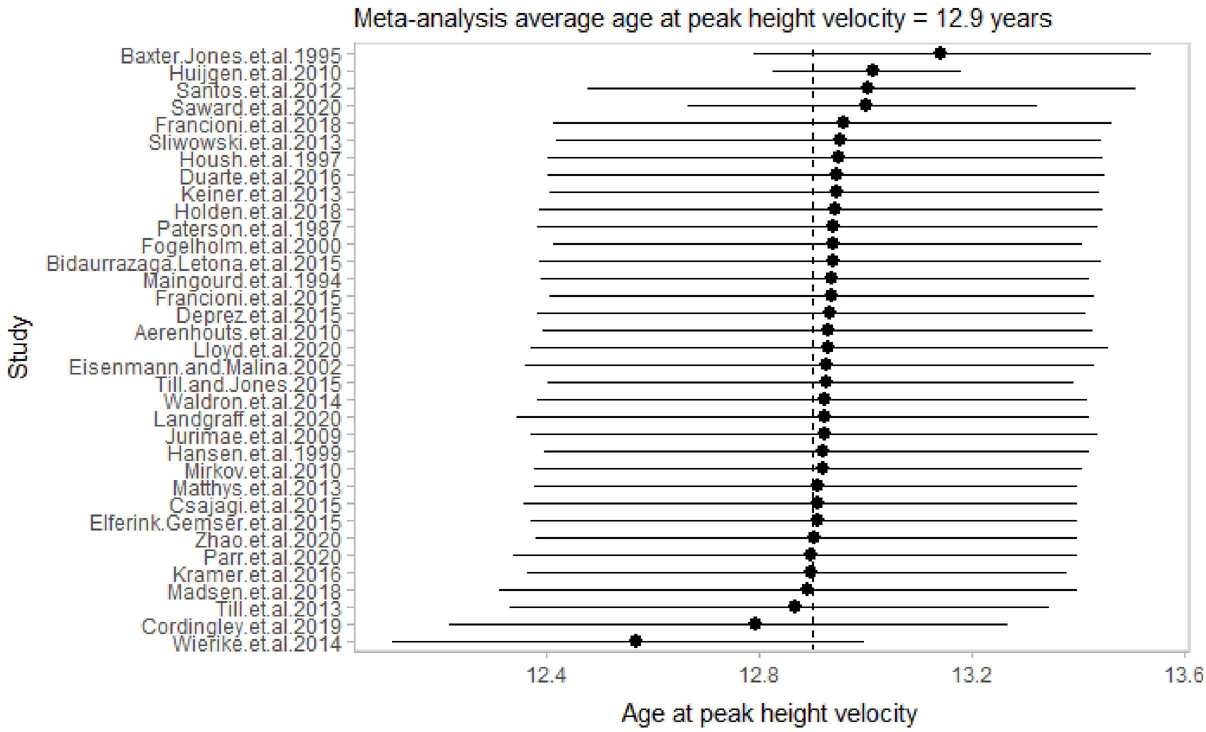

Figure 3. Estimates of age at peak height velocity of young athletes by each study of meta-analysis.

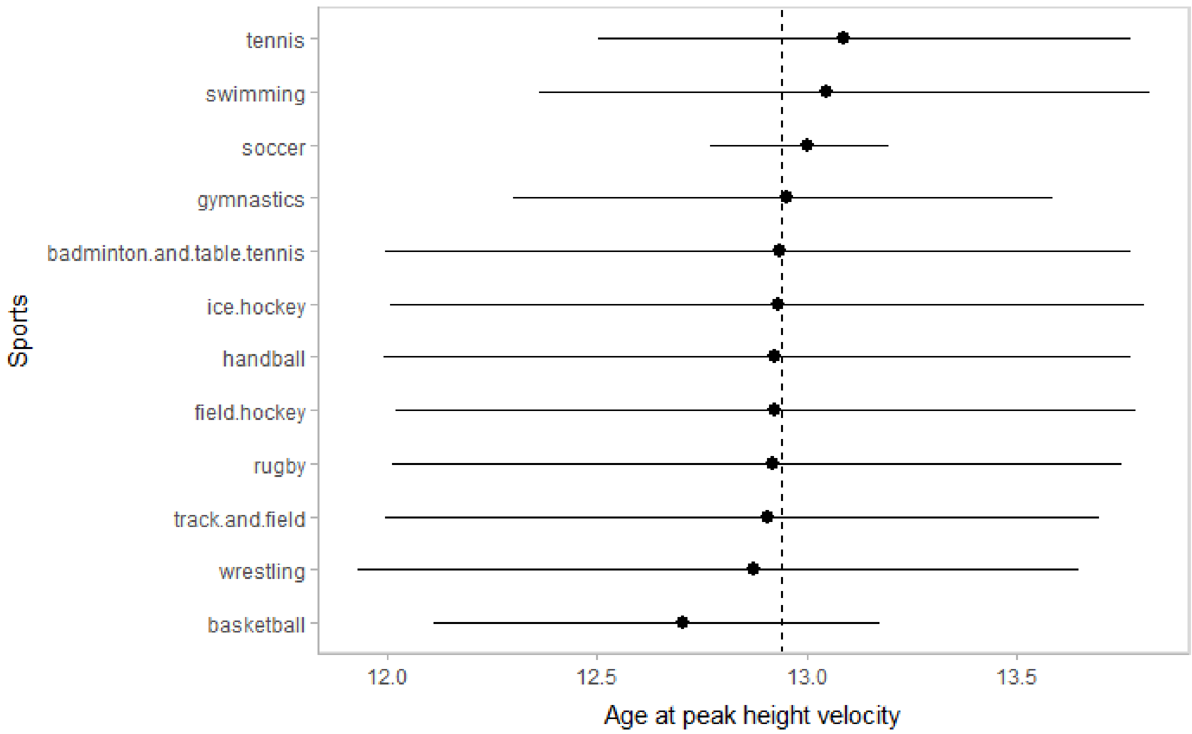

Figure 4. Estimates of age at peak height velocity of young athletes by each sport discipline of meta-analysis.

3.4 Discussion

This meta-analysis aimed to determine the growth curves and estimate the PHV and the average age at PHV in young athletes. Considering the lack of longitudinal studies describing athletes' growth and the need to synthesize this evidence to understand the young athlete's development better, we used longitudinal studies that adequately report anthropometric data to characterize the growth and maturation of young male athletes.

In our study, the estimated average age at PHV in young athletes was 12.9 years. The studies of human growth with general populations are more widely developed than the athletic population, which many studies describe human growth and maturation (122, 166-170). In a review of Malina, Bouchard, and Beunen (89) with general populations, most studies presented PHV between 13.8 and 14.2 years old. Lima et al. (117) performed a meta-analysis based on the review of Malina, Bouchard, and Beunen (89) to estimate the reference age of the pubertal growth spurt onset (11.1 years) and age at PHV (13.9 years) for males. Our estimates for both athlete and non-athlete samples indicate that young athletes reach PHV much earlier than the general population, exactly one year apart. We determine young athletes' growth curve from 11 to 17 years. In addition to early maturation, the young athletes are also taller than the general population references (165). This difference stands out around 13.5 years and remains throughout adolescence, which in this period, athletes have an average height above 75 percent of the general population.

The one-year age difference in PHV between athletes and non-athletes may be influenced by the highly selective characteristics of sports and the desire to identify and develop high-performance athletes (11, 28, 57). Although sport benefits the general population and is recommended for the healthy development of all children (6, 171), some sports are primarily based on performance, which those who perform better are taller (172). Therefore, it suggests that talented young athletes who are on average or small stature, for their age, will be systematically excluded or will drop out of the sports (57, 172, 173). Additionally, comparative studies from different sports have shown a greater stature for youth athletes than non-athletes (149, 151, 174-178).

This contributes to an overrepresentation of athletes with early maturation, especially in sports that prioritize height (e.g., basketball and volleyball) (54, 57, 172, 179). In contrast, late-maturing children tend to perform momentarily worse than mature athletes, especially in the physical domain (53, 117, 180, 181). Therefore, the assumption that early matured players perform better and that it will be maintained and transferred from youth to senior high-performance is not always valid (172, 182-184). When coaches, stakeholders, and parents adopt this argument, the risk of screening out potential athletes just because they had late maturation is too great. The increase in average height from 11 to 14 years old matches with the specializing and investment years in the Developmental Model of Sports Participation (17, 185), in which the sporting environment becomes more selective (34, 57, 58, 171, 186).

In our research, the sample of studies was predominantly representative of the youth sports academy, where athletes are exposed to organized training and competitions with considerable hours per week on an annual basis. These academies are generally focused on the early identification and development of elite young athletes, where early specialization in a single sport is more frequent than participation in different sports and activities (28). Consequently, most studies declare their samples as elite, top-level, or talented athletes, although generally, the samples and training contexts need a more detailed description in the articles.

Because soccer is a worldwide sport, it is expected to have more studies than other sports (187, 188). However, the single studies or even the lack of them in traditional sports (e.g., basketball, volleyball, and handball) presented in this meta-analysis is recognized as a limitation. Thus, further investigations are necessary to provide more evidence and determine athletes' growth and development profile in these sports. Furthermore, since there are significant cultural differences in populations across continents and countries in growth and maturation (189, 190), the European predominance found in this meta-analysis is recognized as an important limitation and highlights the need to conduct longitudinal research on young athletes non-European countries.

There are more longitudinal studies with young athletes than these in this review, but because of significant limitations, they are excluded. Some studies have design limitations, specially mixed-longitudinal studies, where sometimes neither the beginning/end of the study nor the follow-up times are clear. Many studies have a poor description and inconsistencies of sample characteristics, such as chronological age not reported, sample size by the time of follow-up not reported, athletes who left or entered during the study are not reported, data not reported separately by age, gender, or sport. We found many articles that belong to the same main study (e.g., Toya Study

(162, 191, 192), Basque soccer study (130, 142, 193, 194), Player Performance Pathway study (49, 123), and Groningen soccer study (140, 195-197)), however, rarely do articles present this information in the description of the methods, which increases the chance of obtaining repeated data from the same population. In this sense, transparency strategies such as open data and publicly available datasets are good practices to understand better, interpret, and analyze research results (198, 199).

Despite limitations presented in the literature, such as the predominance of soccer samples and studies from the European continent, the results of this study can provide valuable information and synthesis of evidence on human growth and sports participation. To our knowledge, there is no published study that has performed a meta-analysis of longitudinal studies in the field of sports research—even considering the relatively recent increase of studies that perform meta-analyses of longitudinal studies in the general scientific literature (200-203). Given the difficulty in conducting and reporting longitudinal studies, especially in a population as unique as the young athletes, this study is an excellent exercise to provide paths and methods in research aimed at the development of youth sports, in addition to providing clues about growth and athlete maturation.

4 FINAL CONSIDERATIONS

The present dissertation aimed to investigate the interacting influence of deliberate practice, biological maturation, body dimensions on functional performance, and psychosocial characteristics among young basketball players. In addition, we aimed to determine the growth curves and estimate the average age at peak height velocity occurs in young athletes.

Deliberate practice is supposed to develop expertise in sports (7, 25, 65, 182, 184). In this sense, is often stimulated that children who want to become a successful athlete in adulthood have many hours of accumulated practice in the target sport (7, 63). In order to have a more significant accumulation of deliberate practice hours, some strategies are established, such as the beginning of sports participation as early as possible and the exclusive participation in a single sport (21, 24). This phenomenon is characterized in the literature as early specialization, but it is challenging to characterize when a child had early specialization or not (21, 26). Thus, in the first article of this dissertation, we proposed the operationalization of early/late specialization, using two biological milestones to interpret age starting deliberate basketball practice, i.e., the age of onset of the pubertal growth spurt and the age at PHV.

Although early and late specialization are complex processes involving biological, psychological, and social aspects (37), we propose an operationalization from biological milestones, filling a gap in the literature. A classification from biological milestones is relevant because growth and maturation had an essential role in the performance of young athletes (52). Promoters often argue that early specialization will accelerate athletes’ performance and skill level (25). However, young athletes' performance is greatly influenced by growth and maturation timing and tempo (52, 53).

In this sense, this dissertation adds to the literature on the growth and maturation of young athletes since we contribute with a meta-analysis derived estimate of age at peak height velocity and determine the growth curves of young athletes. Studies must investigate young athletes' specific growth and maturation because the selective characteristics of sports and constant search for talent and best performers make the maturation patterns of young athletes different from the general population, as seen in the second study. The average difference in age at PHV between athletes and non-athletes is exactly one year (athletes= 12.9 years, non-athletes= 13.9), and the children who belong to youth sports academies are taller than 75 percent of the general population. Given that stature is a crucial element in some sports, it is expected that the curve of athletes is greater than the general population. However, these findings suggest that the youth sports context systematically selects early-maturing athletes since these athletes may momentarily present better physical and game performance than late-maturing athletes (52, 53, 57, 172, 173). However, the assumption that the best athletes in youth will be the best athletes in adulthood is not valid, as talent is not stable (172, 182, 183, 204).

Regarding the advantages and disadvantages of early specialization, the first study of this dissertation does not confirm the arguments of either promoters or critics of early specialization. The notion that athletes who specialized early present better functional performance than those that specialized late does not observed in this study. In addition, the disadvantages in motivation are also not observed in athletes who specialized early. Thus, the evidence on the effects of early specialization is scarce, and new studies are necessary to understand this phenomenon better.

This dissertation advance regarding early specialization and the tentative of investigating this phenomenon in a multidisciplinary approach is a good practice to study this complex process. However, we recognized that longitudinal studies are ideal for producing better evidence about the variations in characteristics and effects of early specialization. Therefore, we recommend that new studies using an operationalization of early specialization and investigate its benefits and harms in a multidisciplinary approach, especially using longitudinal designs. This dissertation provides valuable information on growth and maturation in young athletes, characterizing the growth curves and estimating an important biological milestone (age at PHV). To our knowledge, there is no published study that has performed a meta-analysis of longitudinal studies in the field of sports research. However, we recognize the limitations (e.g., poor description of original studies and challenges in statistical data analysis) and difficulties encountered in carrying out this type of study (meta-analysis).

First, this dissertation contributes to determining young athletes' growth curves and estimating the age at PHV, which athletes are taller than the general population, and the average age at PHV occurs much earlier than non-athletes. Based on these findings, we concluded that youth sports prioritize athletes with early maturation. Second, this research contributes to the literature of sport specialization and defines and operationalizes early/late specialization. Third, this study adds empirical evidence on the benefits and harms of early specialization, and however, based on our findings, we do not observe any substantial evidence on the advantages or disadvantages of early specialization. Finally, growth and maturation must be taken into account and addressed based on scientific evidence in youth sport contexts to promote sports development for all children, especially athletes with a later stage of maturation.

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APPENDIX A – First page of *study I*, published at IJERPH

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Article

Deliberate Practice, Functional Performance and Psychological Characteristics in Young Basketball Players: A Bayesian Multilevel Analysis

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Abstract: Background: Early sport specialization has increased its popularity mostly based on the deliberate practice theory premises. In this study, we examined the influence of the age of onset of deliberate basketball practice on body size, functional performance (countermovement jump, line drill and yo-yo intermittent recovery level 1), motivation for achievement and competitiveness, motivation for deliberate practice and sources of enjoyment among young Brazilian basketball players. In addition, we adjusted for the influence of gender, age group, maturity status and state basketball federation on the outcomes. Methods: The sample included 120 female and 201 male adolescent basketball players aged 14.0 (1.7) years, on average. We grouped players by the age of onset of deliberate basketball practice as related to biologic maturation milestones (pre-puberty deliberate practice onset, mid-puberty deliberate practice onset and late-puberty deliberate practice onset). Results: There was no substantial variation among contrasting players by the onset of deliberate practice in all of the outcomes. Adjusting for gender, male players with late-puberty deliberate practice onset had better functional performance than players with pre- and mid-puberty onset of practice. Females players with late-puberty deliberate practice onset had slightly worst functional performance than players with pre- and mid-puberty onset of practice. Conclusions: Early deliberate basketball practice does not appear to provide an advantage for the development of physiological functions. Likewise, enjoyment, motivation for deliberate practice and motivation for achievement and competition do not appear to be negatively influenced by early deliberate basketball practice. The debate about the relationship between time spent in deliberate practice and performance development in young athletes will need to emphasize the coaching pedagogical quality and the training environment and account for informal practice and deliberate play.

Keywords: youth sports; maturation; motivation; talent development; specialization

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1. Introduction

In the context of talent development, early sport specialization is often assumed as a premise for expertise attainment [1–3]. Early specialization popularity has increased mostly due to the influence of

APPENDIX B – Supplementary material

Supplementary Material

Deliberate Practice, Functional Performance and Psychological Characteristics in Young Basketball Players: A Bayesian Multilevel Analysis

Ahlan B. Lima[1], Juarez V. Nascimento[1], Thiago J. Leonardi[2], André L. Soares[1], Roberto R. Paes[3], Carlos E. Gonçalves[4] and Humberto M. Carvalho[1], *

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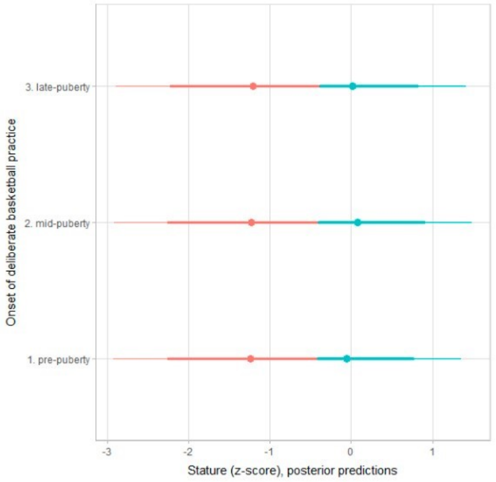
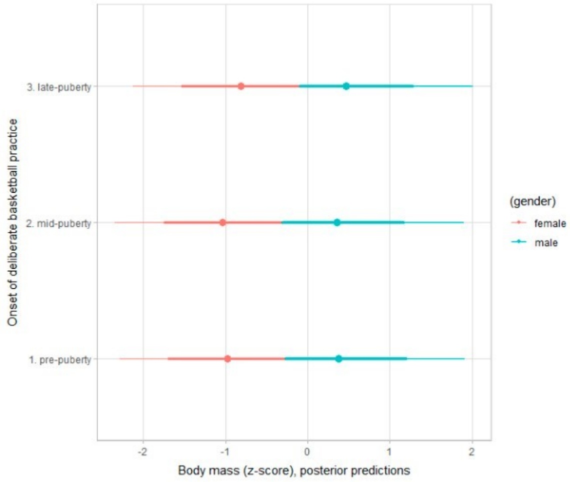
Table S1. Distribution of observations by gender and age group across the basketball state federations.

	Santa Catarina		São Paulo		Rio Grande do Sul		Total
	Female	Male	Female	Male	Female	Male	
Under 11	1		11	23			35
Under 13	12		33	71		10	126
Under 15	17		25	60		14	116
Under 17	17		4	18		5	44
Total	47		73	172		29	321

Table S2. Posterior estimations of youth basketball players by gender and age group.

