Relative Age Effect and Biological Maturation on Inhibitory Control of Motor Response in Basketball

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Abstract

In the context of sports, relative age effect (RAE) generates transitional differences on maturational development non-linear at chronological age. This leads to a lack of selection opportunities in sport teams during pubertal stage. Biological maturation (BM) is the main modulator of these drastic changes in maturation, which affect sport performance. 34 young male basketball players [M_{age}= 10,94 (±1,51) years] are evaluated on inhibitory control of motor response through the computerized Go/no-go task. The study uses two BM indices: "maturity offset" and "percentage of adult height". Results found significant differences on cognitive performance between two different chronological age groups (under10 / top10 years old.). Top10 players show a lower response time (RT) and accuracy adjusted response time than under10. However, the study does not find RAE (birth semester) on cognition. Percentage of adult height predicts both RT and accuracy adjusted RT performance in the entire sample, while maturity offset also did it, but only in the greater chronological age group (top10). Sports field research should consider BM control to explain RAE, and the influence on executive functions, that are crucial for interactive sport performance.

Keywords: Relative age effect; Biological maturation; Cognition; Inhibitory control; Basketball.

Introduction

The sport with young players in their formation phase is highly exclusive because of their focus on short-term performance. Studies strongly suggest that sports teams are made up of players most of whom were born in the first part of the year [quartile (Q) 1-2] in comparison with players who are born in the second part (Q 3-4) (Gil et al., 2014; Torres-Unda et al., 2016). This is called relative age effect (RAE). This occurs due to differences in maturation between those who were born later and earlier in the same year (Cumming et al., 2018). In a large sample of soccer players (9-18 yo) from different elite teams, Q1 players are selected 5,3 times more than Q4 players, with a strong bias at 13-16 yo, because this age range is closer to the peak of somatic development (Lovell et al., 2015). Besides, RAE is even more pronounced in elite teams (Torres-Unda et al., 2013).

Biological maturation (BM) seems to be the leading cause of asynchronous chronological age differences in the pubertal stage, which is more sensitive to dramatic changes in maturative development rate (Gil et al., 2014; Giudicelli et al., 2020). Thus, small changes in BM will result in large differences in sport performance variables, such as anthropometric measures and physical fitness, in individuals of the same chronological age group, both individual (Sögüt et al., 2019) and team sports (McCunn, Weston, Hill, Johnston, & Gibson, 2017; Till, Cobley, O'Hara, Cooke, & Chapman, 2014). Large increases in height (from 10,7 to 15,2 yo), body mass (from 11,9 to 16,1 yo) or sprint (31-43%, from 11,8 to 15,8 yo), have been associated with a short time in soccer players (8-18 yo) (Towlson, Cobley, Parkin, & Lovell, 2018). This is correlated with BM indices (Gastin & Bennett, 2014). Correlation strength increases with chronological age within puberty, from trivial (<11 yo) to strong (approx. 14 yo) (McCunn et al., 2017). Additionally, BM also predicts the better early maturing on-field performance in team sports; high-intensity running distance (> 14km/h), number of high-intensity efforts (%) (Gastin & Bennett, 2014), or scored points per game. (Torres-Unda et al., 2016)

Some commons indices for BM estimation used in literature are: (1) maturity offset, which determines the temporal distance from current age to age at peak height velocity (APHV) (Moore et al., 2015); (2) maturational state (early, average, late) which can be predicted from APHV; (3) percentage of adulthood height reaching at that time (Sherar, Mirwald, Baxter-Jones, & Thomis, 2005). It has been established that the birth quartile effect has little significance to maturity offset (McCunn et al., 2017). Thus, the researcher speculates that selected individuals born in

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the second semester are equal in BM to the rest of the team. This is one of the reasons for the low proportion of selected late matures in sports teams (Malina et al., 2000). Therefore, early maturing seems to be the common pathway for players selection and no performance differences found, despite RAE (Müller, Müller, Hildebrandt, & Raschner, 2016)

