



The relative age effect on physical fitness in preschool children

Rocío Cupeiro^{a*}, Miguel A. Rojo-Tirado^{a*}, Cristina Cadenas-Sánchez^{b,c}, Enrique G. Artero^{d,e}, Ana B. Peinado^a, Idoia Labayen^c, Cecilia Dorado^{f,g}, Natalia M. Arias-Palencia^{h,i}, Diego Moliner-Urdiales^j, Josep Vidal-Conti^k, Julio Conde-Caveda^{l,m}, José Mora-Gonzalez^{b,n}, Germán Vicente-Rodríguez^o, Pedro J. Benito^a and on behalf of the PREFIT project group

^aLFE Research Group, Department of Health and Human Performance, Faculty of Physical Activity and Sport Sciences (INEF), Universidad Politécnica De Madrid, Madrid, Spain; ^bPROFITH “Promoting FITness and Health through Physical Activity” Research Group, Sport and Health University Research Institute (Imuds), Department of Physical Education and Sports, Faculty of Sport Sciences, University of Granada, Granada, Spain; ^cInstitute for Innovation & Sustainable Development in Food Chain (IS-FOOD), Public University of Navarra, Pamplona, Spain; ^dDepartment of Education, Faculty of Education Sciences, University of Almería, Almería, Spain; ^eSPORT Research Group (CTS-1024), CERNEP Research Center, University of Almería, Almería, Spain; ^fDepartment of Physical Education, University of Las Palmas De Gran Canaria, Canary Islands, Spain; ^gResearch Institute of Biomedical and Health Sciences (IUIBS), Las Palmas De Gran Canaria, Spain; ^hHealth and Social Research Center, Universidad De Castilla- La Mancha, Cuenca, Spain; ⁱSchool of Education, Universidad De Castilla- La Mancha, Cuenca, Spain; ^jLIFE Research Group, Faculty of Humanities and Social Sciences, University Jaume I, Castellón, Spain; ^kPhysical Activity and Sport Sciences Research Group, Universitat De Les Illes Balears, Spain; ^lDepartment of Physical Education, Faculty of Education Sciences, University of Cádiz, Puerto Real, Spain; ^mBiomedical Research and Innovation Institute of Cádiz (Inibica), Cádiz, Spain; ⁿCollege of Health and Human Services, University of North Carolina at Charlotte, Charlotte, NC, USA; ^oGENUD (Growth, Exercise, NUtrition and Development) Research Group, Instituto Agroalimentario De Aragón -IA2- (Cita-universidad De Zaragoza), Centro De Investigación Biomédica En Red De Fisiopatología De La Obesidad Y Nutrición (Ciberobn), Faculty of Health and Sport Science (FCSD, Huesca, Spain), Department of Physiatry and Nursing, University of Zaragoza, Zaragoza, Spain

ABSTRACT

The aim of the present study was to investigate the existence of a relative age effect (RAE) on physical fitness of preschoolers. Anthropometry and physical fitness were assessed in 3147 children (3–5 years old) using the PREFIT battery. Based on the birth year, participants were divided into 3 year groups (3-, 4- and 5-years). Within each year group, 4 quarter groups were created: quarter 1, preschoolers born from January to March; quarter 2, from April to June; quarter 3, from July to September; quarter 4, from October to December. The MANCOVA analysis revealed a main effect of year group (Wilks' $\lambda = 0.383$; $F_{10,5996} = 369.64$; $p < 0.001$, $\eta_p^2 = 0.381$) and of quarter (Wilks' $\lambda = 0.874$; $F_{15,8276.6} = 27.67$; $p < 0.001$; $\eta_p^2 = 0.044$) over the whole battery of tests. To the best of our knowledge, this is the first study to report the existence of RAE at the preschool stage. In general, performance improved as the relative age increased (i.e., those born in quarter 1 performed better than those in the other quarters). Individualization strategies should be addressed within the same academic year not only in elementary or secondary years but also in preschoolers.