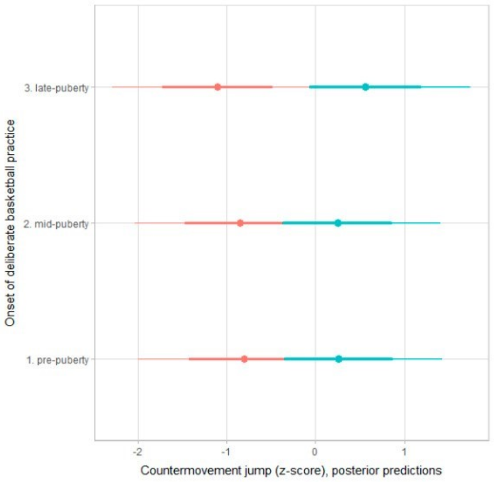
	Female				Male			
	under 11	under 13	under 15	under 17	under 11	under 13	under 15	under 17
Chronological age, years	11.3 (11.2 to 11.4)	13.1 (13.0 to 13.2)	15.0 (14.9 to 15.1)	16.9 (16.8 to 17.0)	11.2 (11.1 to 11.3)	13.0 (12.9 to 13.1)	14.9 (14.8 to 15.0)	16.8 (16.7 to 16.9)
Maturity offset, years	–0.42 (–0.57 to–0.26)	1.22 (1.13 to 1.32)	2.92 (2.82 to 3.01)	4.28 (4.14 to 4.41)	–1.73 (–1.87 to–1.59)	–0.09 (–0.17 to–0.01)	1.60 (1.52 to 1.69)	2.96 (2.83 to 3.10)
Starting basketball practice, years	9.1 (8.6 to 9.6)	9.6 (9.3 to 10.0)	10.4 (10.0 to 10.7)	11.1 (10.6 to 11.6)	9.7 (9.2 to 10.2)	10.3 (10.0 to 10.5)	11.0 (10.7 to 11.3)	11.7 (11.2 to 12.2)
Stature, cm	151.0 (149.0 to 153.0)	161.0 (160.0 to 162.0)	169.0 (168.0 to 171.0)	170.0 (168.0 to 172.0)	159.0 (156.0 to 161.0)	169.0 (168.0 to 170.0)	177.0 (176.0 to 178.0)	178.0 (176.0 to 180.0)
Body mass, kg	47.8 (44.6 to 50.8)	56.6 (54.6 to 58.5)	65.0 (62.9 to 66.9)	64.8 (62.2 to 67.4)	54.3 (51.4 to 57.2)	63.1 (61.4 to 64.8)	71.5 (69.8 to 73.2)	71.3 (68.9 to 73.8)
Countermovement jump, cm	21.6 (20.4 to 22.8)	24.1 (23.3 to 24.8)	27.0 (26.2 to 27.8)	28.9 (27.8 to 29.9)	27.7 (26.5 to 28.9)	30.2 (29.6 to 30.9)	33.2 (32.5 to 33.9)	35.0 (33.9 to 36.1)
Line drill test, s	38.9 (38.3 to 39.4)	36.2 (35.9 to 36.5)	34.4 (34.0 to 34.7)	33.8 (33.4 to 34.3)	37.3 (36.8 to 37.9)	34.7 (34.4 to 35.0)	32.9 (32.6 to 33.2)	32.3 (31.8 to 32.8)
Yo-yo IR1, m	267 (176 to 355)	472 (366 to 472)	642 (586 to 697)	765 (688 to 839)	554 (472 to 638)	707 (663 to 751)	930 (883 to 976)	1053 (978 to 1127)
Deliberate Practice Motivation								
Will to excel, 1–5	3.90 (3.76 to 4.06)	3.94 (3.82 to 4.06)	3.81 (3.69 to 3.93)	3.88 (3.74 to 4.01)	4.30 (4.16 to 4.43)	4.33 (4.23 to 4.44)	4.20 (4.09 to 4.30)	4.27 (4.15 to 4.40)
Will to compete, 1–5	4.23 (4.11 to 4.35)	4.36 (4.27 to 4.46)	4.19 (4.10 to 4.27)	4.19 (4.08 to 4.30)	4.38 (4.27 to 4.49)	4.52 (4.44 to 4.60)	4.34 (4.26 to 4.41)	4.34 (4.23 to 4.45)
Achievement and Competitiveness Motivation								
Mastery, 1–5	4.05 (3.95 to 4.15)	4.05 (3.97 to 4.13)	4.05 (3.97 to 4.13)	4.10 (4.00 to 4.20)	4.26 (4.17 to 4.35)	4.26 (4.20 to 4.33)	4.26 (4.19 to 4.32)	4.31 (4.22 to 4.41)
Work, 1–5	4.24 (4.12 to 4.35)	4.33 (4.25 to 4.41)	4.26 (4.18 to 4.34)	4.17 (4.06 to 4.28)	4.50 (4.39 to 4.59)	4.59 (4.52 to 4.66)	4.52 (4.46 to 4.59)	4.44 (4.32 to 4.54)
Competitiveness, 1–5	3.51 (3.35 to 3.66)	3.47 (3.36 to 3.58)	3.64 (3.54 to 3.75)	3.71 (3.57 to 3.85)	3.78 (3.63 to 3.92)	3.74 (3.65 to 3.83)	3.91 (3.82 to 4.00)	3.98 (3.84 to 4.13)
Sources of Enjoyments in Youth Sports								
Self-referenced competencies, 1–5	4.39 (4.28 to 4.49)	4.37 (4.29 to 4.45)	4.40 (4.32 to 4.49)	4.35 (4.25 to 4.45)	4.53 (4.44 to 4.62)	4.52 (4.45 to 4.58)	4.55 (4.48 to 4.61)	4.50 (4.41 to 4.58)
Others-referenced competencies, 1–5	3.44 (3.20 to 3.65)	3.61 (3.48 to 3.73)	3.64 (3.51 to 3.77)	3.75 (3.57 to 3.94)	3.66 (3.44 to 3.86)	3.83 (3.73 to 3.93)	3.86 (3.76 to 3.96)	3.97 (3.81 to 4.15)
Effort expenditure, 1–5	4.66 (4.54 to 4.77)	4.75 (4.68 to 4.82)	4.73 (4.66 to 4.80)	4.74 (4.65 to 4.82)	4.66 (4.54 to 4.75)	4.74 (4.69 to 4.80)	4.72 (4.66 to 4.77)	4.73 (4.66 to 4.81)
Affiliation with peers, 1–5	4.39 (4.24 to 4.52)	4.50 (4.41 to 4.60)	4.45 (4.36 to 4.54)	4.44 (4.32 to 4.55)	4.41 (4.27 to 4.53)	4.52 (4.45 to 4.60)	4.47 (4.39 to 4.54)	4.46 (4.35 to 4.55)
Positive parental involvement, 1–5	4.53 (4.37 to 4.70)	4.57 (4.46 to 4.68)	4.30 (4.18 to 4.42)	4.49 (4.34 to 4.65)	4.43 (4.28 to 4.59)	4.47 (4.38 to 4.57)	4.20 (4.10 to 4.30)	4.40 (4.26 to 4.53)

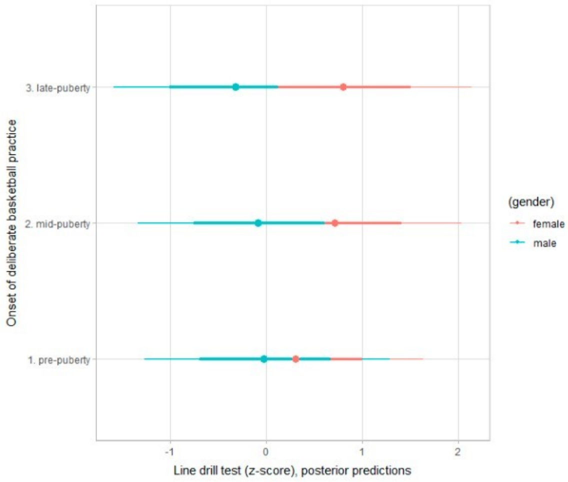




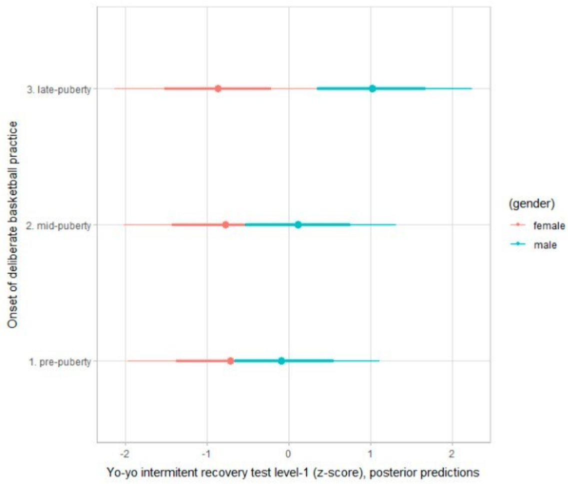
(a) **(b)**

Figure 1. Posterior predictions for stature **(a)** and body mass **(b)** by onset of deliberate basketball practice in young female and male basketball players (80% and 50% credible intervals).



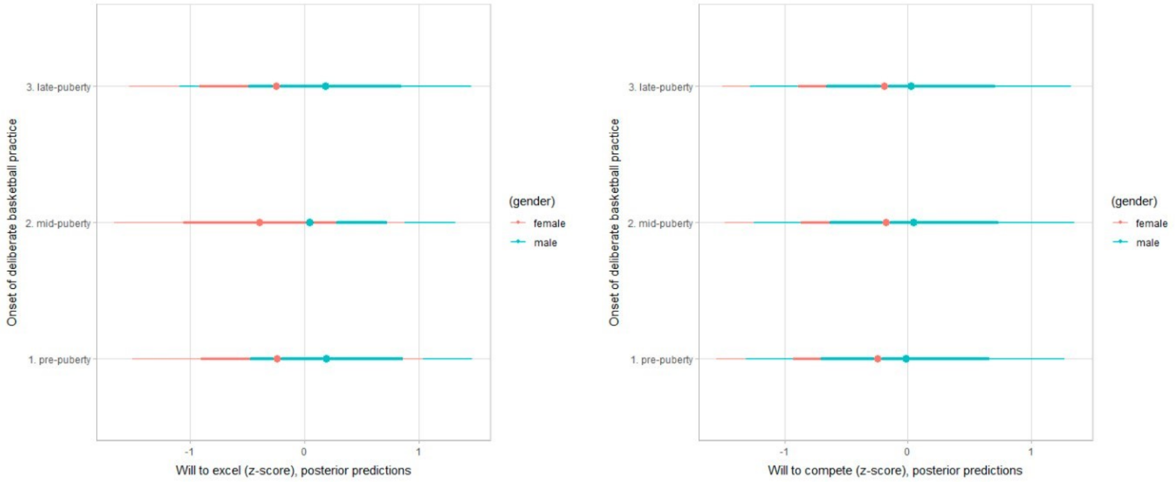


(a) **(b)**



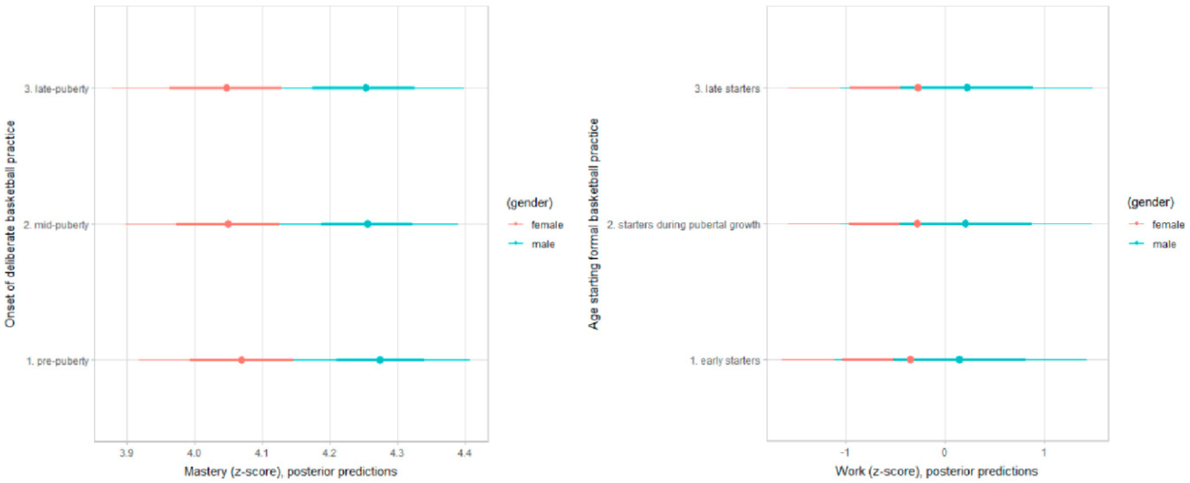
(c)

Figure 2. Posterior predictions for countermovement jump **(a)**, Line drill test **(b)** and yo-yo intermittent recovery test level-1 **(c)** by onset of deliberate basketball practice in young female and male basketball players (80% and 50% credible intervals).

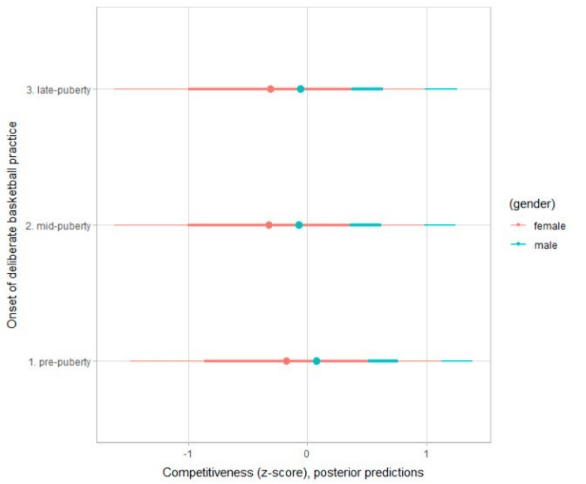


(a) (b)

Figure 3. Posterior predictions for will to excel **(a)** and will to compete **(b)** by onset of deliberate basketball practice in young female and male basketball players (80% and 50% credible intervals).



(a) (b)



(c)

Figure 4. Posterior predictions for mastery **(a),** work **(b)** and competitiveness **(c)** by onset of deliberate basketball practice in young female and male basketball players (80% and 50% credible intervals).

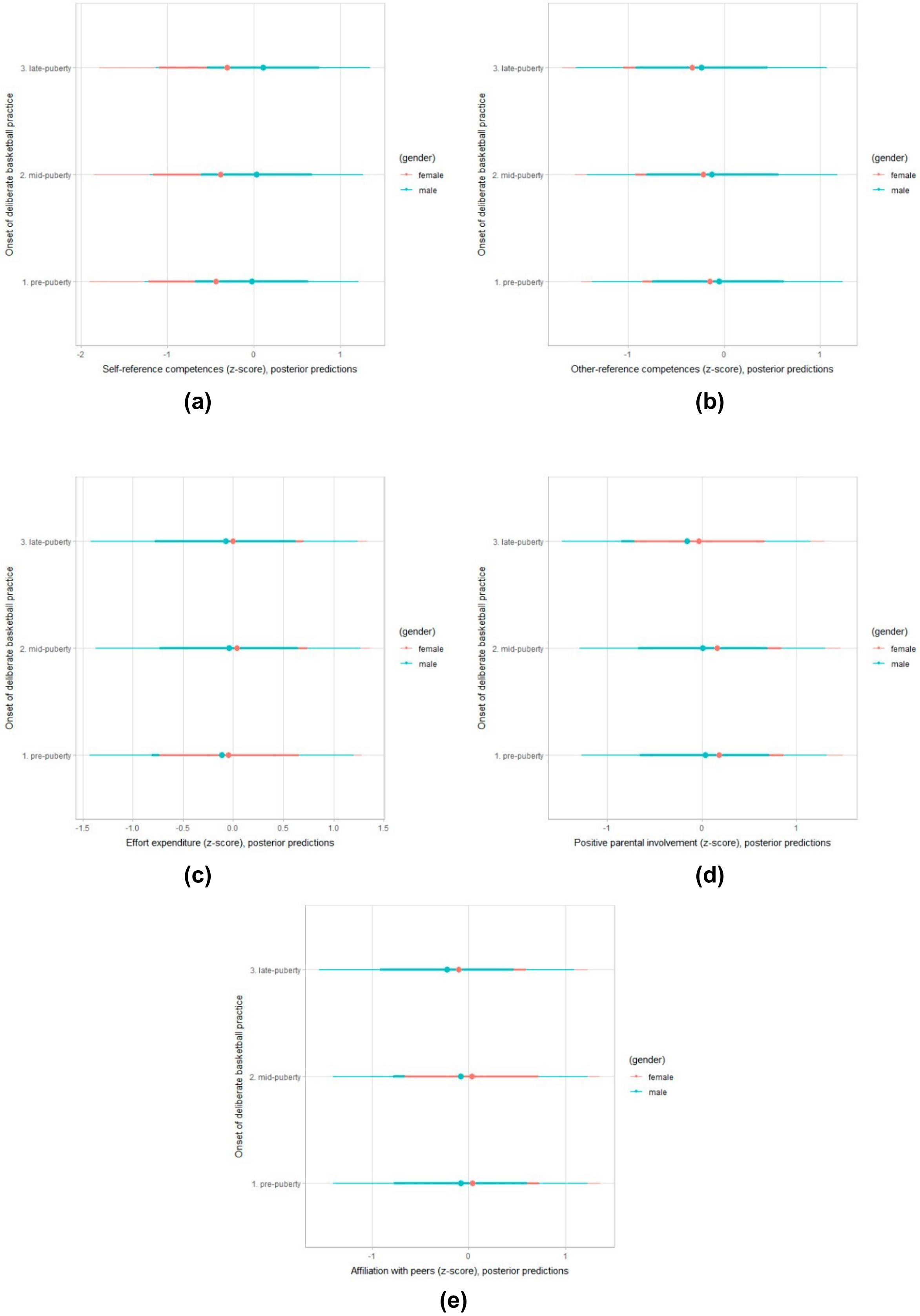
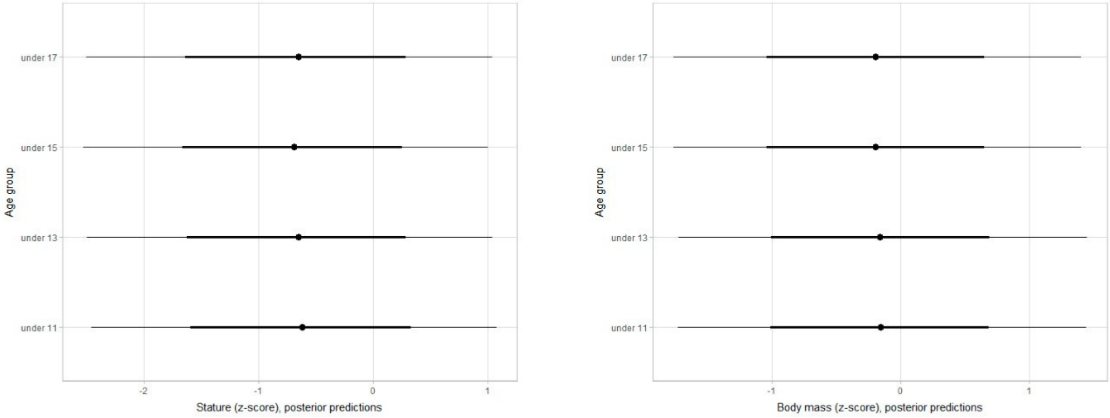
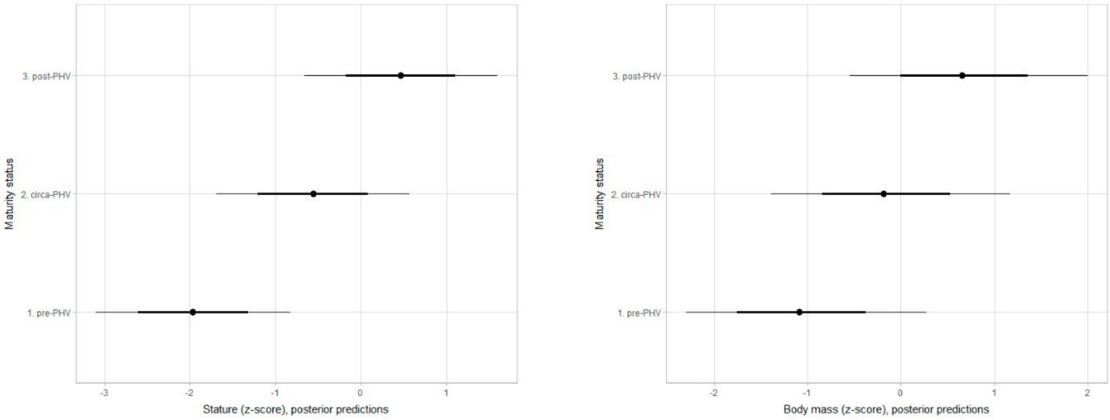


Figure 5. Posterior predictions for self-referenced competences **(a)**, others-referenced competences **(b)**, effort expenditure **(c)**, positive parental involvement **(d)** and affiliation with peers **(e)** by onset of deliberate basketball practice in young female and male basketball players (80% and 50% credible intervals).