RAE represents the underlying cause for the lack of selection opportunities in individuals suffering a transitional disadvantage in biological systems development. Recently, there have been new selection methods that consider BM instead of chronological age (Malina et al., 2019), and have also been included in talent identification (Sarmento, Anguera, Pereira, & Araújo, 2018). This alternative is known as bio-band. Research has frequently given the task of studying the relationship between BM and sports performance, such as anthropometric measures, physical condition, gross motor coordination, etc. However, there are fewer RAE paradigm studies that consider studying general cognition (Huertas et al., 2019; Penna, de Mello, Ferreira, Moraes, & Costa, 2015).

The current study aims to evaluate RAE on inhibitory control of motor response, a specific component of executive functions (EFs). Meta-analytic research has shown that interactive sport expertise exerts a moderating positive effect on general cognition (Scharfen & Memmert, 2019). Interactive sports practice (ie., soccer, basketball, handball etc.), executed in dynamic and complex visuospatial environments, are more effective on cognition than self-paced sports, developed in more predictable stable environments (Voss, Kramer, Basak, Prakash, & Roberts, 2010). Players with higher EFs scores also show greater on-field sports performance (goals, assist) (Torbjörn Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012) and game intelligence (T Vestberg et al., 2020), in soccer. In the case of inhibitory control, experts have usually shown better behaviour performance than non-athletes, both in motor response inhibition to incongruent stop signal event (Heppe & Zentgraf, 2019; Wang et al., 2013), as well as inhibition to distracting visuospatial stimuli (Harris, Wilson, Crowe, & Vine, 2020; Wang, Liang, & Moreau, 2020) in general domain task.

On the other hand, studies assessing maturational development on cognitive abilities have observed significant increases in EFs linked to chronological age, suggesting steep increases from childhood to adolescence on behavioural performance (Pozuelos, Paz-Alonso, Castillo, Fuentes, & Rueda, 2014) and neurofunctional structures supporting EFs (Abundis-Gutiérrez, Checa, Castellanos, & Rueda, 2014; Checa, Castellanos, Abundis-Gutiérrez, & Rosario Rueda, 2014). However, as far as we know, there are no studies that control MB. Hence, the aims of this study are to determine RAE on inhibitory control of motor response in Go/no-go task and test BM differences on that EF.

Method

Participants

Participants were selected for the study according to the possibilities of access to their basketball teams. The sample consisted of 34 children and preadolescents basketball players (7-14 yo, males) [M_{age}= 10,94 (±1,51) yo], from 4 different base teams from a federated club in Murcia (Spain). Approximately 63% were born in the first semester (Q 1-2) of the year, and 37% in the second semester (Q 3-4). Training frequency was 3 sessions per week in all teams.

Procedure

Participants were assessed on cognitive performance in executive task before their training session to avoid the acute effect of physical activity on cognition. We used Go/no-go task, which is commonly used in cognition research for assessing inhibitory control of motor response (i.e., key pressure), from the PEBL2, a computerized test battery (Mueller & Piper, 2014). Subjects performed 2 task blocks. Each block consisted of 160 trials. 20% (32) "No-go" and 80% (128) "Go". Stimuli were presented in random order with time intervals between stimuli of 1,5s. In the centre of the screen was a 2x2 divided square with 4 cells of equal shape and size. A five-pointed blue star was in the centre of each box at the beginning of each trial. In each trial, any of the 4 stars was consecutively switched for a random stimulus represented either by the letter (P) or (R), which represented the response action "Go" or "No-go" depending on if it was the 1st or 2nd block. We asked each participant to press <shift> on the keyboard as fast as possible when perceiving a "Go" stimulus, and to inhibit the motor action of pressing when a "No-go" stimulus appeared. We assess the following cognitive performance measures; i) total accuracy (percentage of correct responses in all trials), ii) incongruent stimulus accuracy (percentage of correct responses in incongruent trials <No-go>), iii) response time (ms), and iv) accuracy adjusted response time (response time in trials where there was no error). We estimated two BM indices; Maturity offset (MO) from the alternative equations model of (Moore et al., 2015) which does not require sitting height in males, [MO= -7,999994 + [0,0036124 x (age x height)]