ARTICLE HISTORY

Accepted 4 March 2020



KEYWORDS

Muscular strength; balance; speed-agility; cardiorespiratory fitness; preschoolers; RAE


Introduction

In most elementary or primary schools, a cut-off date for grouping the children according to their age is used. Therefore, almost a 1-year difference in chronological age could be found between the eldest and youngest children within the same class. This difference in birthdates has been reported to have an effect on the cognitive achievement and motor skill proficiency of the younger versus the elder, in children and adolescents (Roberts & Fairclough, 2012). Numerous studies from the 80 s until the present have consistently found lower attainments for the younger members in both academic/cognitive (Bedard & Dhuey, 2006; Gledhill et al., 2002; Wienen et al., 2018) and physical education/sports performances (Andronikos et al., 2016; Baker et al., 2009; Bell & Daniels, 1990; Birch et al., 2016; Brazo-Sayavera et al., 2017).

The “relative age effect” (RAE) is the influence of the difference in birthdates among the members of a given age cohort (Bell & Daniels, 1990; Roberts & Fairclough, 2012), and it seems to exist in part due to the different maturity status present within the members of the cohort, although the complexity of RAE is larger and other aspects beyond maturation may play an important role, like social or behavioural factors (also known as task and environmental constraints) (Hancock et al., 2013; Wattie et al., 2015). Specifically for physical education and sports participation, this effect can have important implications regarding biased assessment and selection (Brazo-Sayavera et al., 2017; Haycraft et al., 2018), reinforcing the proficiency of older more mature individuals (Cobley et al., 2008; Furley & Memmert, 2016). Thus, RAE may handicap younger children not only in the sport context but also during physical education classes, where most of the contents and evaluation process are

CONTACT Pedro J. Benito  pedroj.benito@upm.es  Department of Health and Human Performance, Faculty of Physical Activity and Sport Sciences-INEF, Universidad Politécnica De Madrid, C/Martin Fierro 7, Madrid 28040, España

*These authors contributed equally to this work

 Supplemental data for this article can be accessed [here](#).

© 2020 Informa UK Limited, trading as Taylor & Francis Group

65 based on physical attainment. The existence of RAE in **fitness-**
related tasks (i.e., physical education, sports performances, fun-
 70 damental skill proficiency or physical literacy) has been found
 in children (Birch et al., 2016; Müller et al., 2015; Nakata et al.,
 2017; Roberts et al., 2012) as well as in adolescents (Cobley et
 75 al., 2009; Dalen et al., 2017; Kearney et al., 2018; Nakata et al.,
 2017; Roberts et al., 2012; Sandercock et al., 2014), although the
 clinical relevance of this effect, evidenced through the value of
 the effect size, has sometimes been questioned (Dutil et al.,
 2018). Therefore, this effect seems to exist throughout all the
 educational period. Furthermore, when RAE investigation is
 made within the context of sports, the selection process present
 might compromise the interpretation of results about the
 mechanisms underlying presents in RAE. Investigating RAE in
 schools eliminates any kind of selection, making it a more
 80 suitable setting for studying this topic.

However, to the best of our knowledge, no study has investi-
 gated the existence of RAE on fitness status in preschoolers
 (3–5 years), a stage at which fitness could be as important as in
 older children (Cadenas-Sanchez, Martinez-Tellez et al., 2016;
 85 Smith et al., 2014). Teachers should be aware of the existence of
 RAE and its consequences (Bell & Daniels, 1990), even in these
 ages, in order to adapt their interventions and assessments. No
 study had described the fitness status in these initial years of
 school until recently, mainly because of the lack of reliable and
 90 valid battery tests for these age levels (Ortega et al., 2015). In
 this context, PREFIT (Assessing FITness levels in PREschoolers)
 battery has been proven to be a feasible and reliable test
 (Cadenas-Sanchez, Martinez-Tellez et al., 2016), which allows
 obtaining physical fitness (cardiovascular, strength and motor
 95 skills) data in children at the preschool stage.

Therefore, the aim of the present study was to investigate
 the existence of RAE on physical fitness of preschool children
 from multiple regions across Spain. It was hypothesized that
 fitness performance measured by the PREFIT battery, would be
 100 higher in preschoolers born in the first quarters of the year
 compared to those born in the last quartile of the same year.