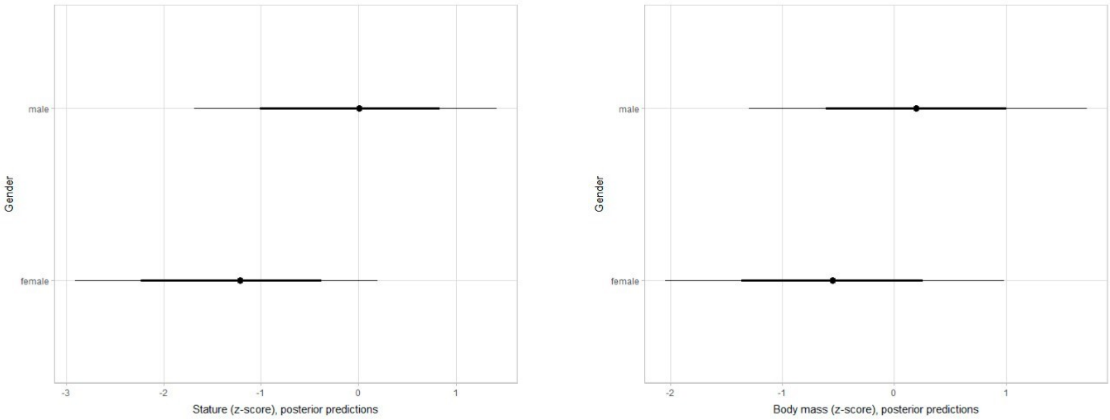
(a) **(b)**

Figure 6. Posterior predictions for stature **(a)** and body mass **(b)** by age group in young female and male basketball players, adjusting for maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals).



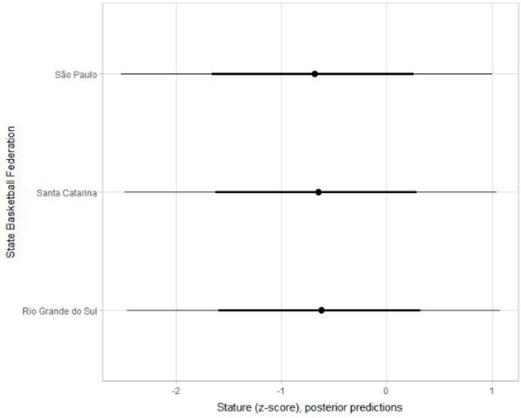
(a) **(b)**

Figure 7. Posterior predictions for stature **(a)** and body mass **(b)** by maturity status in young female and male basketball players, adjusting for age group, age starting basketball practice and state basketball federation (80% and 50% credible intervals).

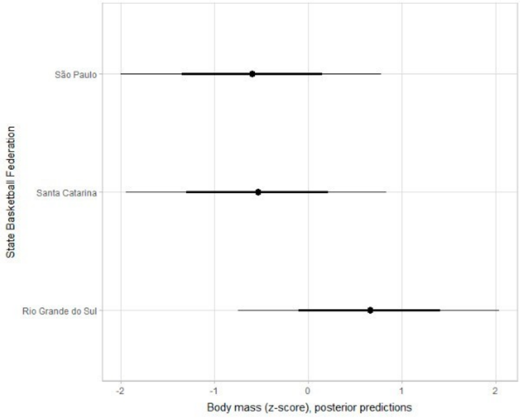


(a) **(b)**

Figure 8. Posterior predictions for stature **(a)** and body mass **(b)** in young female and male basketball players, adjusting for age group, maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals).

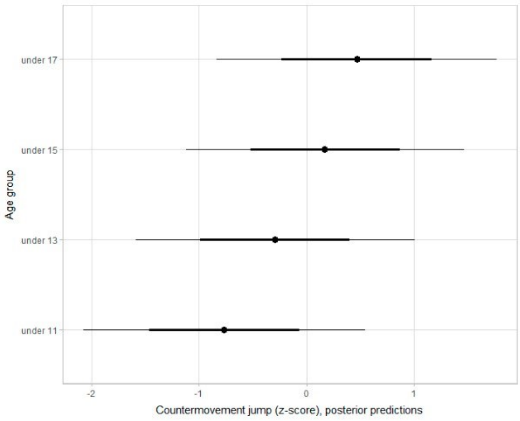


(a)

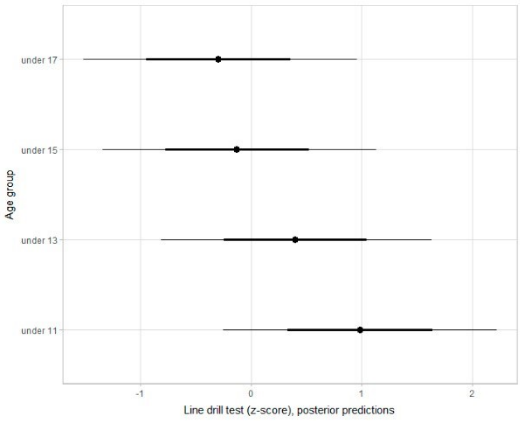


(b)

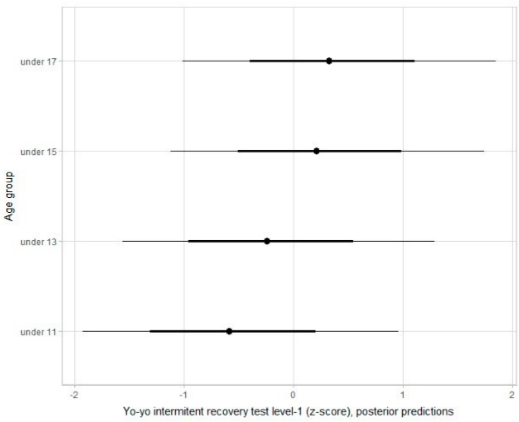
Figure 9. Posterior predictions for stature **(a)** and body mass **(b)** by state basketball federation in young female and male basketball players, adjusting for age group, maturity status and age starting basketball practice (80% and 50% credible intervals).



(a)

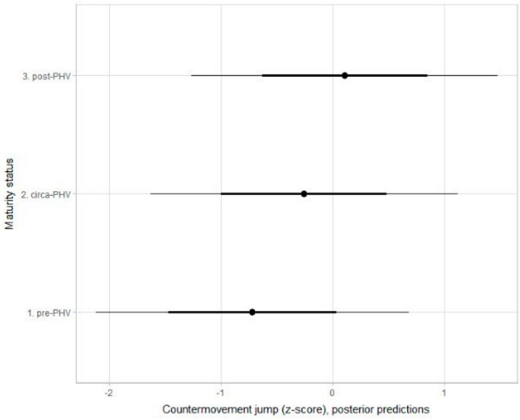


(b)

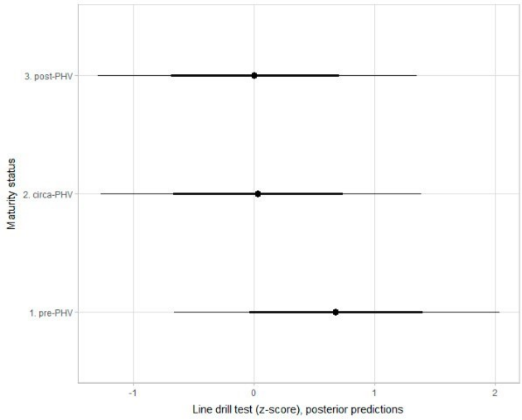


(c)

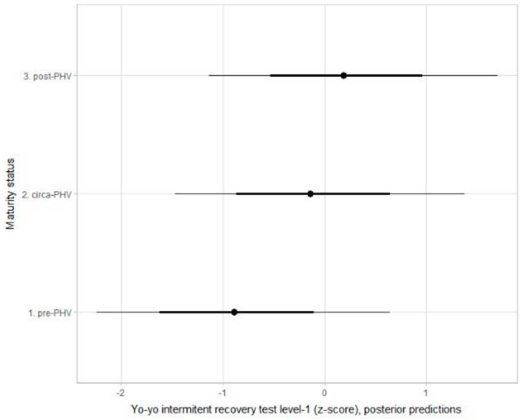
Figure 10. Posterior predictions for countermovement jump **(a)**, Line drill test **(b)** and yo-yo intermittent recovery test level-1 **(c)** by age group in young female and male basketball players, adjusting for maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals).



(a)

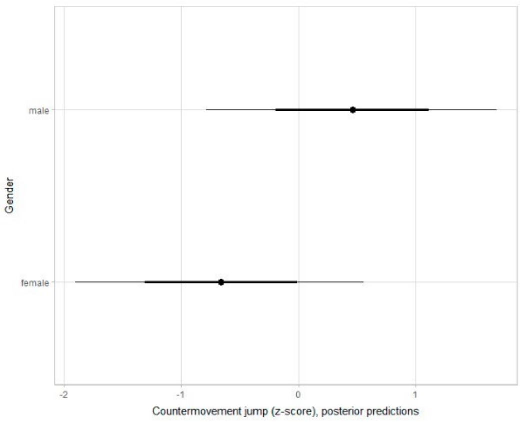


(b)

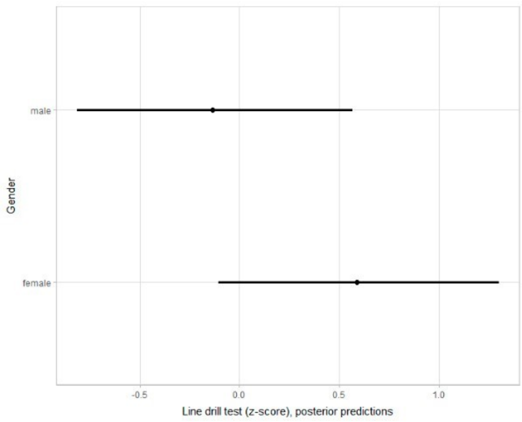


(c)

Figure 11. Posterior predictions for countermovement jump **(a)**, Line drill test **(b)** and yo-yo intermittent recovery test level-1 **(c)** by maturity status in young female and male basketball players, adjusting for age group, age starting basketball practice and state basketball federation (80% and 50% credible intervals).



(a)



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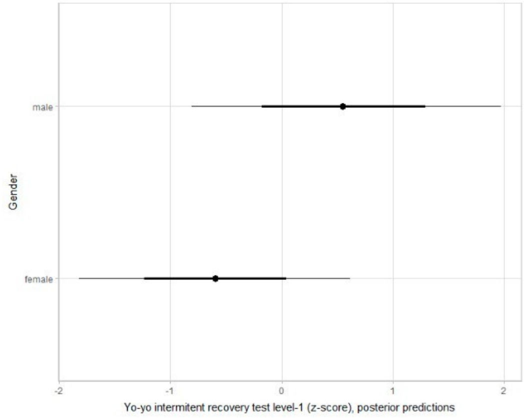
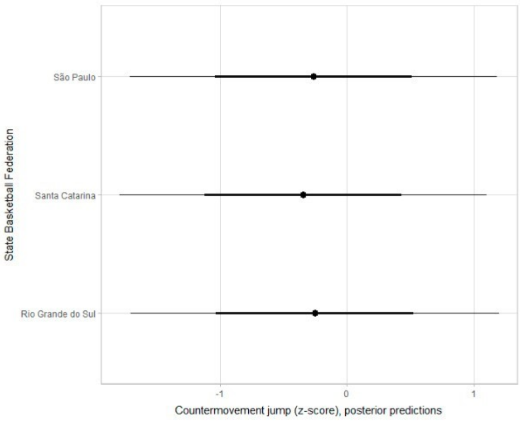
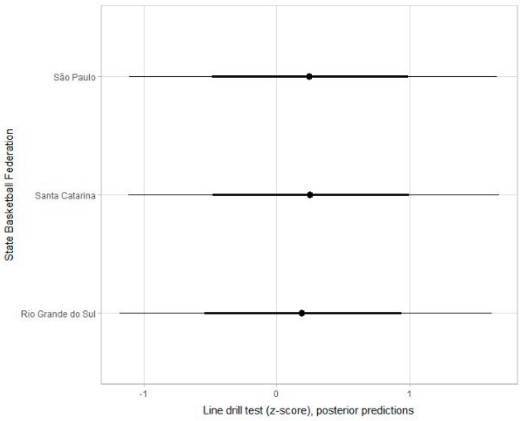


(c)

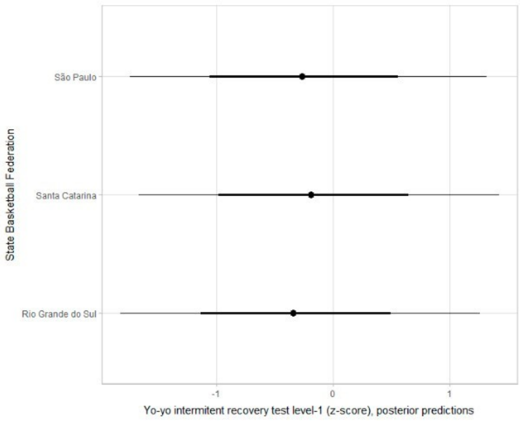
Figure 12. Posterior predictions for countermovement jump **(a)**, Line drill test **(b)** and yo-yo intermittent recovery test level-1 **(c)** in young female and male basketball players, adjusting for age group, maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals).



(a)

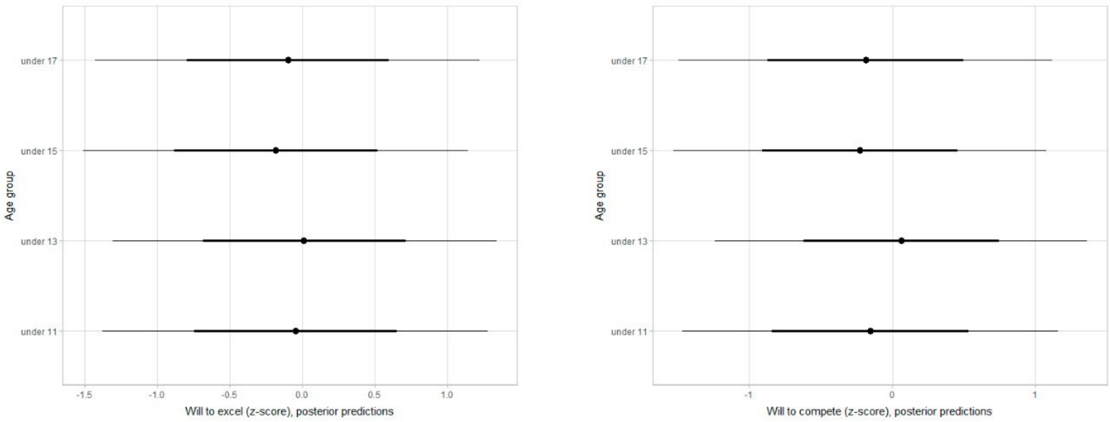


(b)



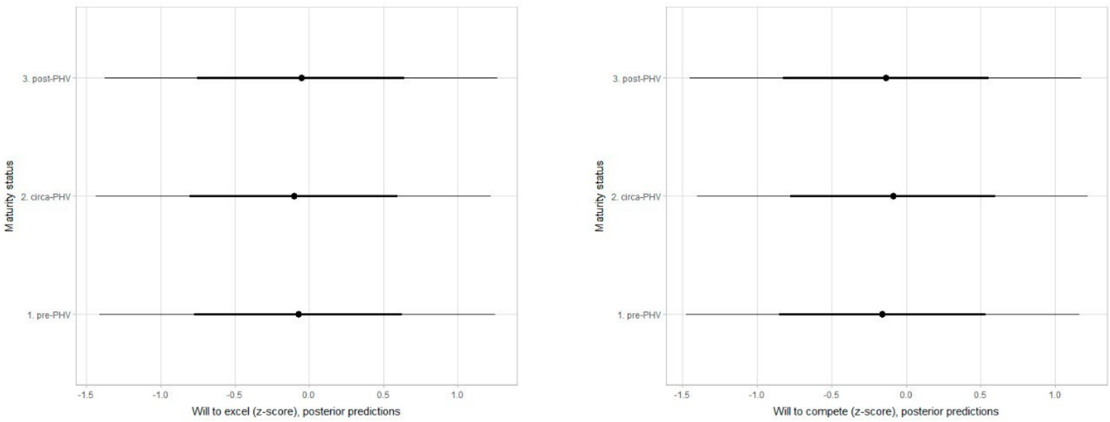
(c)

Figure 13. Posterior predictions for countermovement jump **(a)**, Line drill test **(b)** and yo-yo intermittent recovery test level-1 **(c)** by state basketball federation in young female and male basketball players, adjusting for age group, maturity status and age starting basketball practice (80% and 50% credible intervals).



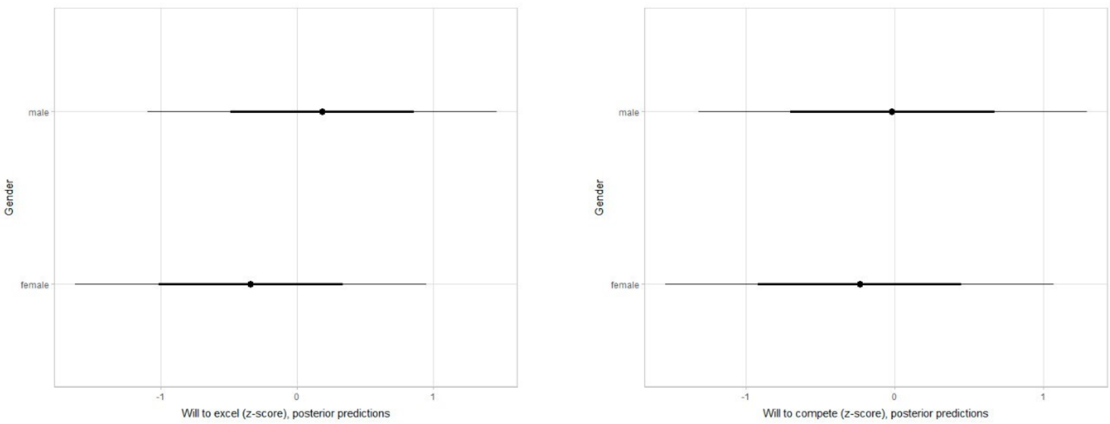
(a) **(b)**

Figure 14. Posterior predictions for will to excel **(a)** and will to compete **(b)** by age group in young female and male basketball players, adjusting for maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals).



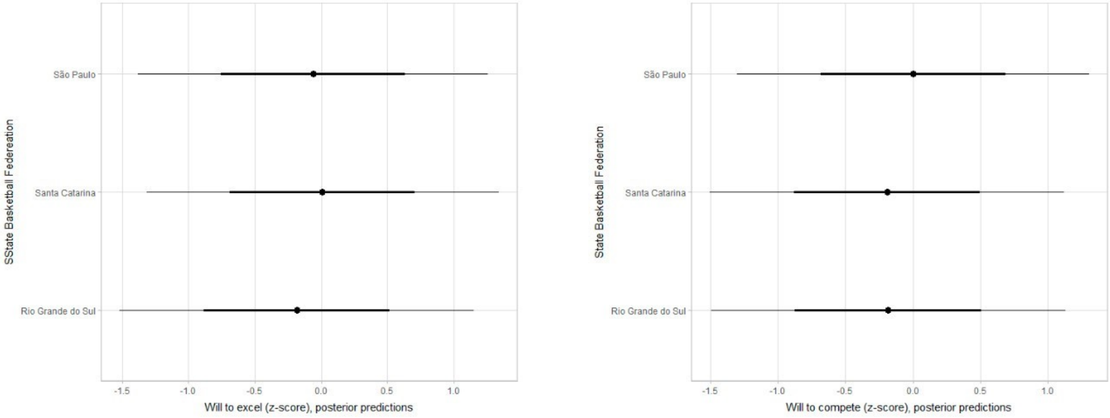
(a) **(b)**

Figure 15. Posterior predictions for will to excel **(a)** and will to compete **(b)** by maturity status in young female and male basketball players, adjusting for age group, age starting basketball practice and state basketball federation (80% and 50% credible intervals).