(Moore et al., 2015). MO indicates the temporal distance from current age to age at peak of height velocity (PHV) [current age (years) – (MO)]. Additionally, we use PHV to obtain maturation state (early, average or late) and then, we were also able to estimate adult height (Sherar et al., 2005). This is a key factor in the pubertal stage because early matures are closer to their adult height than their average or late matures peers. Moreover, early matures reach their APHV earlier, and they also reach a higher growth rate at PHV.

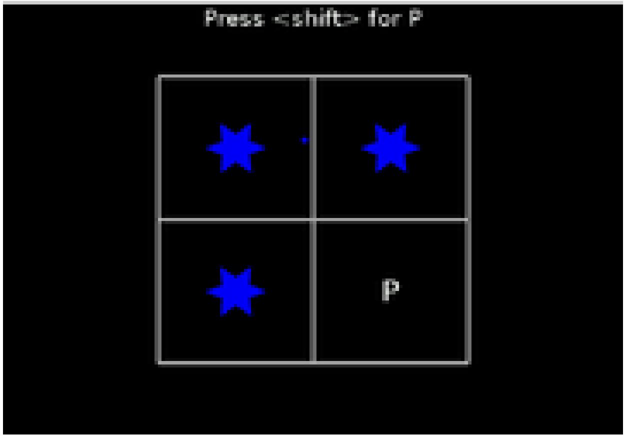


Figure 1. Example of the Go/no-go task. Participants had to press "shift" in the keyboard only when a "P" was shown.

Statistical Analysis

The study divided the sample into two chronological age groups: under 10 yo (u10) and over or equal 10 yo (top10) for assessing differences in performance on the Go/no-go task in order to prove whether the data had a normal distribution and performed a T-student to examine possible statistical differences between groups. To evaluate RAE on inhibitory control performance, we used an ANOVA, both in separate groups and combined. Finally, we evaluate BM influence on cognitive performance using multiple linear regression analysis.

The statistical significance level was established at p< .05. The effect size for T-student was calculated with d, following the interpretation guidelines by Cohen (1988), it is considered a small effect between 0.1-0.3, moderate effect 0.3-0.5, and a large effect above 0.5 (Cohen, 1988). Statistical analysis was performed with SPSS 19 version program.

Results

All interest data are grouped in Table 1. Shapiro-Wilk test indicate that cognitive performance data has a normal distribution.