Methods

Participants and study design

105 This study belongs to the PREFIT Project (www.profit.ugr.es/profit),
 whose complete description can be found elsewhere
 (Cadenas-Sanchez, Martinez-Tellez et al., 2016). A total of
 4338 preschoolers (3–5 years) and their parents were invited
 to participate in the PREFIT Project. Finally, 3198 parents and/
 110 or guardians agreed to participate in the study (participation
 rate: 73.7%) by signing an informed consent. Among them, 19
 children were excluded after the assessments (i.e., they pre-
 sented a motor or cerebral disease that limited the test per-
 formance reported by the school teachers, they cried during
 most tests, they had a cough and mucus, or they did not
 115 understand the instructions of the tests correctly). Therefore,
 3179 preschool children participated in the PREFIT Project,
 from 10 different cities/towns across Spain (i.e., Almería,
 Cádiz, Castellón de la Plana, Cuenca, Granada, Las Palmas de
 Gran Canaria, Madrid, Palma de Mallorca, Vitoria-Gasteiz, and
 120 Zaragoza), maintaining a balance between public and private

schools in each city for a higher socio-economic diversity.
 Prior to the completion of the test battery, a questionnaire,
 which has already been shown to objectively measure physical
 fitness in preschool children, was administered to parents
 125 to determine their child's level of physical activity (Palou et al.,
 2019). In this questionnaire, as an indirect measure of the
 physical activity level of the children, parents were asked to
 classify their children's physical activity level, excluding
 school time, in very low, low, average, high, or very high.
 Then, children took part in physical fitness and anthropometry
 130 evaluations; researchers excluded 32 preschoolers for not
 declaring their birthdates or for being in a course not corre-
 sponding with their age. As a result, a total of 3147 children
 (3-years old [480 boys and 441 girls], 4-years old [593 boys
 and 523 girls] and 5-years old [582 boys and 528 girls]) were
 135 included in this study (4.6 ± 0.9 years old; 1655 boys, 52.6%).
 Data collection took place from January 2014 to November
 2015. The study protocol passed the Review Committee
 for Research Involving Human Subjects evaluation from
 the U.G. (reference number: 845) and adheres to the Helsinki
 140 Declaration of 1961, revised in Fortaleza (Brazil) in 2013.

The PREFIT battery (Ortega et al., 2015), which has been
 proved to be feasible and reliable in preschoolers (Cadenas-
 Sanchez, Martinez-Tellez et al., 2016), comprises the following
 145 tests: weight and height to assess anthropometry, upper-body
 muscular strength (handgrip strength test), lower limb strength
 (standing long jump test), balance (one-leg stance test), speed-
 agility (4×10 m shuttle run test) and cardiorespiratory fitness
 (PREFIT 20 m shuttle run test). Each child was assessed indi-
 150 vidualy in a school setting by trained evaluators using standar-
 dized equipment and following the same methodology in all
 the participating **centres**. Detailed information can be found
 elsewhere (Cadenas-Sanchez, Martinez-Tellez et al., 2016).

Procedures

Before tests were applied, we performed a **warm-up** (3–5 min)
 155 that included running and jumping games. Tests were adminis-
 tered individually and in randomized order, except the PREFIT
 20 m shuttle run test that was performed in the last place and in
 small groups of 4–8 students. In order to make the tests more
 attractive we created two different fairy tales that were
 160 explained to the children before and during the assessment
 (Cadenas-Sanchez, Martinez-Tellez et al., 2016).

Weight (kg) and height (cm) were assessed without shoes
 and wearing light clothes. Weight was measured to the nearest
 0.1 kg with an electronic scale (SECA 213, Hamburg, Germany)
 165 and height was assessed to the nearest 0.1 cm with a stadi-
 ometer (SECA 213, Hamburg, Germany). All measures were
 taken twice but not consecutively. The mean of the two mea-
 surements was used in the analyses.

Upper-body muscular strength was assessed by the hand-
 grip strength test using an analog dynamometer (TKK 5001,
 Grip-A, Takei, Tokyo) (Cadenas-Sanchez, Sanchez-Delgado
 et al., 2016). Preschoolers squeezed gradually and continuously
 for at least **3 s**, performing the test twice (alternately with both
 170 hands). The elbow was extended and avoiding contacting of
 any other part of the body with the dynamometer, except the
 hand being measured. The optimal grip span was fixed in
 175

4.0 cm (Sanchez-Delgado et al., 2015). The best value of the two trials for each hand was chosen, and the average of both hands was used in the analyses (kg).