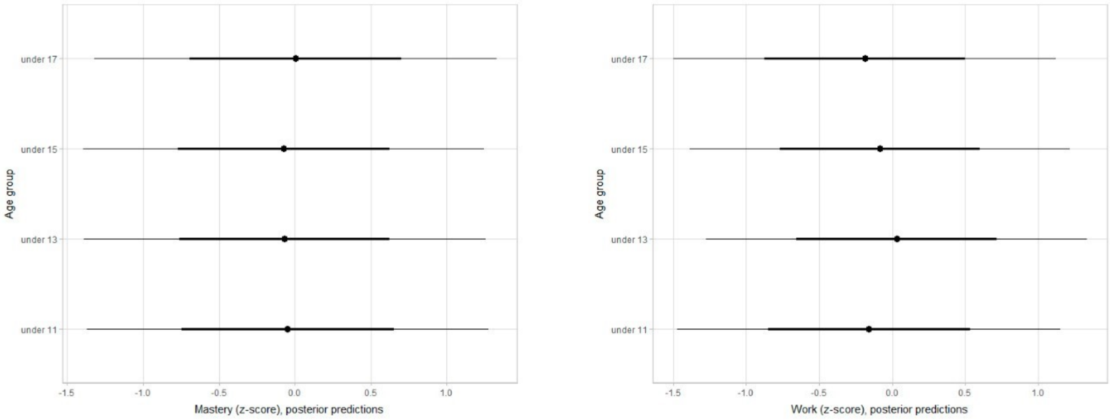
(a) **(b)**

Figure 16. Posterior predictions for deliberate practice motivation dimensions in young female and male basketball players, adjusting for age group, maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals).

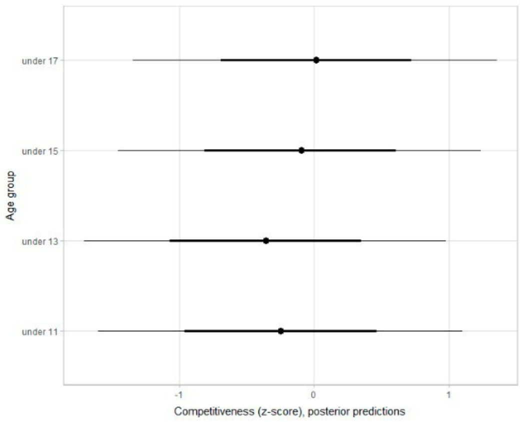


(a) **(b)**

Figure 17. Posterior predictions for will to excel **(a)** and will to compete **(b)** by state basketball federation in young female and male basketball players, adjusting for age group, maturity status and age starting basketball practice (80% and 50% credible intervals).

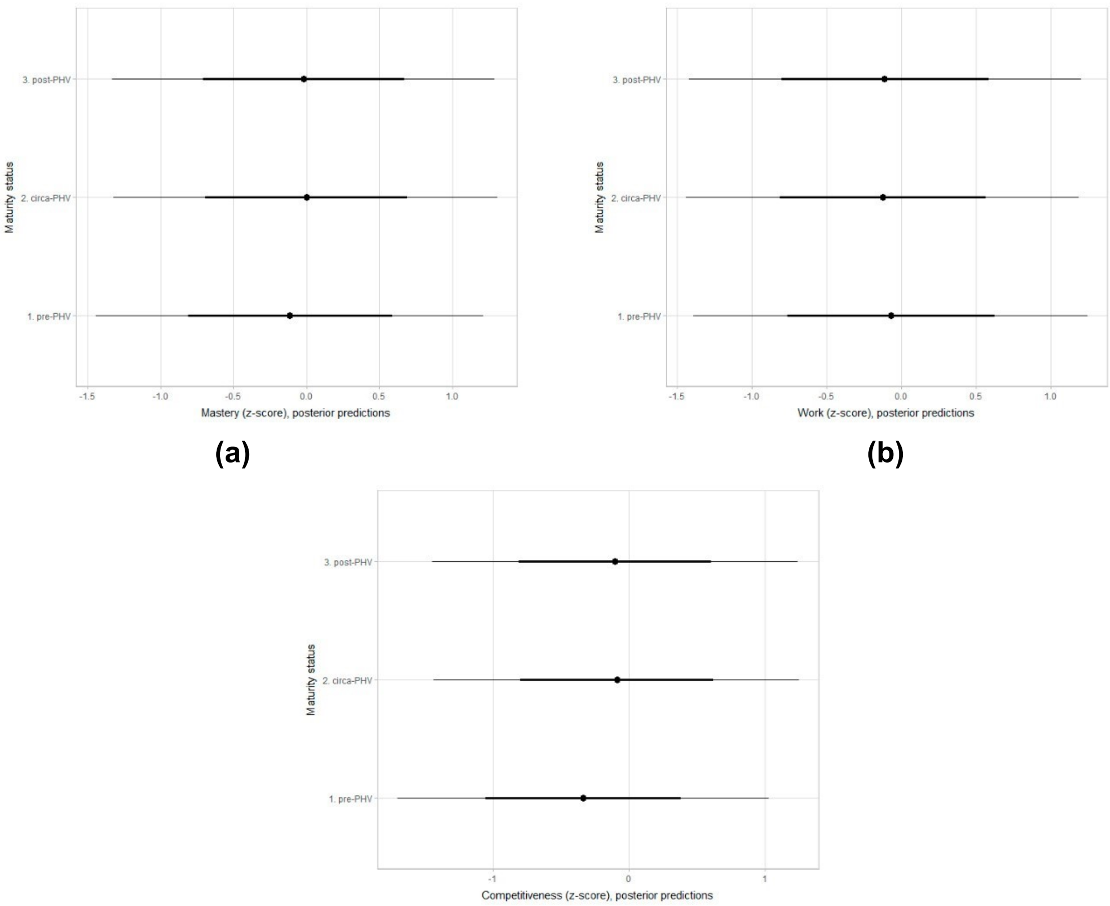


(a) **(b)**



(c)

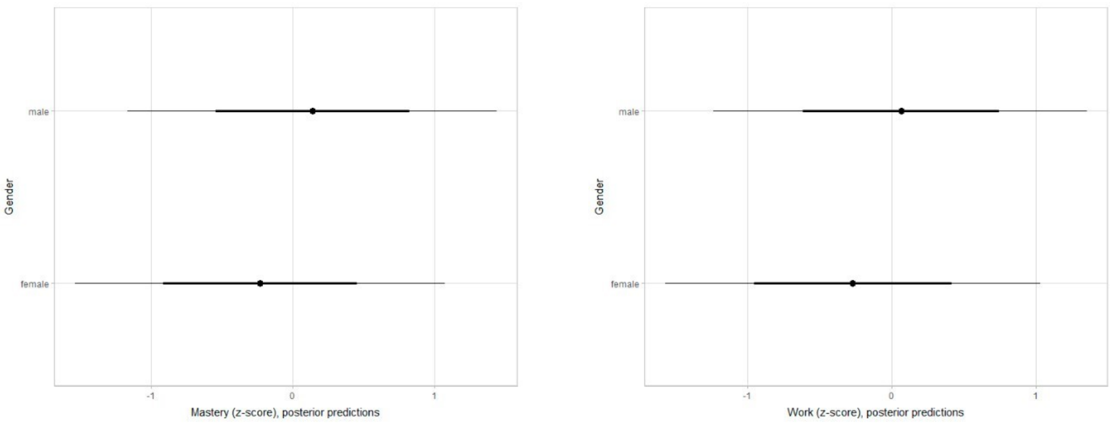
Figure 18. Posterior predictions for mastery **(a),** work **(b)** and competitiveness **(c)** by age group in young female and male basketball players, adjusting for maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals).



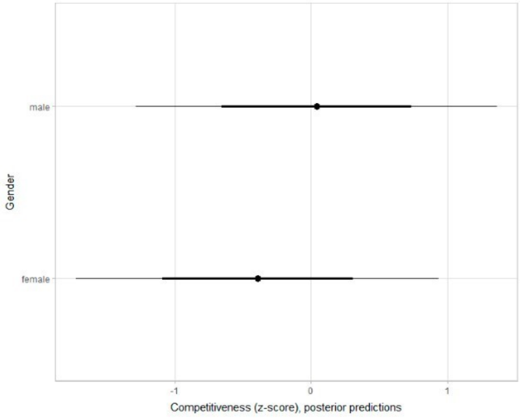
(a) **(b)**

(c)

Figure 19. Posterior predictions for mastery **(a),** work **(b)** and competitiveness **(c)** by maturity status in young female and male basketball players, adjusting for age group, age starting basketball practice and state basketball federation (80% and 50% credible intervals).

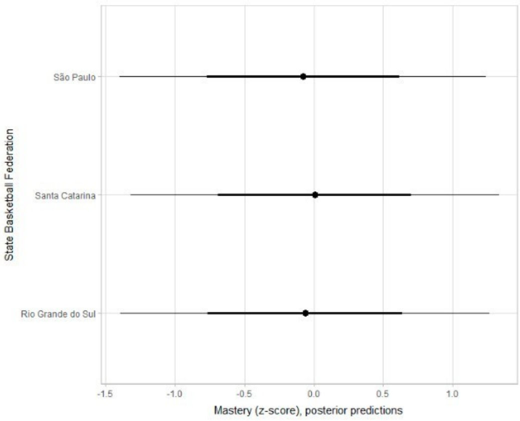


(a) **(b)**

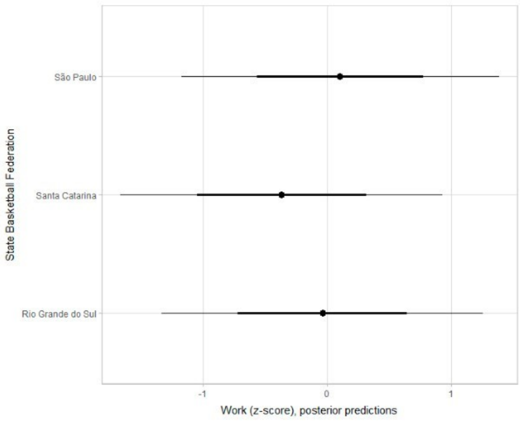


(c)

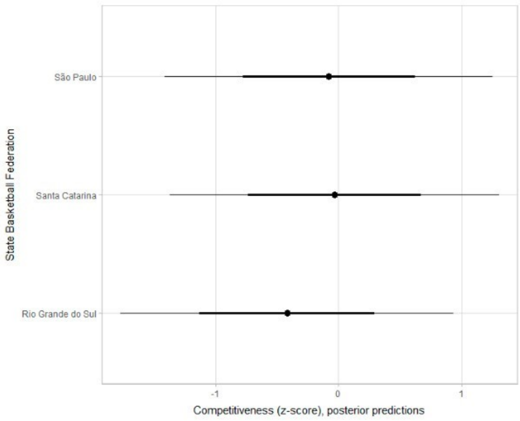
Figure 20. Posterior predictions for mastery **(a),** work **(b)** and competitiveness **(c)** in young female and male basketball players, adjusting for age group, maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals).



(a)

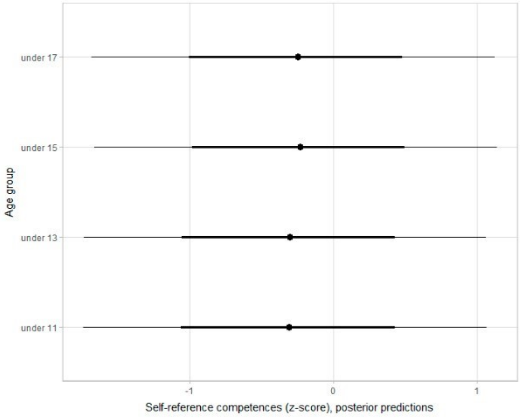


(b)

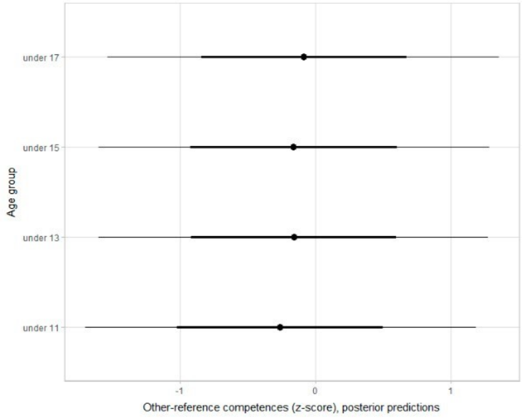


(c)

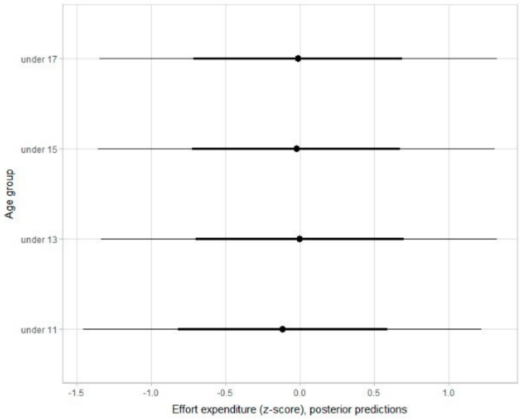
Figure 21. Posterior predictions for mastery **(a),** work **(b)** and competitiveness **(c)** by state basketball federation in young female and male basketball players, adjusting for age group, maturity status and age starting basketball practice (80% and 50% credible intervals).



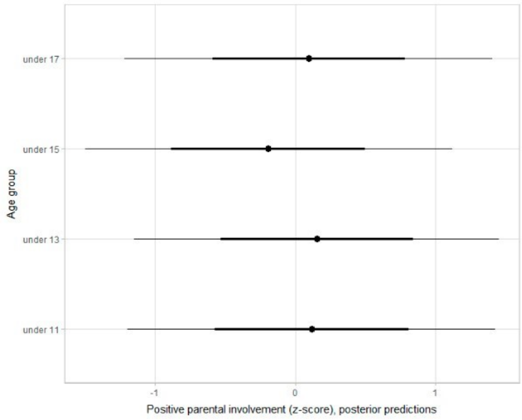
(a)



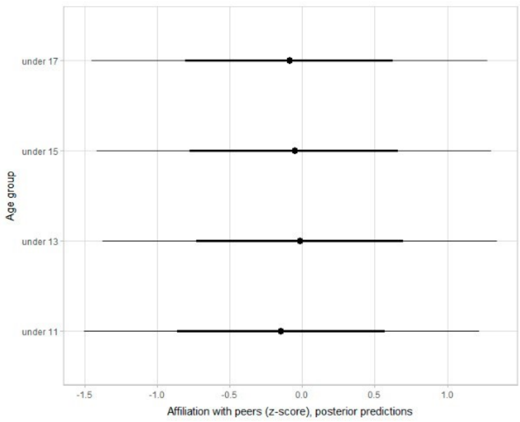
(b)



(c)



(d)



(e)

Figure 22. Posterior predictions for self-referenced competences **(a)**, others-referenced competences **(b)**, effort expenditure **(c)**, positive parental involvement **(d)** and affiliation with peers **(e)** by age group in young female and male basketball players, adjusting for maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals).

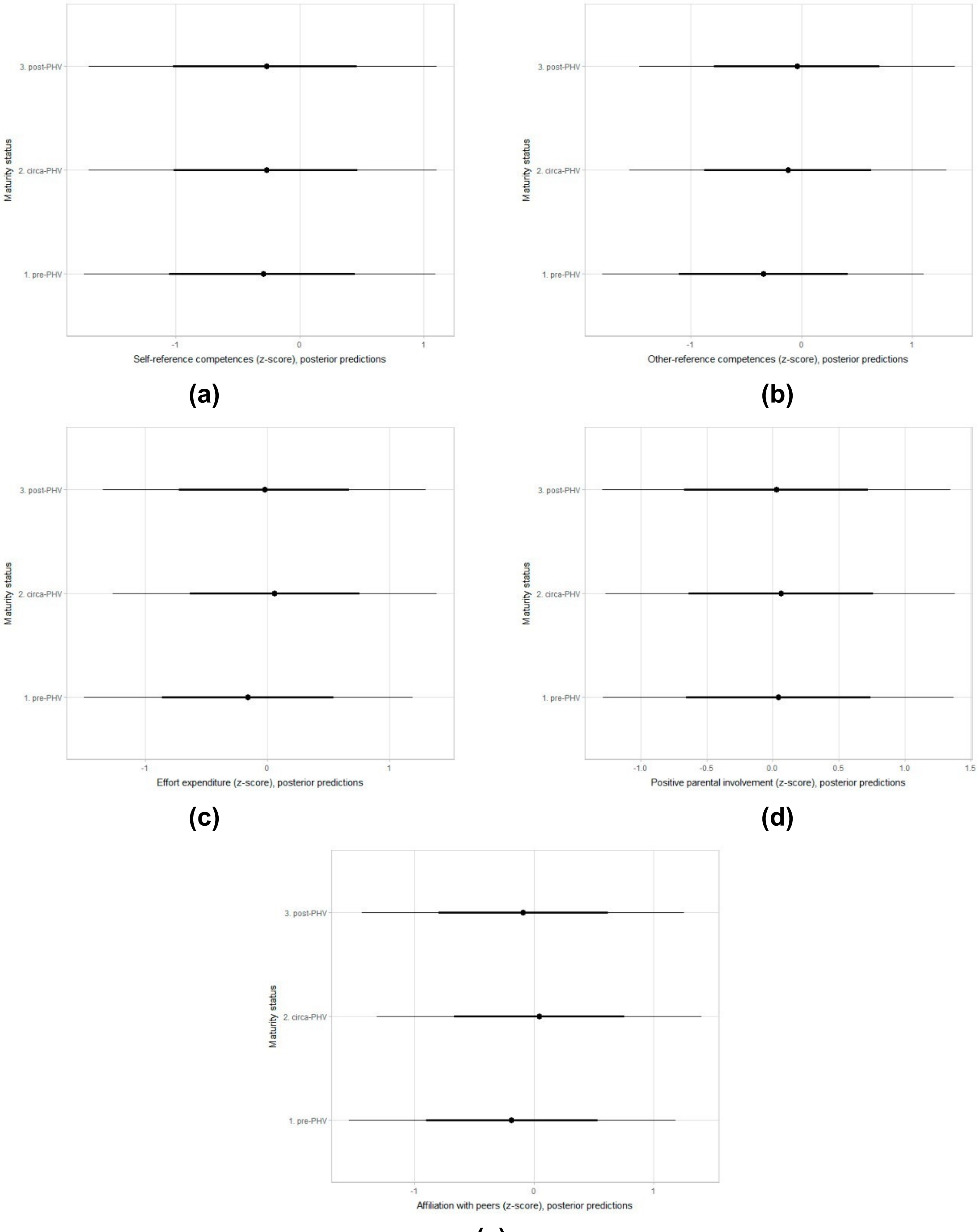


Figure 23. Posterior predictions for self-referenced competences **(a)**, others-referenced competences **(b)**, effort expenditure **(c)**, positive parental involvement **(d)** and affiliation with peers **(e)** by maturity status in young female and male basketball players, adjusting for age group, age starting basketball practice and state basketball federation (80% and 50% credible intervals).