Figure 2a

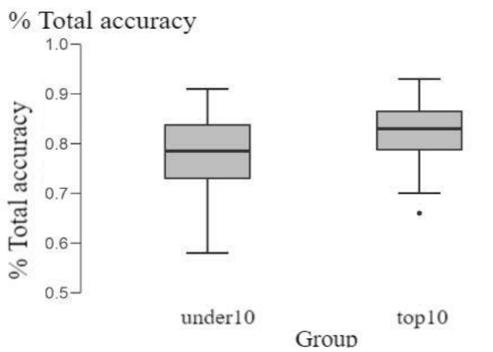


Figure 2b

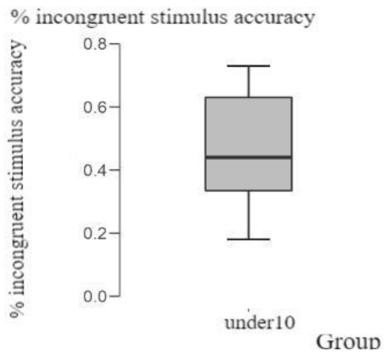


Figure 2c

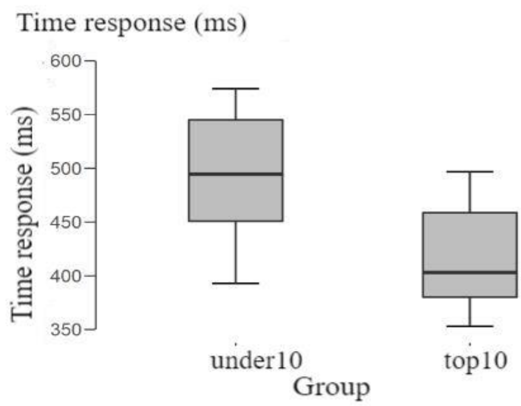
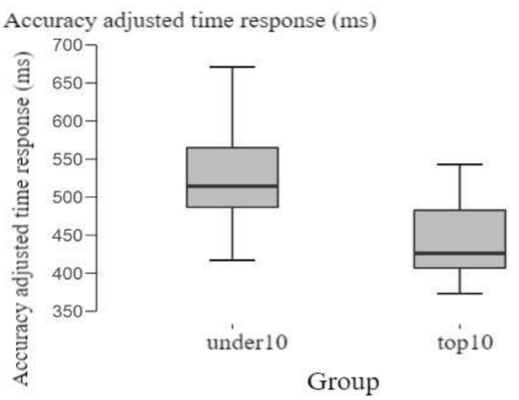


Figure 2d



Figures 2a, 2b, 2c and 2d: Comparison between chronological age groups in (a) % total accuracy, (b) % incongruent stimulus accuracy, (c) response time, and (d) accuracy adjusted response time incongruent

Table 1

Descriptive statistic.

Variable	Total	Sub10	Top10
Age (years)	10.94(± 1.51)	8.89(± 0.50)	11.56(± 1.09)
Total accuracy (%)	82.17(± 7.39)	81.14(± 9.95)	82.48(± 6.67)
Incongruent stimulus accuracy (%)	46.47(± 18.74)	53.57(± 15.36)	44.30(± 19.43)
Total response (ms)	430.65(± 57.53)	489.95(±54.01)	412.61(±45.92)
Accuracy adjusted response time (ms)	455.15(± 57.95)	513.06(±51.13)	437.53(±48.19)
Height (cm)	148.70(± 12.70)	135.85(± 6.18)	152.61(±11.56)
Maturity offset	-2.06(± 1.27)	-3.63(± 0.31)	-1.58(± 1.04)
Age at peak of height velocity (years)	13.01(± 0.39)	12.53(± 0.34)	13.15(± 0.28)
Adult height (cm)	180.30(± 6.58)	179.10(± 5.39)	180.67(± 6.97)
Percentage of adult height (%)	82.53(± 4.95)	75.82(± 1.33)	84.57(± 3.62)

Note: ms = milliseconds; cm = centimeters. Maturity offset = -7,999994 + [0,0036124 x (age x height)]. Age at peak of height velocity = age $_{actual}$ – maturity offset.