Lower body muscular strength was assessed by the standing long jump test. This test consisted in jumping as far as possible with both feet at the same time and separated from each other approximately at the shoulder's width, remaining upright. Preschoolers performed 3 jumps and the best of these attempts was used in the analyses (cm). In order to help and guide the preschoolers to jump, we decided to draw footprints to help preschoolers to detect the take-off line and start jump.

Speed-agility was assessed by the 4 × 10 m shuttle run test. This test consisted in running and turning as fast as possible between 2 parallel lines (10 m apart) drawn on the floor, covering 40 m. To make this test simpler, 2 evaluators were positioned in both extremes and participants had to touch the evaluator hand (placed behind the line) and go back at maximum speed. The best of the 2 attempts was manually registered (using a stopwatch) by an experienced evaluator and was used in the analyses (i.e., lower time registered in seconds).

Static balance was assessed by the one-leg stance test. The child stood on one-leg still with the supporting leg on the floor and the free leg flexed at the knee, maintaining the balance position as long as possible. The chronometer was activated when the free leg leaves the floor. The test ended when the child could not maintain the required position. The test was done once with each leg and the mean (seconds) was used in the analysis.

Cardiorespiratory fitness was assessed using a modified version of the original 20 m shuttle run test (Léger et al., 1988): The PREFIT 20 m shuttle run test (Cadenas-Sánchez et al., 2014; Cadenas-Sanchez, Martinez-Tellez et al., 2016). Briefly, participants had to run back and forth between 2 lines 20 m apart with an audio signal. The test finished when the child failed to reach the end lines concurrent with the audio signal on 2 consecutive occasions or when the child stopped because of exhaustion. Bearing in mind the young age of the preschoolers, some adaptations from the original test were made by decreasing the initial speed (i.e., 6.5 km h⁻¹ instead of the original 8.5 km h⁻¹) and by having 2 evaluators running with a reduced group of children (e.g., 4–8 preschoolers of the same age) in order to provide an adequate pace and control. We recorded an audio track with the acoustic signals for the preschoolers-adapted start speed at 6.5 km h⁻¹ and increases of 0.5 km h⁻¹ every minute. For a higher sensitivity, the test results were expressed as the number of laps completed, instead of minutes or stages as habitually. The feasibility, reliability and maximality of this test in preschoolers have been reported elsewhere (Cadenas-Sánchez et al., 2014; Cadenas-Sanchez, Martinez-Tellez et al., 2016).

In addition, the parents or legal tutors completed a socio-economical and physical activity questionnaire where they reported the physical activity level of the children.

Relative Age Effect (RAE)

In Spain, the cut-off date to access the different academic courses is January 1, and the start date of the academic course is the middle of September, so the children start school

between the ages of 2.75 years (2 years and 9 months) and 3.75 years (3 years and 9 months). To determine the existence of RAE, birthdates of preschoolers were firstly recorded to reflect their birth quarter. Therefore, based on the birth year, participants were divided into 3 year groups: 3-year-old, 4-year-old and 5-year-old. Furthermore, within each year group and based on the birthdate, 4 quarter groups were created. These groups were quarter 1, gathering children born from January to March; quarter 2, children from April to June; quarter 3, from July to September; and quarter 4, from October to December.