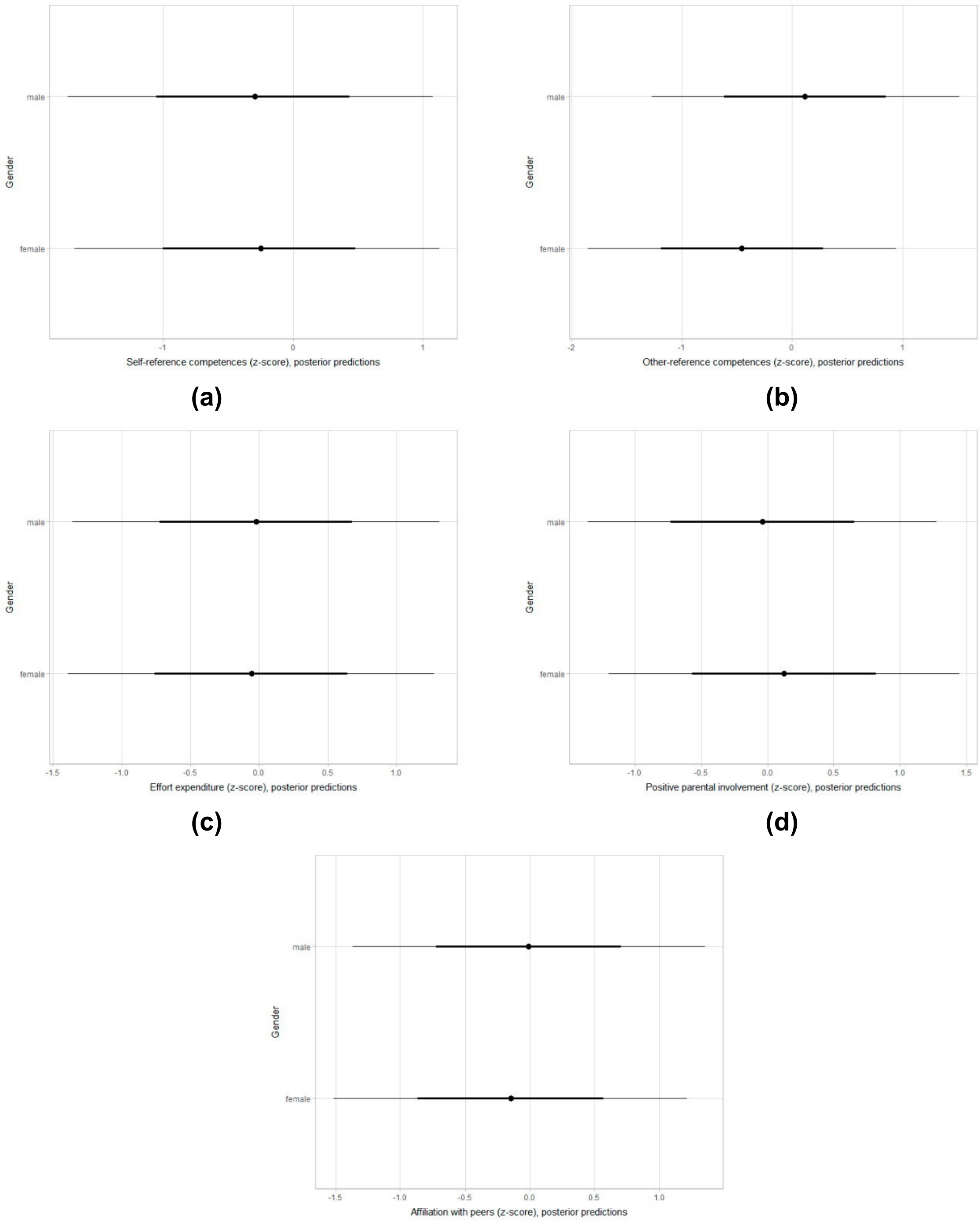


Figure 24. Posterior predictions for self-referenced competences **(a)**, others-referenced competences **(b)**, effort expenditure **(c)**, positive parental involvement **(d)** and affiliation with peers **(e)** in young female and male basketball players, adjusting for age group, maturity status, age starting basketball practice and state basketball federation (80% and 50% credible intervals).

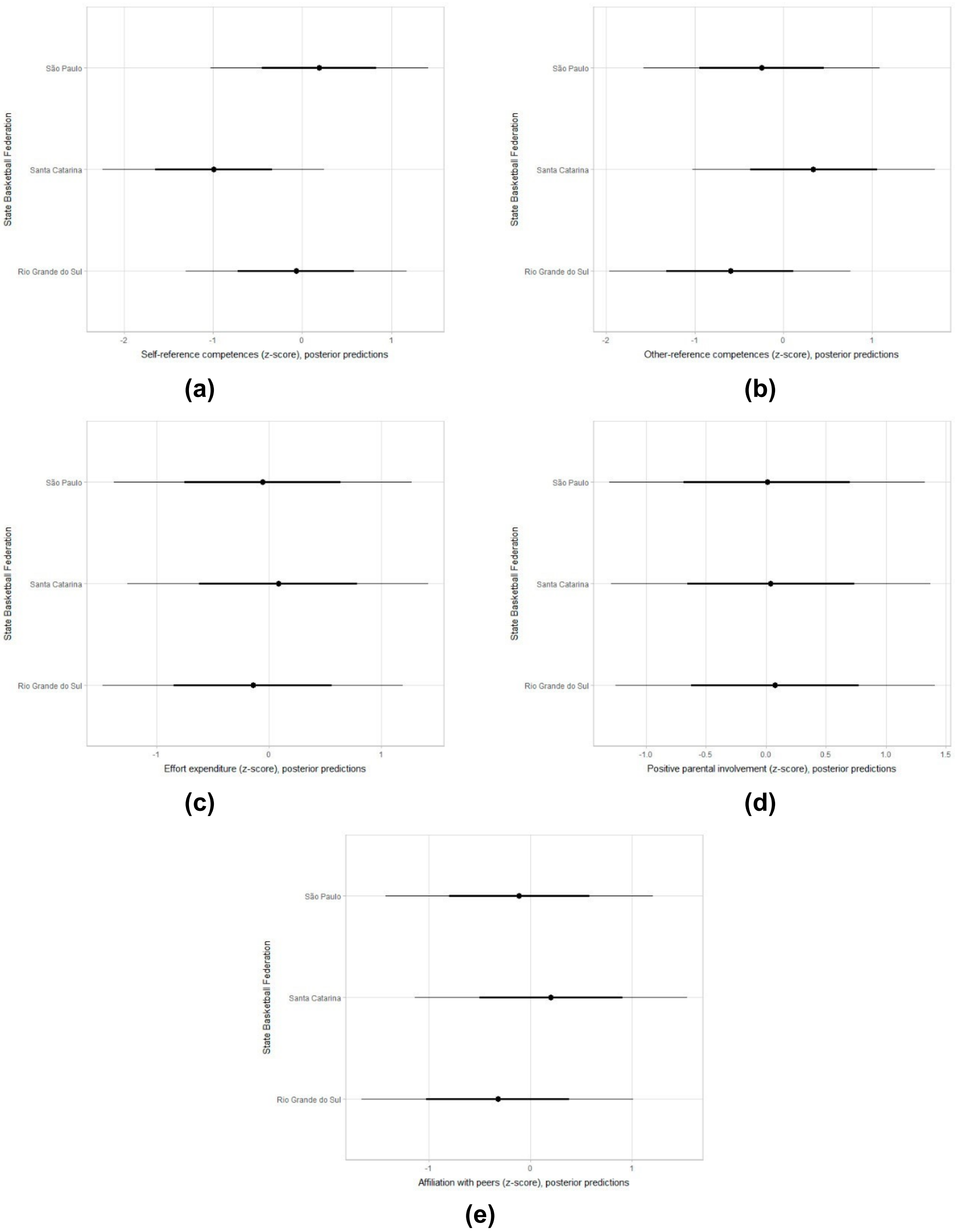


Figure 25. Posterior predictions for self-referenced competences **(a)**, others-referenced competences **(b)**, effort expenditure **(c)**, positive parental involvement **(d)** and affiliation with peers **(e)** by state basketball federation in young female and male basketball players, adjusting for age group maturity status and age starting basketball practice (80% and 50% credible intervals).