Figure 3a

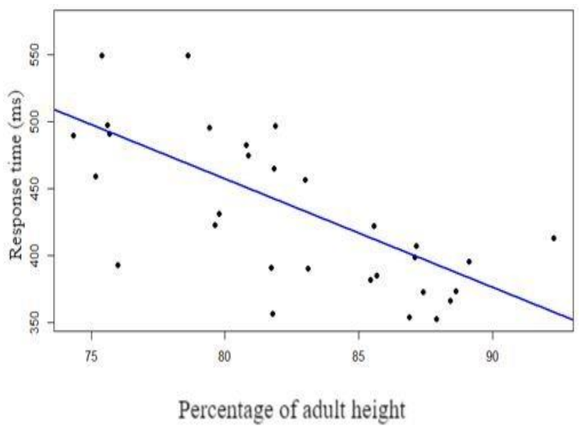


Figure 3b

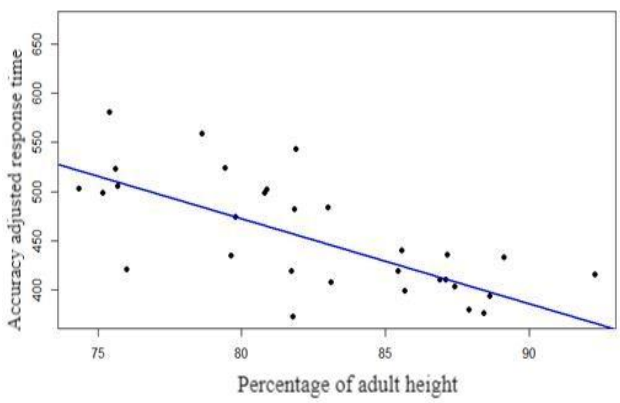
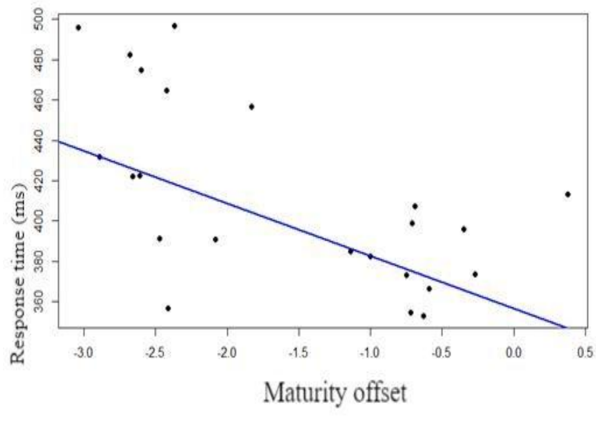


Figure 3c



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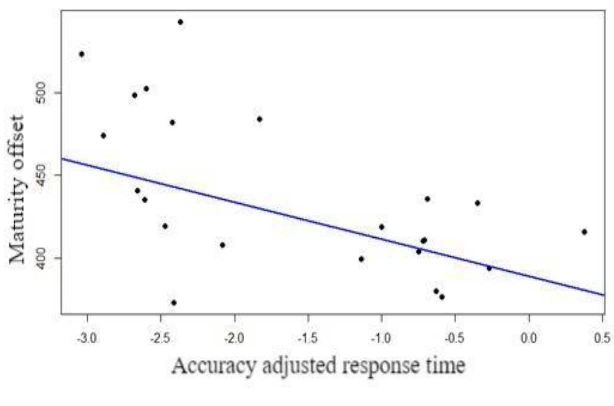

Figures 3a, 3b, 3c and 3d: Significant results of multiple linear regression analysis in response time and accuracy adjusted response time; (a, b) percentage of adult height in the whole sample, and (c, d) maturity offset in top10 group

T-student analysis shows significant differences between the chronological age groups in both response time (RT) and accuracy adjusted RT. Top10 group has a lower RT (t= 5,175; p< .001; *d*= 1,613) and RT accuracy adjusted (t= 4,881; p< .001; *d*= 1,522), indicating a more efficient performance. However, the study does not find significant differences between groups in both total accuracy (t= -1,685, p= .100) and incongruent stimulus accuracy (t= 0,556, p= .581). These results are presented in Figures 2a, 2b, 2c and 2d.

ANOVA test does not find significant results in RAE (born in a first or second semester) on inhibitory control of motor response, neither in the entire sample nor between both chronological age groups.

Multiple linear regression analysis, which include the percentage of adult height and maturity offset as predictive variables, shows that percentage of adult height significantly predicts RT and RT accuracy adjusted [(R^2=

0,467; P< .001); (R^2= 0,475; P< .001), respectively] in the entire sample. Additionally, the test also reveals that maturity offset significantly predict RT and RT accuracy adjusted [(R^2= 0,348; P= .002); (R^2= 0,358; P< .002), respectively], only in top10 group. However, no significant results are found in under10 group. These results are represented in Figures 3a, 3b, 3c and 3d.