Data analysis

All statistical analyses were carried out using the SPSS software (SPSS v.24, IBM Corporation, New York, USA), with the significance level set at $p < 0.05$. After checking for normality with Kolmogorov–Smirnov tests, descriptive characteristics of the sample were calculated. Differences in all anthropometrics and fitness variables across quarter categories, year group (3-years, 4-years and 5-years) and sex were examined with multivariate analysis of covariance (MANCOVA) and univariate analysis of covariance (ANCOVA). The adjustment was performed to avoid the potential effect of the different measurement dates (ranging from January 2014 to November 2015). The cofactor was the difference in days between the date of evaluation, and the birthday date of the year of evaluation (for example, a child born on November 22 and measured on May 7 would have a cofactor equal to -199). Effect size was calculated by partial eta-squared (η_p^2) and small, moderate and large effect corresponded to values equal or greater than 0.001, 0.059, and 0.138, respectively (Cohen, 1988). Prior to the main analysis and to avoid potential bias, an exploratory analysis of the physical activity level reported by parents were carried using an ANCOVA (quarter × sex × year group) adjusting by the same cofactor as above (i.e., the difference in days between the date of evaluation, and the birthday date of the year of evaluation), to examine any difference in physical activity level among quarters. In addition, the range of scores obtained in each fitness test was divided into 10 intervals (i.e., each interval covering one-tenth of the range), thus establishing 9 cut-off points for each test in each year group. Interval number 1 included the lowest performance scores and interval number 10 the best performance scores. The number of cases between cut-off points was counted to observe the frequency of preschoolers in each interval.

Results

A total of 3147 healthy preschool children, aged 3–5 years, were evaluated in this study showing significant relative age effects when compared by quarter, within each year group analysed. The distribution of the participants was 921 children aged 3 years ($n = 241$ [26.2%], $n = 241$ [26.2%], $n = 222$ [24.1%] and $n = 217$ [23.5%], from quarters 1, 2, 3 and 4, respectively), 1116 children aged 4 years ($n = 285$ [25.5%], $n = 270$ [24.2%], $n = 266$ [23.8%] and $n = 295$ [26.4%], from quarters 1, 2, 3 and 4, respectively) and 1110 children aged 5 years ($n = 262$ [23.6%], $n = 289$ [26.0%], $n = 277$ [25.0%] and

Table 1. Participants' characteristics ($N = 3147$).

		Quarter 1 (Born from January to March)		Quarter 2 (Born from April to June)		Quarter 3 (Born from July to September)		Quarter 4 (Born from October to December)	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Weight (kg)	3 years	16.90	0.20	16.48	0.20	16.04 ^a	0.21	15.56 ^{ab}	0.22
	4 years	19.47*	0.18	18.79*	0.19	18.22 ^{a*}	0.20	17.83 ^{ab*}	0.18
	5 years	22.41* [#]	0.19	21.83* [#]	0.18	20.48 ^{ab*#}	0.19	19.86 ^{ab*#}	0.19
Height (m)	3 years	1.02	0.00	1.00 ^a	0.00	0.98 ^{ab}	0.00	0.96 ^{abc}	0.00
	4 years	1.09*	0.00	1.07 ^{a*}	0.00	1.05 ^{ab*}	0.00	1.04 ^{ab*}	0.00
	5 years	1.15* [#]	0.00	1.14* [#]	0.00	1.12 ^{ab*#}	0.00	1.11 ^{abc*#}	0.00

Q6 Data are presented as mean \pm standard error of mean (SEM); ^a $p < 0.05$ different to quarter 1; ^b $p < 0.05$ different to quarter 2; ^c $p < 0.05$ different to quarter 3; * $p < 0.05$ different to 3 years; and [#] $p < 0.05$ different to 4 years.

290 $n = 282$ [25.4%], from quarters 1, 2, 3 and 4, respectively). The
 exploratory analysis of the physical activity level reported by
 parents showed no differences among quarters and no inter-
 action with quarter and sex or year group (data not shown).
 Descriptive characteristics of participants are shown in
 295 **Table 1**. The MANCOVA analysis revealed that there were no
 triple interaction (quarter \times sex \times year group) (Wilks'
 $\lambda = 0.993$; $F_{30,11,994} = 0.66$; $p = 0.92$; $\eta_p^2 = 0.001$) and no
 double interaction between sex and quarter (Wilks'
 $\lambda = 0.993$; $F_{15,8276.6} = 1.45$; $p = 0.115$, $\eta_p^2 = 0.002$), but revealed
 300 a main effect of year group (Wilks' $\lambda = 0.383$; $F_{10,5996} = 369.64$;
 $p < 0.001$, $\eta_p^2 = 0.381$) and a main effect of quarter (Wilks'
 $\lambda = 0.874$; $F_{15,8276.6} = 27.67$; $p < 0.001$; $\eta_p^2 = 0.044$) over the
 whole battery of tests. The univariate analysis showed a sig-
 nificant main effect of year group for weight ($F_{2,3000} = 679.3$;
 305 $p < 0.001$; $\eta_p^2 = 0.312$) and height ($F_{2,3000} = 2347.5$; $p < 0.001$;
 $\eta_p^2 = 0.610$). In addition, a main effect of quarter was reported
 for these 2 variables (weight: $F_{3,3000} = 57.2$; $p < 0.001$;
 $\eta_p^2 = 0.054$; Height: $F_{3,3000} = 118$; $p < 0.001$; $\eta_p^2 = 0.158$).
 The pairwise comparisons are shown in **Table 1**.