Codes for all the models in the manuscript:

```
library(magrittr) library(dplyr) library(purrr) library(forcats) library(tidyr) library(modelr)
library(tidybayes) library(ggplot2) library(ggstance) library(ggridges) library(cowplot)
library(rstan) library(brms) library(ggrepel) library(RColorBrewer) library(gganimate)
```

```
theme_set(theme_tidybayes() + panel_border() + background_grid())

rstan_options(auto_write = TRUE)
options(mc.cores = parallel::detectCores())

#meta analysis

aphv1<brm(mean_age_PHV|se(se)~1+(1|id)+(1|ge
nder), data = meta_APHV, family = "gaussian",
prior = c(prior(normal(0,2),class = sd)), control =
list(adapt_delta = 0.99,max_treedepth = 15)) iphv1
<
brm(mean_age_initiation_PHV|se(se)~1+(1|id)+(1|g
ender), data = meta_IPHV,

family = "gaussian",
prior = c(prior(normal(0,2),class=sd)),
control = list(adapt_delta = 0.99,max_treedepth = 15))

#performance

m1<brm(yoyo_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|state)+(1|speci
    alizatio n:gender),
  data = bball, family = gaussian,
          prior = c(prior(normal(0,2),class =
Intercept),prior(normal(0,2),class = sd)),      chains = 4, iter = 2000,
warmup = 1000, cores = 4,    control =
list(adapt_delta=0.99,max_treedepth=15))

plot(m1)
pp_ckeck(m1)
summary(m1)
coef(m1)

yoyo.special.sex.s<-bball %>%
group_by(gender) %>%
```

```
data_grid(age_group,specialization,gender, mat_sample,state) %>%
  add_predicted_draws(m1) %>%
 ggplot(aes(x = .prediction, y = specialization,color = (gender))) +
   stat_pointintervalh(.width = c(.8,.5))+ labs(y= "Specialization")+ labs(x= "Yo-yo intermitent recovery test level-1 (z-score), posterior predictions")

yoyo.sex.s<-bball %>%
 data_grid(age_group,specialization,gender, mat_sample,state) %>%
  add_predicted_draws(m1) %>%
 ggplot(aes(x = .prediction, y = gender)) +
 stat_pointintervalh(.width = c(.8,.5))+ labs(y= "Gender")+ labs(x= "Yo-yo intermitent recovery test level-1 (z-score), posterior predictions")

yoyo.age.s<-bball %>%
data_grid(age_group,specialization,gender, mat_sample,state) %>%
add_predicted_draws(m1) %>%
ggplot(aes(x = .prediction, y = age_group)) +
stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Age group")+ labs(x= "Yo-yo intermitent recovery test level-1 (z-score), posterior predictions")

yoyo.mat.s<-bball %>%
data_grid(age_group,specialization,gender, phv_cat,state) %>%
add_predicted_draws(m1) %>%
ggplot(aes(x = .prediction, y = phv_cat)) +
stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Maturity status")+ labs(x = "Yo-yo intermitent recovery test level-1 (z-score), posterior predictions")

yoyo.state.s<-bball %>%
data_grid(age_group,specialization,gender, phv_cat,state) %>%
add_predicted_draws(m1) %>%
ggplot(aes(x = .prediction, y = state)) +
stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x= "Yo-yo intermitent recovery test level-1 (z-score), posterior predictions")

yoyo.special.state.s<-bball %>%
data_grid(age_group,specialization,gender, phv_cat,state) %>%
```

```
add_predicted_draws(m1) %>%

ggplot(aes(x = .prediction, y = state, color = (specialization))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Yo-yo
    intermitent recovery test level-1 (z-score), posterior predictions")


m2<-

    brm(ld_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|state)+(1|specializ
    ation:ge nder),

   data = bball,

         family = gaussian, prior = c(prior(normal(0,1),class =
Intercept),prior(normal(0,1),class = sd)),      chains = 4, iter = 2000, warmup = 1000,
cores = 4,       control = list(adapt_delta = 0.99,max_treedepth = 15))


plot(m2)
pp_ckeck(m2)
summary(m2)

coef(m2)


ld.special.sex.s<-bball %>%
group_by(gender) %>%

data_grid(age_group,specialization,gender, mat_sample,state) %>%

add_predicted_draws(m2) %>%

ggplot(aes(x = .prediction, y = specialization,color = (gender))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Specialization")+ labs(x = "Line drill test (z-
    score), posterior predictions")


ld.sex.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m2) %>%

ggplot(aes(x = .prediction, y = gender)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Gender")+ labs(x = "Line drill test (z-score),
    posterior predictions")


ld.age.s<-bball %>%
data_grid(age_group,specialization,gender, phv_cat,state)
%>%

add_predicted_draws(m2) %>%

ggplot(aes(x = .prediction, y = age_group)) +
```

```
stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Age group")+ labs(x = "Line drill test (z-score), posterior predictions")

ld.mat.s<-bball %>%
data_grid(age_group,specialization,gender, phv_cat,state) %>%
add_predicted_draws(m2) %>%
ggplot(aes(x = .prediction, y = phv_cat)) +
stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Maturity status")+ labs(x = "Line drill test (z-score), posterior predictions")

ld.state.s<-bball %>%
data_grid(age_group,specialization,gender, phv_cat,state) %>%
add_predicted_draws(m2) %>%
ggplot(aes(x = .prediction, y = state)) +
stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Line drill test (zscore), posterior predictions")

ld.special.state.s<-bball %>%
data_grid(age_group,specialization,gender, phv_cat,state) %>%
add_predicted_draws(m2) %>%
ggplot(aes(x = .prediction, y = state, color = (specialization))) +
stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Line drill test (zscore), posterior predictions")

m3<brm(jump_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|state)+(1|specializatio n:gender),
 data = bball,
      family = Gaussian, prior = c(prior(normal(0,1),class =
Intercept),prior(normal(0,1),class = sd)),    chains = 4, iter = 2000, warmup = 1000,
cores = 4,     control = list(adapt_delta = 0.99,max_treedepth = 15))

plot(m3)
pp_ckeck(m3)
summary(m3)
coef(m3)

jump.special.sex.s<-bball %>%
group_by(gender) %>%
data_grid(age_group,specialization,gender, mat_sample,state) %>%
```

```
add_predicted_draws(m3) %>%

ggplot(aes(x = .prediction, y = specialization,color = (gender))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Specialization")+ labs(x = "Countermovement
    jump (zscore), posterior predictions")


jump.sex.s<-bball %>%

data_grid(age_group,specialization,gender, mat_sample,state) %>%

add_predicted_draws(m3) %>%

ggplot(aes(x = .prediction, y = gender)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Gender")+ labs(x = "Countermovement jump
    (z-score), posterior predictions")


jump.age.s<-bball %>%

data_grid(age_group,specialization,gender, mat_sample,state) %>%

add_predicted_draws(m3) %>%

ggplot(aes(x = .prediction, y = age_group)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Age group")+ labs(x = "Countermovement
    jump (zscore), posterior predictions")


jump.mat.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m3) %>%

ggplot(aes(x = .prediction, y = phv_cat)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Maturity status")+ labs(x = "Countermovement
    jump (zscore), posterior predictions")


jump.state.s<-bball %>%
data_grid(age_group,specialization,gender, phv_cat,state)
%>%

add_predicted_draws(m3) %>%

ggplot(aes(x = .prediction, y = state)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball
    Federation")+ labs(x = "Countermovement jump (z-score), posterior predictions")


jump.special.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m3) %>%
```

```
ggplot(aes(x = .prediction, y = state, color=(specialization))) +

stat_pointintervalh(.width      =        c(.8,.5))+        labs(y  =        "State  Basketball
        Federation")+ labs(x  = "Countermovement jump (z-score), posterior predictions")

###################

#body size

m4<-

brm(h_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|state)+(1|specializatio
   n:gende r),

        data = bball,
family = gaussian,

        prior = c(prior(normal(0,1),class =
Intercept),prior(normal(0,1),class = sd)),      chains = 4, iter = 2000,
warmup = 1000, cores = 4,    control = list(adapt_delta =
0.99,max_treedepth = 15))

plot(m4)
pp_ckeck(m4)
summary(m4)

coef(m4)

h.special.sex.s<-bball %>%
group_by(gender) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m4) %>%

ggplot(aes(x = .prediction, y = specialization,color = (gender))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Specialization")+ labs(x = "Stature (z-score),
   posterior predictions")

h.sex.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m4) %>%

ggplot(aes(x = .prediction, y = gender)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Gender")+ labs(x = "Stature (z-score),
   posterior predictions")

h.age.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%
```

```
add_predicted_draws(m4) %>%

ggplot(aes(x = .prediction, y = age_group)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Age group")+ labs(x = "Stature (z-score),
    posterior predictions")


h.mat.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m4) %>%

ggplot(aes(x = .prediction, y = phv_cat)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Maturity status")+ labs(x = "Stature (z-score),
    posterior predictions")


h.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m4) %>%

ggplot(aes(x = .prediction, y = state)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x =
    "Stature (z-score), posterior predictions")


h.special.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m4) %>%

ggplot(aes(x = .prediction, y = state, color=(specialization))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x =
    "Stature (z-score), posterior predictions")


m5<brm(w_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|state)+(1|specializ
    ation:ge nder),
data=bball,

family=gaussian, prior = c(prior(normal(0,1),class =
Intercept),prior(normal(0,1),class = sd)),      chains = 4, iter = 2000, warmup =
1000, cores = 4,         control = list(adapt_delta = 0.99,max_treedepth = 15))


plot(m5)
pp_ckeck(m5)
summary(m5)

coef(m5)
```

```
w.special.sex.s<-bball %>%
group_by(gender) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m5) %>%

ggplot(aes(x = .prediction, y = specialization,color = (gender))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Specialization")+ labs(x = "Body mass (z-
    score), posterior predictions")


w.sex.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m5) %>%

ggplot(aes(x = .prediction, y = gender)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Gender")+ labs(x = "Body mass (z-score),
    posterior predictions")


w.age.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m5) %>%

ggplot(aes(x = .prediction, y = age_group)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Age group")+ labs(x = "Body mass (z-score),
    posterior predictions")


w.mat.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m5) %>%

ggplot(aes(x = .prediction, y = phv_cat)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Maturity status")+ labs(x = "Body mass (z-
    score), posterior predictions")


w.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m5) %>%

ggplot(aes(x = .prediction, y = state)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Body
    mass (zscore), posterior predictions")
```

```
w.special.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m5) %>%

ggplot(aes(x = .prediction, y = state, color=(specialization))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Body
    mass (zscore), posterior predictions")

###############################################

#deliberate practice motivation


m6<-
brm(excel_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|state),
data = bball,

        family = gaussian, prior = c(prior(normal(0,1),class =
Intercept),prior(normal(0,1),class = sd)),      chains = 4, iter = 2000, warmup = 1000,
cores = 4,        control = list(adapt_delta = 0.99,max_treedepth = 15))


plot(m6)
pp_ckeck(m6)
summary(m6)

coef(m6)


excel.special.sex.s<-bball %>%

group_by(gender) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m6) %>%

ggplot(aes(x = .prediction, y = specialization,color = (gender))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Specialization")+ labs(x = "Will to excel (z-
    score), posterior predictions")


excel.sex.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m6) %>%

ggplot(aes(x = .prediction, y = gender)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Gender")+ labs(x = "Will to excel (z-score),
    posterior predictions")


excel.age.s<-bball %>%
```

```
data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m6) %>%

ggplot(aes(x = .prediction, y = age_group)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Age group")+ labs(x = "Will to excel (z-score),
    posterior predictions")


excel.mat.s<-bball %>%
data_grid(age_group,specialization,gender, phv_cat,state)
%>%

add_predicted_draws(m6) %>%

ggplot(aes(x = .prediction, y = phv_cat)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Maturity status")+ labs(x = "Will to excel (z-
    score), posterior predictions")


excel.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m6) %>%

ggplot(aes(x = .prediction, y = state)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "SState Basketball Federeation")+ labs(x =
    "Will to excel (z-score), posterior predictions")


excel.special.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m6) %>%

ggplot(aes(x = .prediction, y = state, color=(specialization))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Will
    to excel (zscore), posterior predictions")


m7<-
brm(compete_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|state),
data = bball,

        family = gaussian, prior = c(prior(normal(0,1),class =
Intercept),prior(normal(0,1),class = sd)),      chains = 4, iter = 2000, warmup = 1000,
cores = 4,       control = list(adapt_delta = 0.99,max_treedepth = 15))


plot(m7)
pp_ckeck(m7)
summary(m7)
coef(m7)
```

```
compete.special.sex.s<-bball %>%
group_by(gender) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m7) %>%

ggplot(aes(x = .prediction, y = specialization,color = (gender))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Specialization")+ labs(x = "Will to compete (z-
    score), posterior predictions")


compete.sex.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m7) %>%

ggplot(aes(x = .prediction, y = gender)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Gender")+ labs(x = "Will to compete (z-score),
    posterior predictions")


compete.age.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m7) %>%

ggplot(aes(x = .prediction, y = age_group)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Age group")+ labs(x = "Will to compete (z-
    score), posterior predictions")


compete.mat.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m7) %>%

ggplot(aes(x = .prediction, y = phv_cat)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Maturity status")+ labs(x = "Will to compete (z-
    score), posterior predictions")


compete.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m7) %>%

ggplot(aes(x = .prediction, y = state)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Will
    to compete (z-score), posterior predictions")
```

```
compete.special.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m7) %>%

ggplot(aes(x = .prediction, y = state, color=(specialization))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Will
    to compete (z-score), posterior predictions")


##########

#achievement motivation


m8<-
brm(competitiveness_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|state),
data = bball,

family=gaussian, prior = c(prior(normal(0,1),class = Intercept),prior(normal(0,1),class = sd)),

          chains = 4, iter = 2000, warmup = 1000, cores
= 4,      control = list(adapt_delta =
0.99,max_treedepth = 15))


plot(m8)
pp_ckeck(m8)
summary(m8)

coef(m8)


competitiveness.special.sex.s<-bball %>%

group_by(gender) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m8) %>%

ggplot(aes(x = .prediction, y = specialization,color = (gender))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Specialization")+ labs(x = "Competitiveness
    (z-score), posterior predictions")


competitiveness.sex.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m8) %>%

ggplot(aes(x = .prediction, y = gender)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Gender")+ labs(x = "Competitiveness (z-
    score), posterior predictions")
```

```
competitiveness.age.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m8) %>%

ggplot(aes(x = .prediction, y = age_group)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Age group")+ labs(x = "Competitiveness (z-score), posterior predictions")


competitiveness.mat.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m8) %>%

ggplot(aes(x = .prediction, y = phv_cat)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Maturity status")+ labs(x = "Competitiveness (z-score), posterior predictions")


competitiveness.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m8) %>%

ggplot(aes(x = .prediction, y = state)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Competitiveness (z-score), posterior predictions")


competitiveness.special.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m8) %>%

ggplot(aes(x = .prediction, y = state, color=(specialization))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Competitiveness (z-score), posterior predictions") m9<-brm(work_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|state), data=bball, family = gaussian, prior = c(prior(normal(0,1),class = Intercept),prior(normal(0,1),class = sd)), chains = 4, iter = 2000, warmup = 1000, cores = 4, control = list(adapt_delta = 0.99,max_treedepth = 15))

plot(m9)
pp_ckeck(m9)
summary(m9)

coef(m9)
```

```
work.special.sex.s<-bball %>%
group_by(gender) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m9) %>%

ggplot(aes(x = .prediction, y = specialization,color = (gender))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Specialization")+ labs(x = "Work (z-score),
    posterior predictions")


work.sex.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m9) %>%

ggplot(aes(x = .prediction, y = gender)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Gender")+ labs(x = "Work (z-score), posterior
    predictions")


work.age.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m9) %>%

ggplot(aes(x = .prediction, y = age_group)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Age group")+ labs(x = "Work (z-score),
    posterior predictions")


work.mat.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m9) %>%

ggplot(aes(x = .prediction, y = phv_cat)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Maturity status")+ labs(x = "Work (z-score),
    posterior predictions")


work.state.s<-bball %>%
data_grid(age_group,specialization,gender, phv_cat,state)
%>%

add_predicted_draws(m9) %>%

ggplot(aes(x = .prediction, y = state)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Work
    (z-score), posterior predictions")
```

```
work.special.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m9) %>%

ggplot(aes(x = .prediction, y = state, color = (specialization))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Work
    (z-score), posterior predictions")


m10<-
brm(mastery_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|state
),         data = bball,    family = gaussian,

           prior = c(prior(normal(0,1),class =
Intercept),prior(normal(0,1),class = sd)),      chains = 4, iter = 2000,
warmup = 1000, cores = 4,    control = list(adapt_delta =
0.99,max_treedepth = 15))


plot(m10)
pp_ckeck(m10)
summary(m10)

coef(m10)


mastery.special.sex.s<-bball %>%
group_by(gender) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m10) %>%

ggplot(aes(x = .prediction, y = specialization,color = (gender))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Specialization")+ labs(x = "Mastery (z-score),
    posterior predictions")


mastery.sex.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m10) %>%

ggplot(aes(x = .prediction, y = gender)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Gender")+ labs(x = "Mastery (z-score),
    posterior predictions")


mastery.age.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m10) %>%
```

```
ggplot(aes(x = .prediction, y = age_group)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Age group")+ labs(x = "Mastery (z-score), 
    posterior predictions")


mastery.mat.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m10) %>%

ggplot(aes(x = .prediction, y = phv_cat)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Maturity status")+ labs(x = "Mastery (z-score), 
    posterior predictions")


mastery.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m10) %>%

ggplot(aes(x = .prediction, y = state)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = 
    "Mastery (zscore), posterior predictions")


mastery.special.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m10) %>%

ggplot(aes(x = .prediction, y = state, color=(specialization))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = 
    "Mastery (zscore), posterior predictions")


#################################

#enjoyment



m11<-
brm(self_ref_comp_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|state), 
data=bball,

family=gaussian, 
prior=c(prior(normal(0,1),class=Intercept),prior(normal(0,1),class=sd)),    chains 
= 4, iter = 2000, warmup = 1000, cores = 4,           control = 
list(adapt_delta=0.99,max_treedepth=15))
```

```
plot(m11)
pp_ckeck(m11)
summary(m11)

coef(m11)


self_ref_comp.special.sex.s<-bball %>%

group_by(gender) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m11) %>%

ggplot(aes(x = .prediction, y = specialization,color = (gender))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Specialization")+ labs(x = "Self-reference
   competences (zscore), posterior predictions")


self_ref_comp.sex.s<-bball %>%
data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m11) %>%

ggplot(aes(x = .prediction, y = gender)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Gender")+ labs(x = "Self-reference
   competences (z-score), posterior predictions")


self_ref_comp.age.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m11) %>%

ggplot(aes(x = .prediction, y = age_group)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Age group")+ labs(x = "Self-reference
   competences (zscore), posterior predictions")


self_ref_comp.mat.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m11) %>%

ggplot(aes(x = .prediction, y = phv_cat)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Maturity status")+ labs(x = "Self-reference
   competences (z-score), posterior predictions")


self_ref_comp.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m11) %>%
```

```
ggplot(aes(x = .prediction, y = state)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Self-reference competences (z-score), posterior predictions")


self_ref_comp.special.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m11) %>%

ggplot(aes(x = .prediction, y = state)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Self-reference competences (z-score), posterior predictions")


m12<-
brm(other_ref_comp_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|state), data = bball, family=gaussian,

prior=c(prior(normal(0,1),class = Intercept),prior(normal(0,1),class
= sd)), chains = 4, iter = 2000, warmup = 1000, cores = 4, control
= list(adapt_delta = 0.99,max_treedepth = 15))


plot(m12)
pp_ckeck(m12)
summary(m12)

coef(m12)


other_ref_comp.special.sex.s<-bball %>%

group_by(gender) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m12) %>%

ggplot(aes(x = .prediction, y = specialization,color = (gender))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Specialization")+ labs(x = "Other-reference competences (z-score), posterior predictions")


other_ref_comp.sex.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m12) %>%

ggplot(aes(x = .prediction, y = gender)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Gender")+ labs(x = "Other-reference competences (zscore), posterior predictions")
```

```
other_ref_comp.age.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m12) %>%

ggplot(aes(x = .prediction, y = age_group)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Age group")+ labs(x = "Other-reference
    competences (zscore), posterior predictions")


other_ref_comp.mat.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%
add_predicted_draws(m12) %>%

ggplot(aes(x = .prediction, y = phv_cat)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Maturity status")+ labs(x = "Other-reference
    competences (z-score), posterior predictions")


other_ref_comp.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m12) %>%

ggplot(aes(x = .prediction, y = state)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x =
    "Other-reference competences (z-score), posterior predictions")


other_ref_comp.special.state.s<-bball %>%
group_by(specialization) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m12) %>%

ggplot(aes(x = .prediction, y = state,color = (specialization))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x =
    "Other-reference competence (z-score), posterior predictions")


m13<-
brm(effort_exp_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|state),
data = bball,

family = gaussian, prior = c(prior(normal(0,1),class =
Intercept),prior(normal(0,1),class = sd)),      chains = 4, iter = 2000, warmup = 1000,
cores = 4, control = list(adapt_delta = 0.99,max_treedepth = 15))


plot(m13)
pp_ckeck(m13)
summary(m13)
```

```
coef(m13)

effort_exp.special.sex.s<-bball %>%
group_by(gender) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m13)%>%

ggplot(aes(x = .prediction, y = specialization,color = (gender))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Specialization")+ labs(x = "Effort expenditure
(z-score), posterior predictions")

effort_exp.sex.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m13)%>%

ggplot(aes(x = .prediction, y = gender)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Gender")+ labs(x = "Effort expenditure (z-
score), posterior predictions")

effort_exp.age.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m13)%>%

ggplot(aes(x = .prediction, y = age_group)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Age group")+ labs(x = "Effort expenditure (z-
score), posterior predictions")

effort_exp.mat.s<-bball %>%
data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m13)%>%

ggplot(aes(x = .prediction, y = phv_cat)) +   stat_pointintervalh(.width = c(.8,.5))+ labs(y =
"Maturity status")+ labs(x = "Effort expenditure (z-score), posterior predictions")

effort_exp.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m13)%>%

ggplot(aes(x = .prediction, y = state)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Effort
expenditure (z-score), posterior predictions")
```

```
effort_exp.special.state.s<-bball %>%
group_by(specialization) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m13) %>%

ggplot(aes(x = .prediction, y = state,color = (specialization))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x = "Effort expenditure (z-score), posterior predictions")


m14<-
  brm(pos_parent_involv_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|sta
  te), data=bball,

family=gaussian,

prior=c(prior(normal(0,1),class = Intercept),prior(normal(0,1),class
= sd)), chains = 4, iter = 2000, warmup = 1000, cores = 4, control
= list(adapt_delta = 0.99,max_treedepth = 15))


plot(m14)
pp_ckeck(m14)
summary(m14)

coef(m14)


pos_parent_involv.special.sex.s<-bball %>%

group_by(gender) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m14)%>%

ggplot(aes(x = .prediction, y = specialization,color = (gender))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Specialization")+ labs(x = "Positive parental involvement (z-score), posterior predictions")


pos_parent_involv.sex.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m14) %>%

ggplot(aes(x = .prediction, y = gender)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Gender")+ labs(x = "Positive parental involvement (zscore), posterior predictions")


pos_parent_involv.age.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%
```

```
add_predicted_draws(m14) %>%

ggplot(aes(x = .prediction, y = age_group)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y= "Age group")+ labs(x= "Positive parental
involvement (zscore), posterior predictions")


pos_parent_involv.mat.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m14) %>%

ggplot(aes(x = .prediction, y = phv_cat)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y= "Maturity status")+ labs(x= "Positive parental
involvement (z-score), posterior predictions")


pos_parent_involv.state.s<-bball %>%

 data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m14) %>%

ggplot(aes(x = .prediction, y = state)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x =
"Positive parental involvement (z-score), posterior predictions")


pos_parent_involv.special.state.s<-bball %>%
group_by(specialization) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m14) %>%

ggplot(aes(x = .prediction, y = state,color = (specialization))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x =
"Positive parental involvement (z-score), posterior predictions")


m15<-
brm(affil_peer_s~(1|age_group)+(1|specialization)+(1|phv_cat)+(1|gender)+(1|state
), data=bball, family=gaussian, prior=c(prior(normal(0,5),class =
Intercept),prior(normal(0,2.5),class = sd)),

chains = 4, iter = 2000, warmup = 1000, cores = 4,
control = list(adapt_delta=0.99,max_treedepth =
15))


plot(m15)
pp_ckeck(m15)
summary(m15)

coef(m15)
```

```
affil_peer.special.sex.s<-bball %>%
group_by(gender) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m15) %>%

ggplot(aes(x = .prediction, y = specialization,color = (gender))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Specialization")+ labs(x = "Affiliation with peers (zscore), posterior predictions")


affil_peer.sex.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m15) %>%

ggplot(aes(x = .prediction, y = gender)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Gender")+ labs(x = "Affiliation with peers (z-score), posterior predictions")


affil_peer.age.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m15) %>%

ggplot(aes(x = .prediction, y = age_group)) +  stat_pointintervalh(.width = c(.8,.5))+ labs(y = "Age group")+ labs(x = "Affiliation with peers (z-score), posterior predictions")

affil_peer.mat.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m15) %>%

ggplot(aes(x = .prediction, y = phv_cat)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y= "Maturity status")+ labs(x= "Affiliation with peers (zscore), posterior predictions")


affil_peer.state.s<-bball %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m15) %>%

ggplot(aes(x = .prediction, y = state)) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y= "State Basketball Federation")+ labs(x= "Affiliation with peers (z-score), posterior predictions")
```

```
affil_peer.special.state.s<-bball %>%
group_by(specialization) %>%

data_grid(age_group,specialization,gender, phv_cat,state) %>%

add_predicted_draws(m15) %>%

ggplot(aes(x = .prediction, y = state,color = (specialization))) +

stat_pointintervalh(.width = c(.8,.5))+ labs(y = "State Basketball Federation")+ labs(x =
"Affiliation with peers (z-score), posterior predictions")
```

APPENDIX C – Full search strategy of first search

MEDLINE (Medical Literature Analysis and Retrieval System Online via PubMed)

Web of Science Core Collection

SPORTDiscus (via EBSCOhost)

SCOPUS

Database Search Strategy

The search terms presented in table 1 were used for conducting the search strategy in each databases (MEDLINE, Web of Science, SPORTDiscus and SCOPUS). The search terms were organized by blocks: patients/population (two blocks), intervention/sports, outcomes and study type. All search terms were used in all databases, according to the specificity of each one. After searching the blocks individually, a search was performed with the combined blocks.

Table 1. Terms used during electronic databases search.

Block 1		Block 2		Block 3		Block 4		Block 5
Patients/ Population	**AND**	**Patients/ Population**	**AND**	**Intervention/ Sports**	**AND**	**Outcomes**	**AND**	**Study type**
young OR youth OR adolescent OR teen OR youths OR adolescents OR teens OR child OR children OR teenagers OR teenager		players OR player OR athletes OR athlete		sports OR sport OR soccer OR football OR basketball OR volleyball OR handball OR hockey OR cricket OR baseball OR rugby OR lacrosse OR softball OR netball OR bicycling OR boxing OR golf OR gymnastics OR “martial arts” OR tennis OR running OR skating OR skiing OR “track and field” OR swimming OR mountaineering OR “racquet sports” OR “water sports” OR walking OR “weight lifting” OR wrestling OR athletics		sprint OR jump OR “aerobic endurance” OR “physical endurance” OR strength OR power OR agility OR “medicine ball throw” OR “physical performance” OR “functional performance” OR “physical fitness” OR “functional capacities” OR “functional capacity” OR “physiological responses” OR “physiological response” OR “physiological adaptations” OR “physiological adaptation” OR height OR stature OR “body mass” OR “body weight” OR vo2 OR “peak height velocity” OR PHV OR maturation OR “short-term power output”		longitudinal OR “repeated measures” OR “repeated measure”

Database Search Strategy – MEDLINE (via PubMed)

Database name: MEDLINE - Medical Literature Analysis and Retrieval System Online via PubMed (1946-present)

Date searched: 2020-03-13

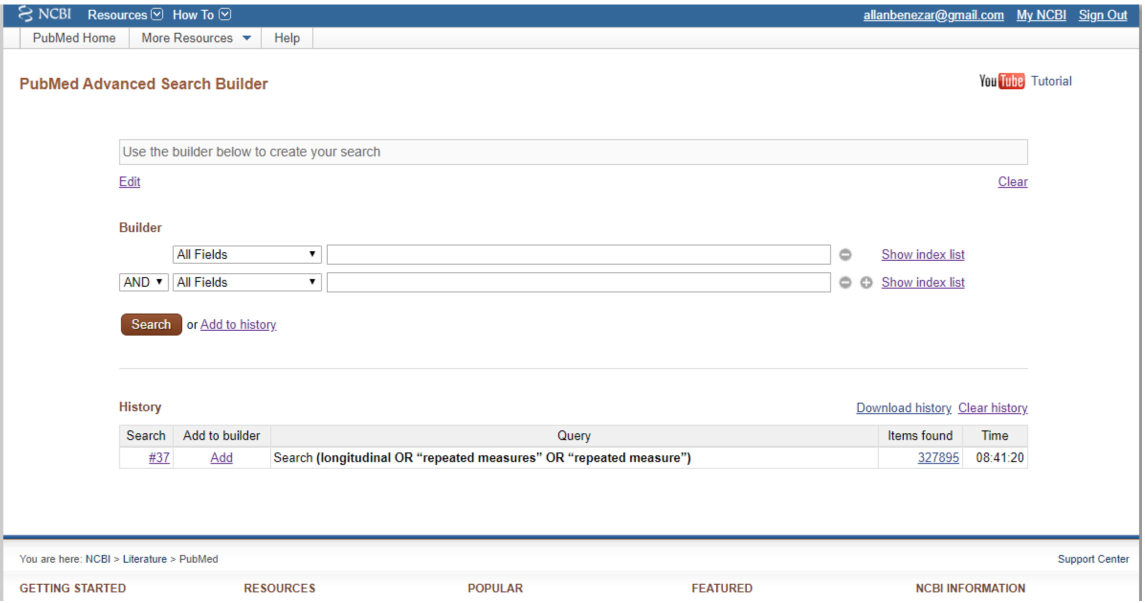
Date range: NA

Filters: No filters

Language: English

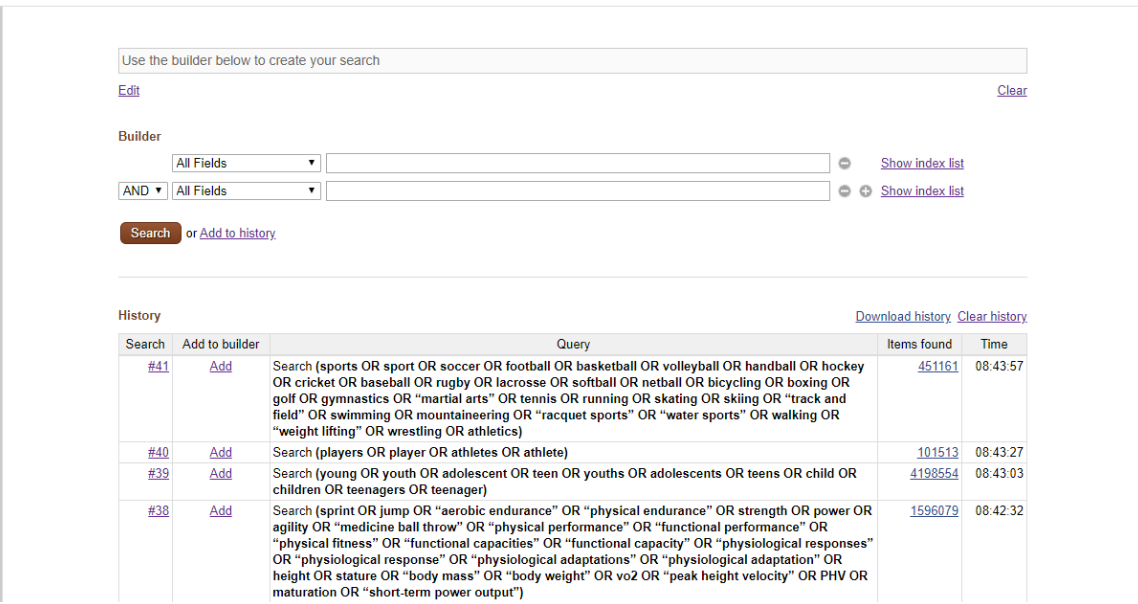
Total records: 942 results

Figure 1 . Search results for Block 5 (MEDLINE).