Discussion

The study has sought to analyse the relationship between RAE and cognitive control. To do this, we measure inhibitory control performance in the computerized Go/no-go task in young basketball players from 7 to 14 years old. The sample is asymmetrically distributed concerning birth quartile (RAE). Approximately 63% of players are born in the first semester (Q1-Q2). Furthermore, this is the first study considering BM control as a possible predictor of individual differences in inhibitory control performance in a sports context. Results confirm that top10 group has a better behavioural performance on RT and RT accuracy adjusted than u10 group, indicating top10 is more efficient. Furthermore, the birth semester effect is not observed on any behavioural performance.

The limited available evidence is in line with these results. Huertas et al. (2019) found that u12 soccer players outperform u10 players on irrelevant visuospatial stimuli inhibition accuracy in flanker task with added difficulty (target stimulus appearance in other location with lower ratio), confirming chronological age effect. Furthermore, in line with our results, there is no RAE (Huertas et al., 2019). The lack of evidence on RAE is also found in elite base u-13 soccer players. Researchers do not observe the birth semester effect on inhibitory control task about distracting stimuli (Penna et al., 2015).

Maturational development literature of attentional control has examined the chronological age effect on perceptual inhibition during childhood and adolescence. Results show a progressive enhancement through growth, even into early adulthood (Abundis-Gutiérrez et al., 2014; Checa et al., 2014). Although response accuracy seems to have a linear increase with chronological age, we can observe a turning point in response time in children between 8-9 years old. Other studies do not find a significant enhancement of executive control over 7 years old (Rueda et al., 2004), which may be due to the low cognitive task demands.

Unfortunately, no studies have previously controlled BM effect on cognition. Stepwise regression analysis has determined that maturity offset can predict both, RT inhibition of motor response variables only in top10 group. This could be because younger players (u10) are still too far from their APHV, and for this reason, the increasing rate of cognitive performance would maintain a linear enhancement at chronological age, without abrupt variations in a short time. It is important to consider that the common minimum age in BM literature coincides with the oldest age group in our study (McCunn et al., 2017; Söğüt et al., 2019).

There are several reasons to discuss why RAE does not cause EFs differences. First, interactive sport expertise based on practice (Wang, Yang, Moreau, & Muggleton, 2017; Zhang, Ding, Wang, Qi, & Luo, 2015), or the own selection of most outstanding players for the teams (Sakamoto, Takeuchi, Ihara, Ligao, & Suzukawa, 2018), have a fundamental role on cognitive control, including the different types of inhibitory control. Thus, higher cognition of these players could have a homogenizing effect exceeding baseline BM differences within the groups. For this reason, the recruitment of players with greater cognitive abilities could explain the absence of RAE differences on inhibition of motor response.

Finally, the study finds a reversal RAE in elite (Cobley, Baker, Wattie, & McKenna, 2009), which increases from childhood to adulthood. That is, Q1 players have the longest and most successful sports careers. One possible explanation may be the “underdog hypothesis”, which postulates that relative youngest players or late matures suffer a greater cognitive challenge than their early maturing peers in interactive sports (Gibbs, Jarvis, & Dufur, 2012). This scenario is more adaptative for the cognitive and motor skills development of these disadvantaged players. Future research should take this into account.

Conclusions

The present study determines chronological age differences on inhibition of motor response in a general domain task in young basketball players. Older players (≥10 yo) had a better cognitive performance -in terms of response time- rather than younger players (<10 yo) on inhibiting a habitual but not relevant response more quickly. Despite observed RAE in our sample, we did not find such differences for relative age (between different birth semesters). Furthermore, we found that biological maturation index was shown to predict the efficient behavioural performance on motor inhibition. Therefore, sports studies must consider biological maturation control when examining these cognitive control variables in children and/or adolescents around the pubertal stage, beyond isolated chronological age.

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