310 **The main** effect of year group was also observed for all fitness
 tests performed: handgrip strength test ($F_{2,3002} = 1103.91$;
 $p < 0.001$; $\eta_p^2 = 0.424$), standing long jump test
 ($F_{2,3002} = 1184.97$; $p < 0.001$; $\eta_p^2 = 0.441$), 4×10 m shuttle run
 test ($F_{2,3002} = 1348.05$; $p < 0.001$; $\eta_p^2 = 0.473$), one-leg stance test
 315 ($F_{2,3002} = 309.5$; $p < 0.001$; $\eta_p^2 = 0.171$), and PREFIT 20 m shuttle
 run test ($F_{2,3002} = 509.93$; $p < 0.001$; $\eta_p^2 = 0.254$). Similarly, **the**
 main effect of quarter was significant for all fitness tests: hand-
 grip strength test ($F_{3,3002} = 76.16$; $p < 0.001$; $\eta_p^2 = 0.071$),
 standing long jump test ($F_{3,3002} = 17.63$; $p < 0.001$; $\eta_p^2 = 0.017$),
 320 4×10 m shuttle run test ($F_{3,3002} = 94.22$; $p < 0.001$; $\eta_p^2 = 0.086$),
 one-leg stance test ($F_{3,3002} = 17.73$; $p < 0.001$; $\eta_p^2 = 0.017$), and
 PREFIT 20 m shuttle run test ($F_{3,3002} = 17.96$; $p < 0.001$;
 $\eta_p^2 = 0.018$). We observed significant interactions (year group \times
 quarter) for 4×10 m shuttle run test ($F_{6,3002} = 5.38$; $p < 0.001$;
 325 $\eta_p^2 = 0.011$) and one-leg stance test ($F_{6,3002} = 2.51$; $p = 0.02$;
 $\eta_p^2 = 0.005$). The pairwise comparisons are shown in **Table 2**.

330 **Figure 1** (handgrip strength test and standing long jump
 test) and **Figure 2** (one-leg stance test, 4×10 m shuttle run test
 and PREFIT 20 m shuttle run test) show the distribution of
 frequencies in percentage, from the fourth to the first quarters,
 in each year group, for the different intervals of the 5 fitness
 tests. In general, these figures show a higher percentage of
 preschoolers in interval 10 (i.e., the best performing preschool-
 335 ers) among those who were born in quarter 1, to the detriment
 to those who were born in the fourth quarter, for each age

group, and for all tests evaluated. It can also be observed the
 contrary tendency, for those who were in interval 1.

Discussion

The main finding of this study is the existence of an effect of the
 relative age (i.e., RAE) over physical fitness, measured with the
 340 feasible and reliable PREFIT battery in children from 3 to 5 years
 old. In general, our data indicate that performance improves as
 the relative age increases. Despite the profuse amount of liter-
 ature reporting the presence of RAE in physical fitness and
 sports selection, this is the first time that RAE has been reported
 345 in preschoolers (3 to 5 years old).