Search	Add to builder	Query	Items found	Time
#37	Add	Search (longitudinal OR "repeated measures" OR "repeated measure")	327895	08:41:20

Figure 2 - Search results for Block 1, Block 2, Block 3 and Block 4 separately (MEDLINE).



Search	Add to builder	Query	Items found	Time
#41	Add	Search (sports OR sport OR soccer OR football OR basketball OR volleyball OR handball OR hockey OR cricket OR baseball OR rugby OR lacrosse OR softball OR netball OR bicycling OR boxing OR golf OR gymnastics OR "martial arts" OR tennis OR running OR skating OR skiing OR "track and field" OR swimming OR mountaineering OR "racquet sports" OR "water sports" OR walking OR "weight lifting" OR wrestling OR athletics)	451161	08:43:57
#40	Add	Search (players OR player OR athletes OR athlete)	101513	08:43:27
#39	Add	Search (young OR youth OR adolescent OR teen OR youths OR adolescents OR teens OR child OR children OR teenagers OR teenager)	4198554	08:43:03
#38	Add	Search (sprint OR jump OR "aerobic endurance" OR "physical endurance" OR strength OR power OR agility OR "medicine ball throw" OR "physical performance" OR "functional performance" OR "physical fitness" OR "functional capacities" OR "functional capacity" OR "physiological responses" OR "physiological response" OR "physiological adaptations" OR "physiological adaptation" OR height OR stature OR "body mass" OR "body weight" OR vo2 OR "peak height velocity" OR PHV OR maturation OR "short-term power output")	1596079	08:42:32

Figure 3. Search results for all blocks combined (MEDLINE).

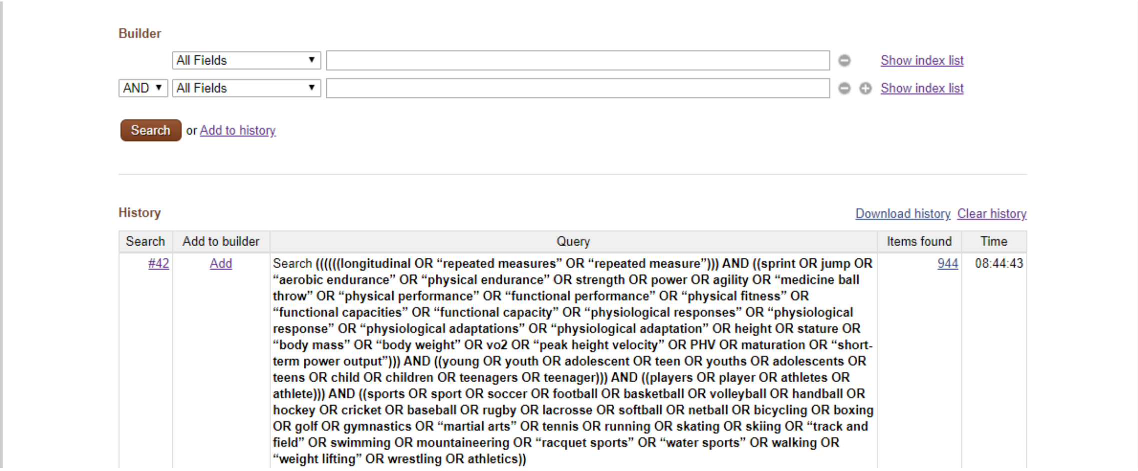
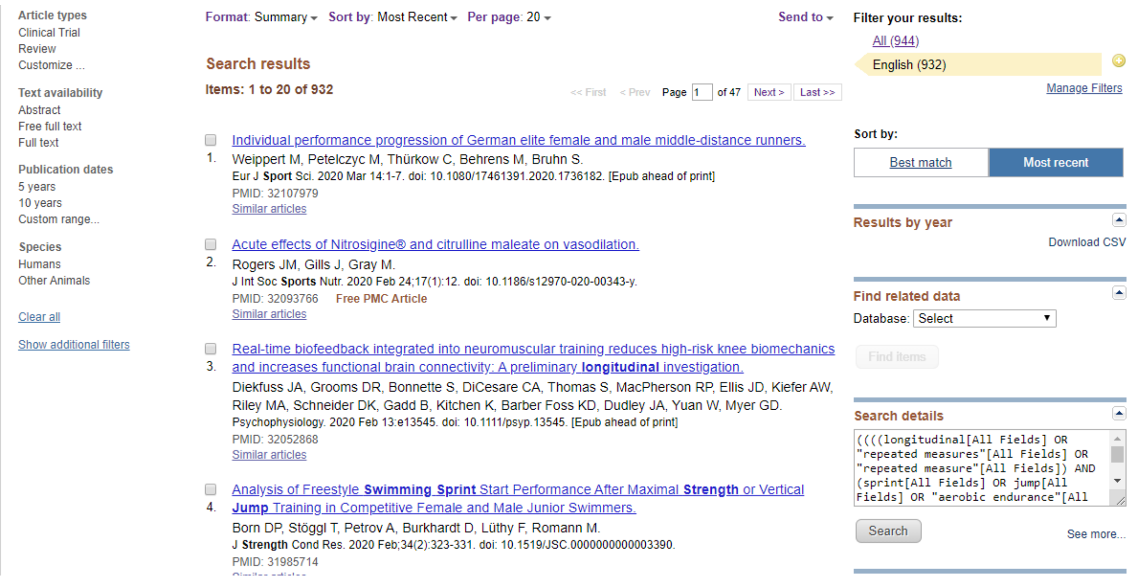


Figure 4. Search results for all blocks combined with English filter (MEDLINE).



Database Search Strategy – WEB OF SCIENCE

Database name: Web of Science Core Collection (1945-present)

Date searched: 2020-03-13

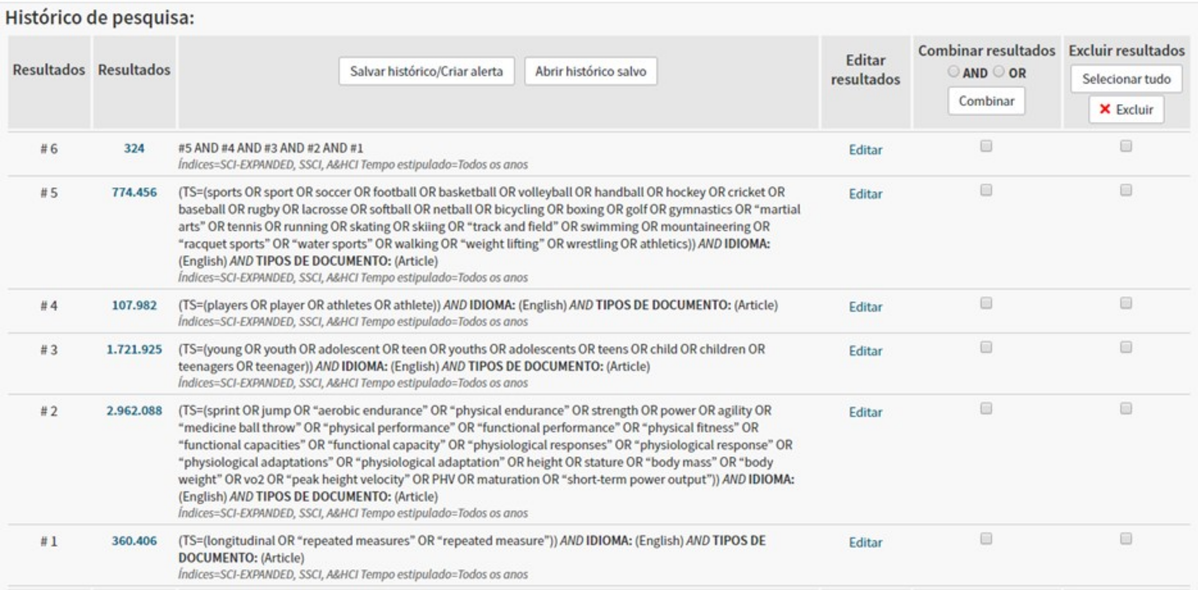
Date range: NA

Filters: Articles

Language: English

Total records: 324 results

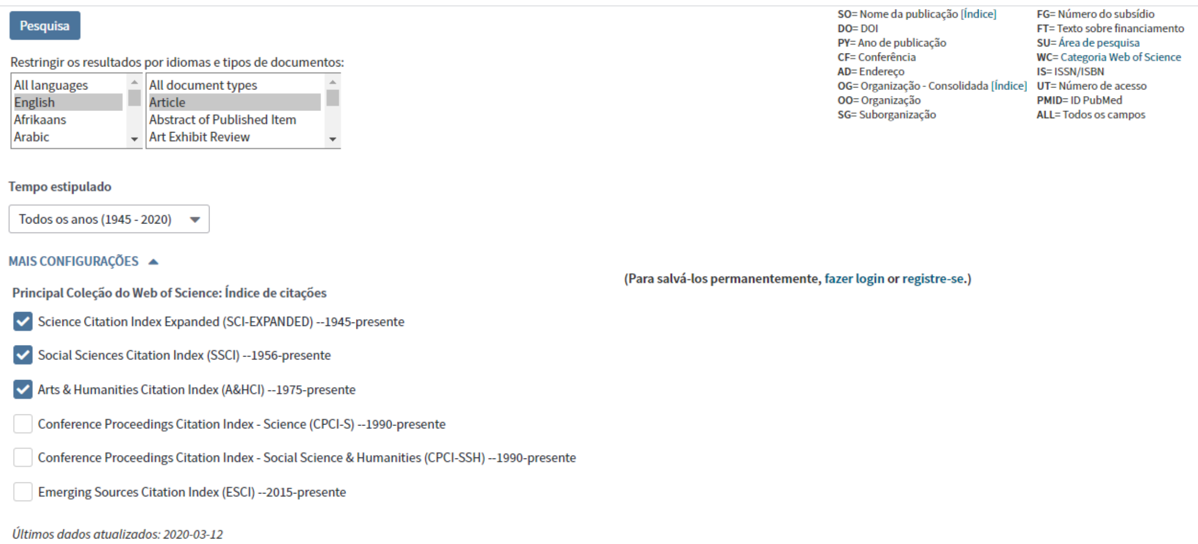
Figure 5. Search results for all blocks separately and combined with English and article filters (Web of Science).



Histórico de pesquisa:

Resultados	Resultados	Salvar histórico/Criar alerta · Abrir histórico salvo	Editar resultados	Combinar resultados (AND / OR) Combinar	Excluir resultados (Selecionar tudo) Excluir
# 6	324	#5 AND #4 AND #3 AND #2 AND #1 *Índices=SCI-EXPANDED, SSCI, A&HCI Tempo estipulado=Todos os anos*	Editar		
# 5	774.456	(TS=(sports OR sport OR soccer OR football OR basketball OR volleyball OR handball OR hockey OR cricket OR baseball OR rugby OR lacrosse OR softball OR netball OR bicycling OR boxing OR golf OR gymnastics OR "martial arts" OR tennis OR running OR skating OR skiing OR "track and field" OR swimming OR mountaineering OR "racquet sports" OR "water sports" OR walking OR "weight lifting" OR wrestling OR athletics)) *AND* **IDIOMA:** (English) *AND* **TIPOS DE DOCUMENTO:** (Article) *Índices=SCI-EXPANDED, SSCI, A&HCI Tempo estipulado=Todos os anos*	Editar		
# 4	107.982	(TS=(players OR player OR athletes OR athlete)) *AND* **IDIOMA:** (English) *AND* **TIPOS DE DOCUMENTO:** (Article) *Índices=SCI-EXPANDED, SSCI, A&HCI Tempo estipulado=Todos os anos*	Editar		
# 3	1.721.925	(TS=(young OR youth OR adolescent OR teen OR youths OR adolescents OR teens OR child OR children OR teenagers OR teenager)) *AND* **IDIOMA:** (English) *AND* **TIPOS DE DOCUMENTO:** (Article) *Índices=SCI-EXPANDED, SSCI, A&HCI Tempo estipulado=Todos os anos*	Editar		
# 2	2.962.088	(TS=(sprint OR jump OR "aerobic endurance" OR "physical endurance" OR strength OR power OR agility OR "medicine ball throw" OR "physical performance" OR "functional performance" OR "physical fitness" OR "functional capacities" OR "functional capacity" OR "physiological responses" OR "physiological response" OR "physiological adaptations" OR "physiological adaptation" OR height OR stature OR "body mass" OR "body weight" OR vo2 OR "peak height velocity" OR PHV OR maturation OR "short-term power output")) *AND* **IDIOMA:** (English) *AND* **TIPOS DE DOCUMENTO:** (Article) *Índices=SCI-EXPANDED, SSCI, A&HCI Tempo estipulado=Todos os anos*	Editar		
# 1	360.406	(TS=(longitudinal OR "repeated measures" OR "repeated measure")) *AND* **IDIOMA:** (English) *AND* **TIPOS DE DOCUMENTO:** (Article) *Índices=SCI-EXPANDED, SSCI, A&HCI Tempo estipulado=Todos os anos*	Editar		

Figure 6. Filters used for search in Web of Science database.



Database Search Strategy – SPORTDiscus

Database name: SPORTDiscus with Full Text via EBSCOhost (1985-present)

Date searched: 2020-03-13

Date range: NA

Filters: publication type= academic journal; document type= article.

Language: English

Total records: 284 results

Figure 7. Filters used for search in SPORTDiscus database.

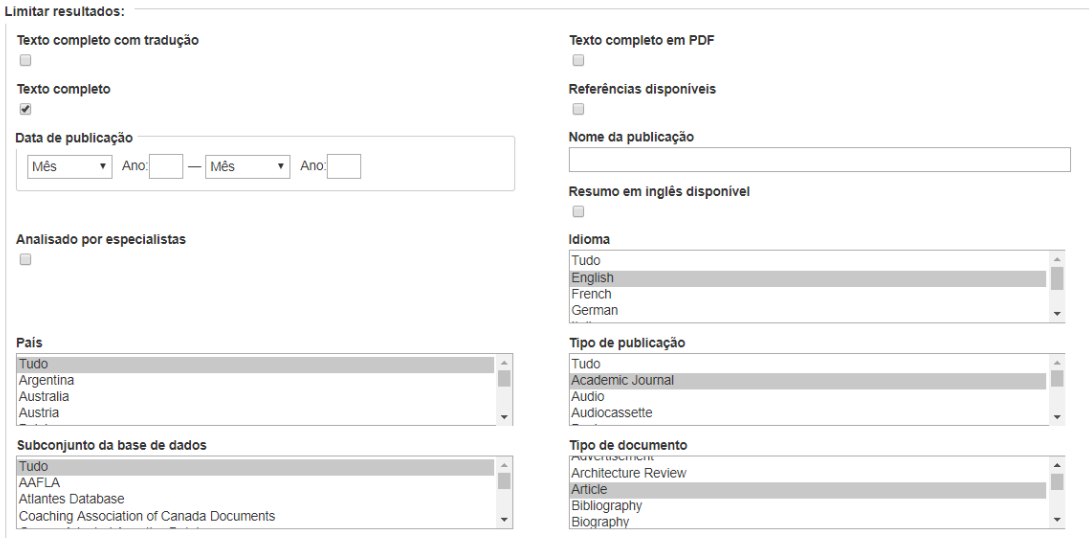


Figure 8. Search results for Block 1 (SPORTDiscus).

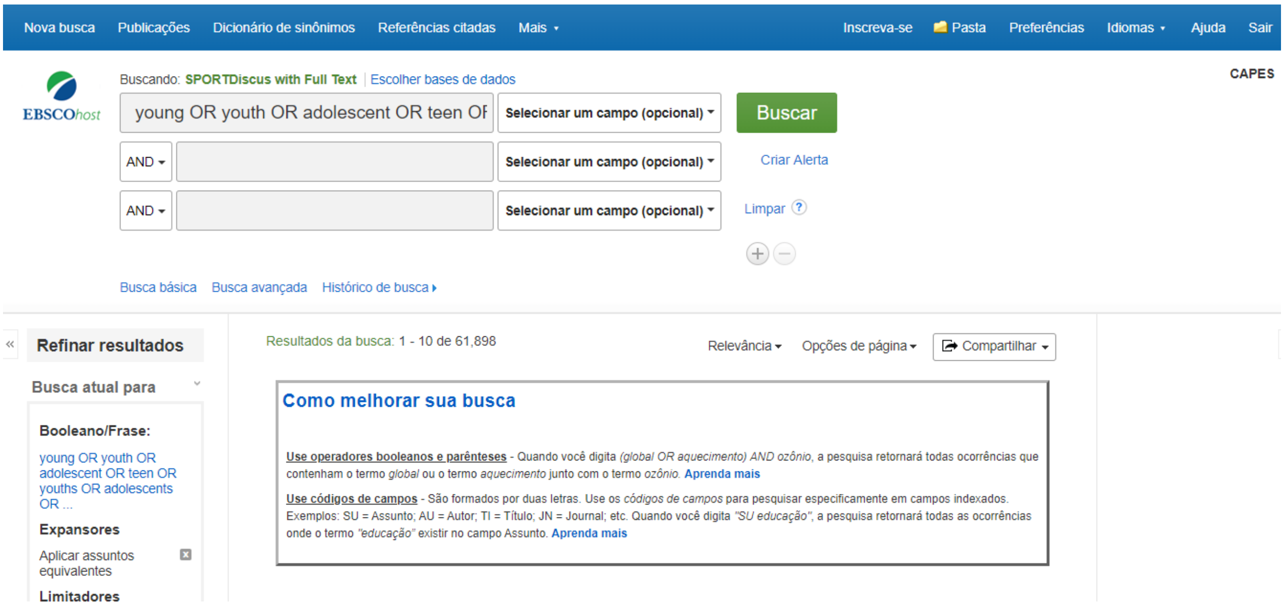


Figure 9. Search results for Block 2 (SPORTDiscus).

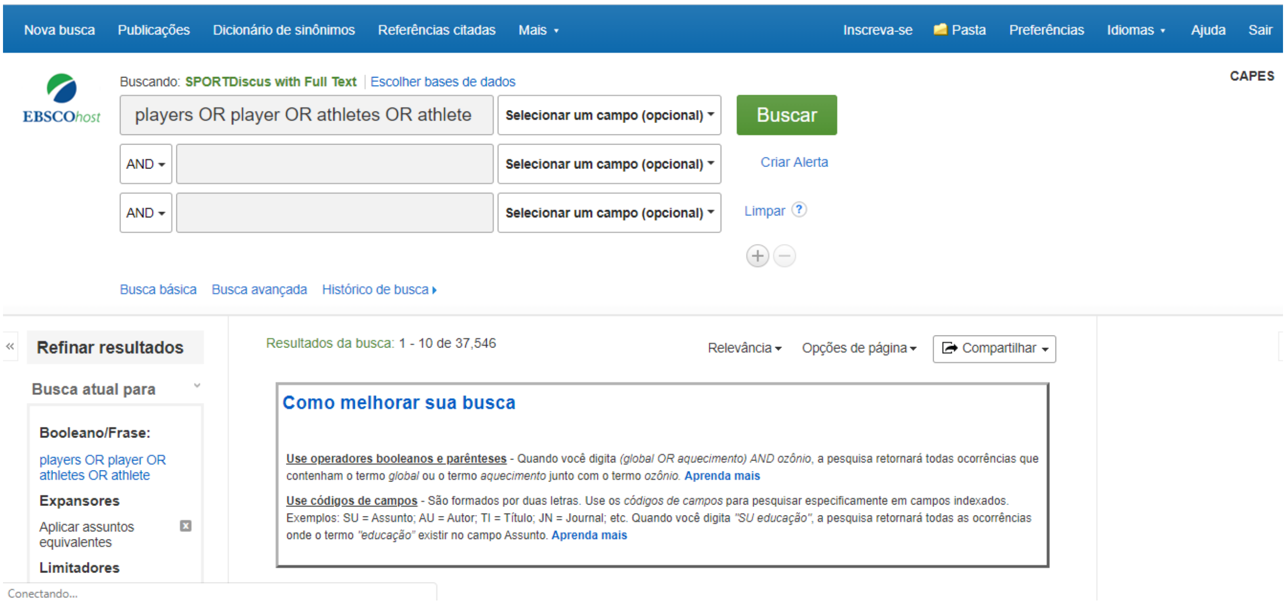


Figure 10. Search results for Block 3 (SPORTDiscus).

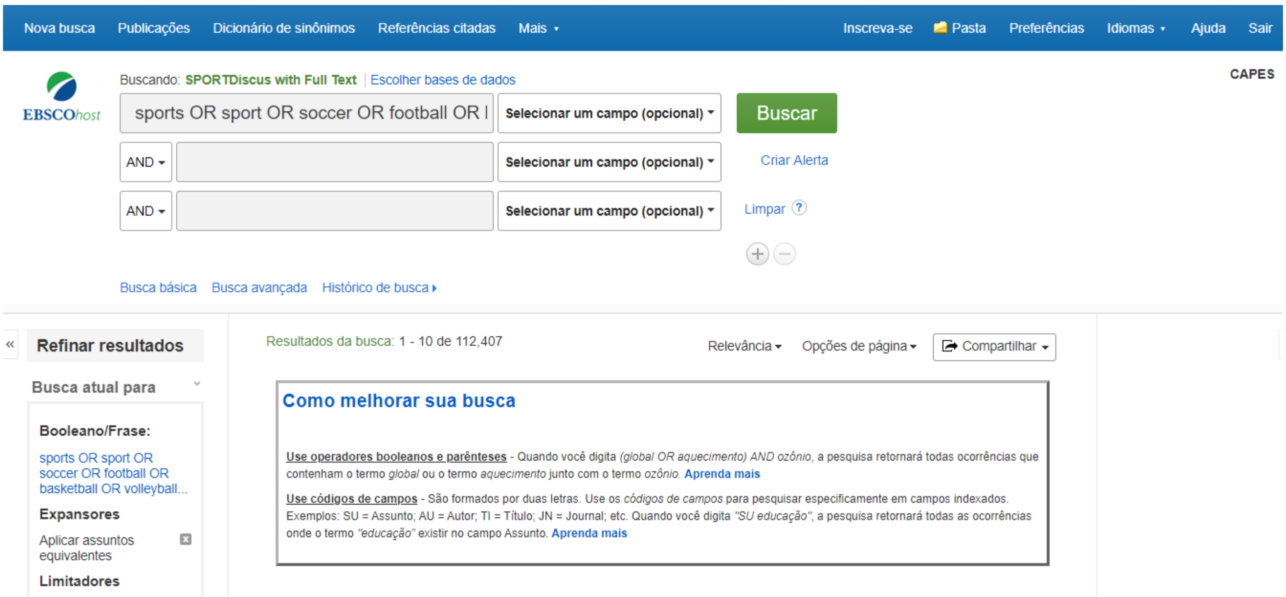


Figure 11. Search results for Block 4 (SPORTDiscus).

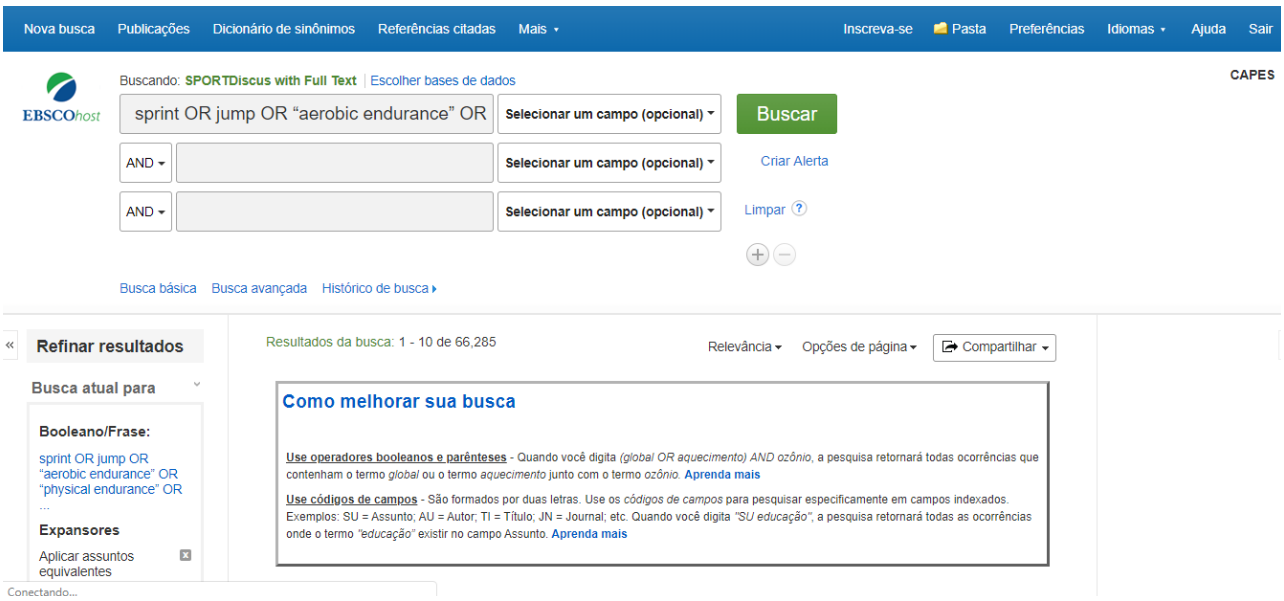


Figure 12. Search results for Block 5 (SPORTDiscus).

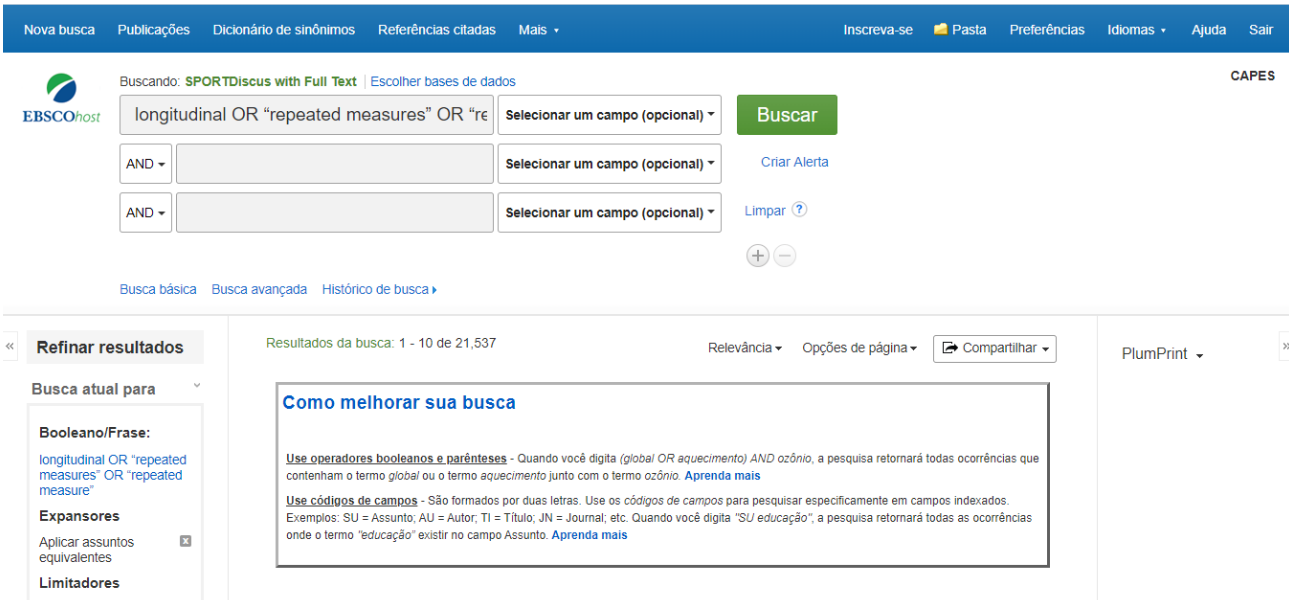
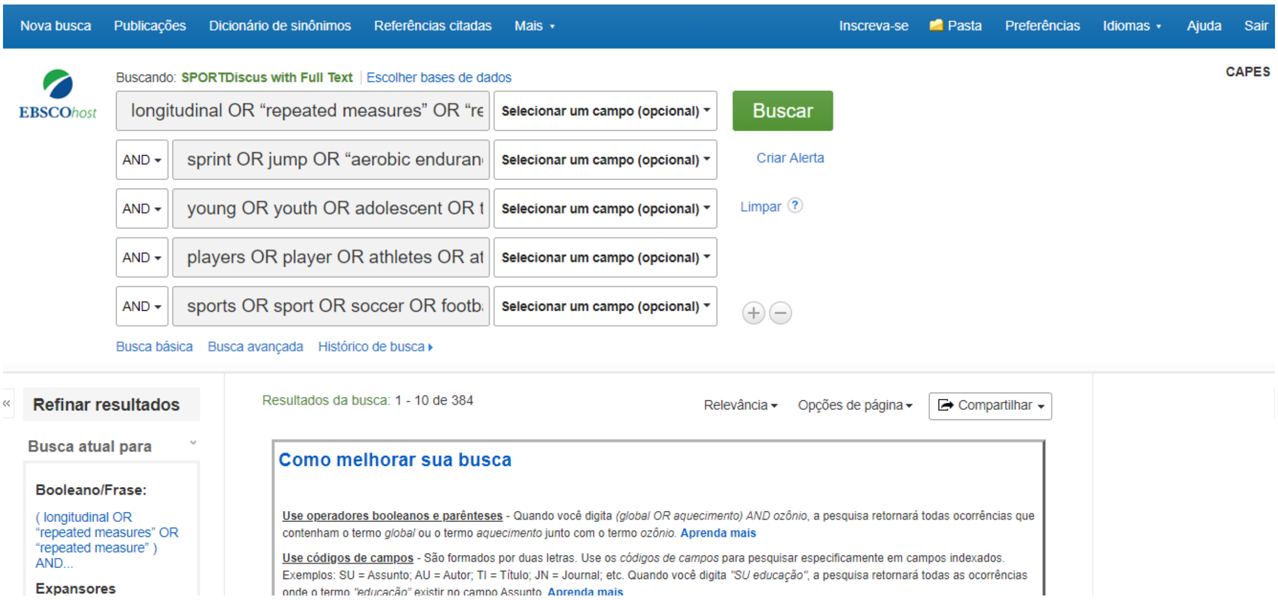


Figure 13. Search results for all blocks combined (SPORTDiscus).



Database Search Strategy - SCOPUS

Database name: SPORTDiscus (Elsevier)

Date searched: 2020-03-13

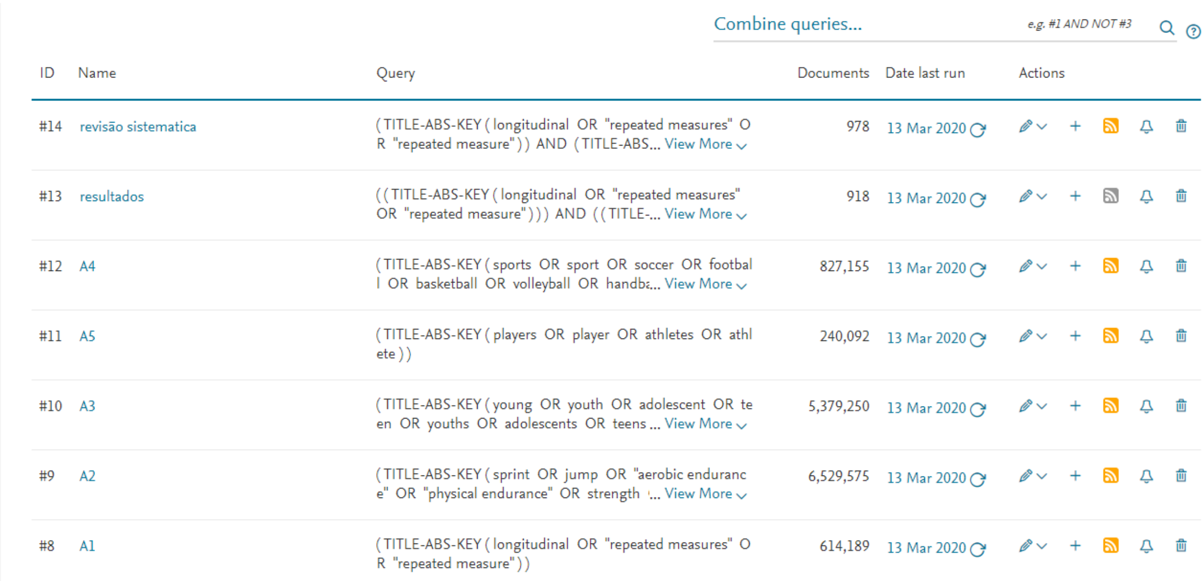
Date range: NA

Filters: Title,abstract, key-words; document type= article; source type= journals.

Language: English

Total records: 918 results

Figure 14. Search results for all blocks separately and combined (SCOPUS).

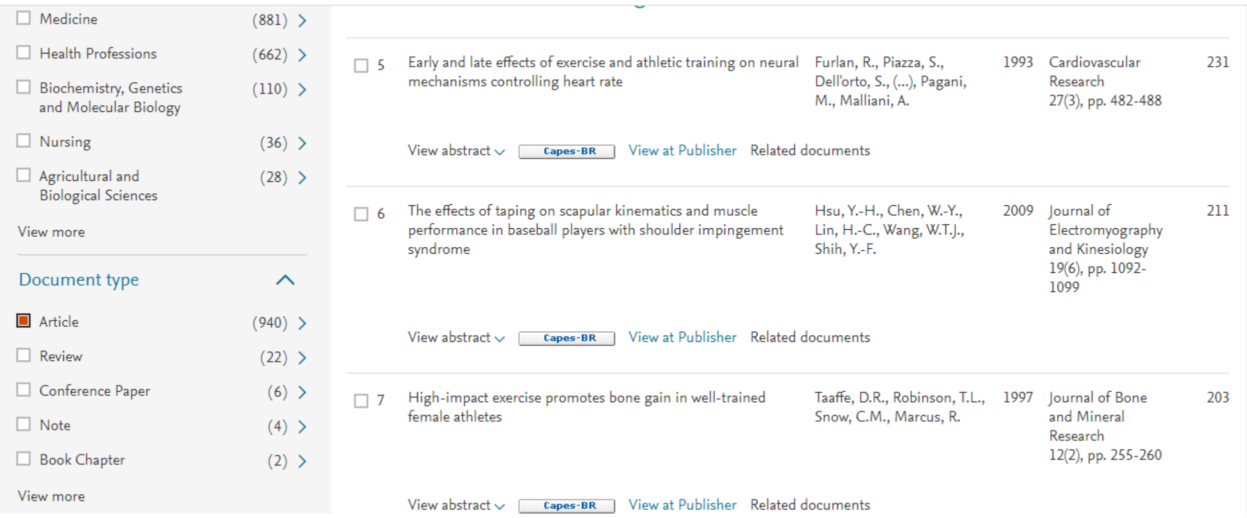


Combine queries... e.g. #1 AND NOT #3

ID	Name	Query	Documents	Date last run	Actions
#14	revisão sistematica	(TITLE-ABS-KEY (longitudinal OR "repeated measures" OR "repeated measure")) AND (TITLE-ABS... View More	978	13 Mar 2020	
#13	resultados	((TITLE-ABS-KEY (longitudinal OR "repeated measures" OR "repeated measure"))) AND ((TITLE-... View More	918	13 Mar 2020	
#12	A4	(TITLE-ABS-KEY (sports OR sport OR soccer OR football OR basketball OR volleyball OR handb... View More	827,155	13 Mar 2020	
#11	A5	(TITLE-ABS-KEY (players OR player OR athletes OR athlete))	240,092	13 Mar 2020	
#10	A3	(TITLE-ABS-KEY (young OR youth OR adolescent OR teen OR youths OR adolescents OR teens ... View More	5,379,250	13 Mar 2020	
#9	A2	(TITLE-ABS-KEY (sprint OR jump OR "aerobic endurance" OR "physical endurance" OR strength ... View More	6,529,575	13 Mar 2020	
#8	A1	(TITLE-ABS-KEY (longitudinal OR "repeated measures" OR "repeated measure"))	614,189	13 Mar 2020	

Note: #8= results for block 5; #9= results for block 4; #10= results for block 1; #11= results for block 2; #12= results for block 3; #13= results for all blocks combined with filters; #14= results for all blocks combined without filters.

Figure 15. Filters used for search in SCOPUS database – document type.



Medicine (881)
Health Professions (662)
Biochemistry, Genetics and Molecular Biology (110)
Nursing (36)
Agricultural and Biological Sciences (28)
View more

Document type
Article (940)
Review (22)
Conference Paper (6)
Note (4)
Book Chapter (2)
View more

5 Early and late effects of exercise and athletic training on neural mechanisms controlling heart rate — Furlan, R., Piazza, S., Dell'orto, S., (...), Pagani, M., Malliani, A. — 1993 — Cardiovascular Research 27(3), pp. 482-488 — 231
View abstract Capes-BR View at Publisher Related documents

6 The effects of taping on scapular kinematics and muscle performance in baseball players with shoulder impingement syndrome — Hsu, Y.-H., Chen, W.-Y., Lin, H.-C., Wang, W.T.J., Shih, Y.-F. — 2009 — Journal of Electromyography and Kinesiology 19(6), pp. 1092-1099 — 211
View abstract Capes-BR View at Publisher Related documents

7 High-impact exercise promotes bone gain in well-trained female athletes — Taaffe, D.R., Robinson, T.L., Snow, C.M., Marcus, R. — 1997 — Journal of Bone and Mineral Research 12(2), pp. 255-260 — 203
View abstract Capes-BR View at Publisher Related documents

Figure 16. Filters used for search in SCOPUS database – document type.= results f

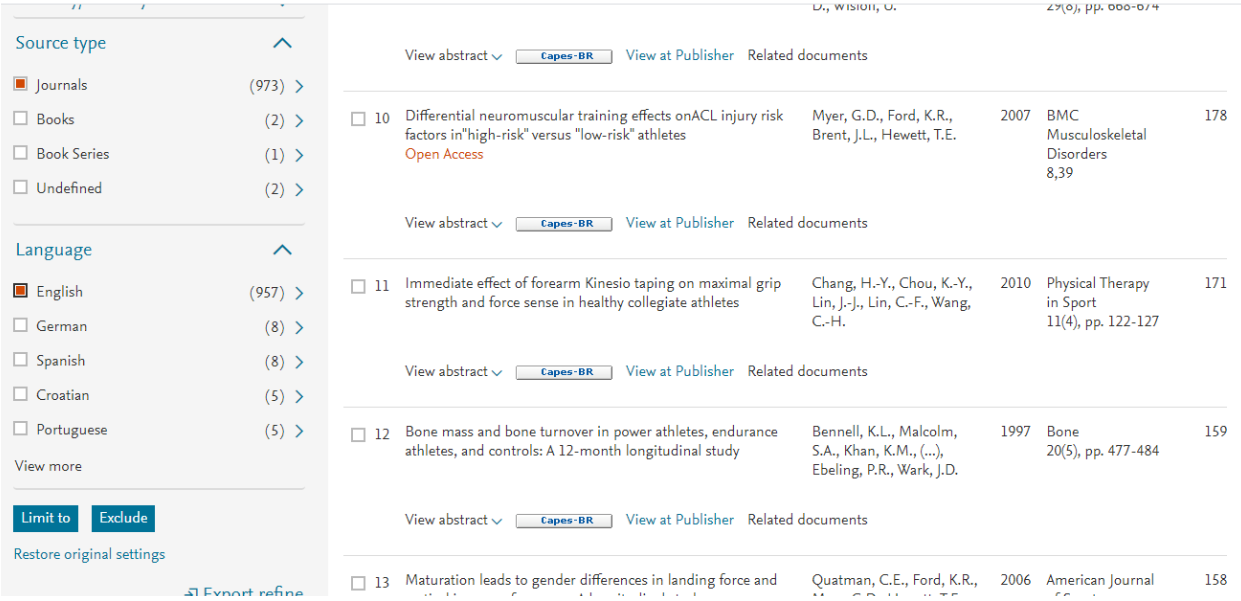


Figure 17. results for search SCOPUS database with filters.