The multivariate analysis and its associated effect sizes
 indicate the presence of small to moderate RAE over the
 performance in the whole fitness battery, and that this effect
 differs depending on the year group as inferred from the
 350 double interaction between quarter of birth and year group.
 To the best of our knowledge, only the study by Cobley et al.
 compared RAE among the different year groups of their sam-
 ple, with children between 11 and 14 years old, finding no
 double interaction between birthdate and year group (Cobley
 355 et al., 2008). The differences with our data are probably due to
 the different age ranges studied. In fact, in preschoolers,
 3 months difference in birthdate time can account for up to
 8% of their life, while in 11-year-olds it accounts for around
 2%. The latter has relevant implications for teachers and
 360 trainers as short-term programming is needed at preschool
 age to adapt to their specific fitness development.

Finding better performance as the age increases is to be
 expected, since older children have higher motor development
 and body growth than their younger counterparts (Wattie et al.,
 365 2015). In fact, recent works from our group developed with the
 same sample (Cadenas-Sanchez et al., 2019) and previous studies
 developed with children above 6 years old and adolescents
 (Gulías-González et al., 2014; De Miguel-Étayo et al., 2014; Roriz
 De Oliveira et al., 2014) reported better values in the older
 370 children when compared by academic year group. However,
 the present study emphasizes the fact that in preschoolers within
 the same academic year group, in a time frame as short as a
 quarter (3 months), diverse physical performance can be found.
 This is in line with the idea of the cut-off dates as an important
 375 factor influencing the skills acquisition in several areas (physical,
 cognitive, self-efficacy, etc.) of children's development (Dutil et
 al., 2018). Therefore, compensation and individualization strate-
 gies for interventions, selections or evaluations should be

Table 2. Results of the fitness performance tests across age groups.

		Quarter 1 (Born from January to March)		Quarter 2 (Born from April to June)		Quarter 3 (Born from July to September)		Quarter 4 (Born from October to December)	
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Handgrip strength test (kg)	3 years	5.57	0.12	5.07 ^a	0.12	4.68 ^a	0.12	4.31 ^{ab}	0.13
	4 years	7.52*	0.11	7.22*	0.11	6.71 ^{ab*}	0.11	6.26 ^{abc*}	0.11
	5 years	9.68 [#]	0.11	9.08 ^{a*#}	0.11	8.38 ^{ab*#}	0.11	7.92 ^{abc*#}	0.11
Standing long jump test (cm)	3 years	60.44	1.07	55.71 ^a	1.07	52.20 ^a	1.12	45.03 ^{abc}	1.15
	4 years	79.24*	0.98	77.37*	1.01	72.84 ^{ab*}	1.02	68.52 ^{abc*}	0.98
	5 years	94.22 [#]	1.01	90.05 ^{a*#}	0.97	86.47 ^{a*#}	0.99	84.18 ^{ab*#}	0.99
One-leg stance test (sec)	3 years	6.52	1.03	5.55	1.04	4.49	1.08	4.04	1.11
	4 years	15.73*	0.95	11.64 ^{a*}	0.98	11.88 ^{a*}	0.99	9.47 ^{a*}	0.95
	5 years	26.01 [#]	0.98	25.66 ^{a*}	0.94	20.18 ^{ab*#}	0.96	19.50 ^{ab*#}	0.96
4 × 10 m shuttle run test (s)	3 years	18.40	0.12	18.89 ^a	0.12	19.49 ^{ab}	0.12	20.29 ^{abc}	0.12
	4 years	16.05*	0.11	16.33*	0.11	16.56 ^{a*}	0.11	17.27 ^{abc*}	0.11
	5 years	14.76 [#]	0.11	14.95 ^{a*#}	0.11	15.31 ^{a*#}	0.11	15.48 ^{ab*#}	0.11
PREFIT 20 m shuttle run test (laps)	3 years	15.16	0.64	12.98	0.64	10.57 ^a	0.67	9.75 ^{ab}	0.69
	4 years	22.45*	0.59	20.51*	0.61	19.18 ^{a*}	0.62	17.11 ^{ab*}	0.59
	5 years	28.76 [#]	0.61	27.14 ^{a*#}	0.59	24.93 ^{ab*#}	0.60	24.44 ^{ab*#}	0.59

Data are presented as mean ± standard error of mean (SEM); ^a*p*<0.05 different to quarter 1; ^b*p*<0.05 different to quarter 2; ^c*p*<0.05 different to quarter 3; **p* < 0.05 different to 3 years; and #*p* < 0.05 different to 4 years.

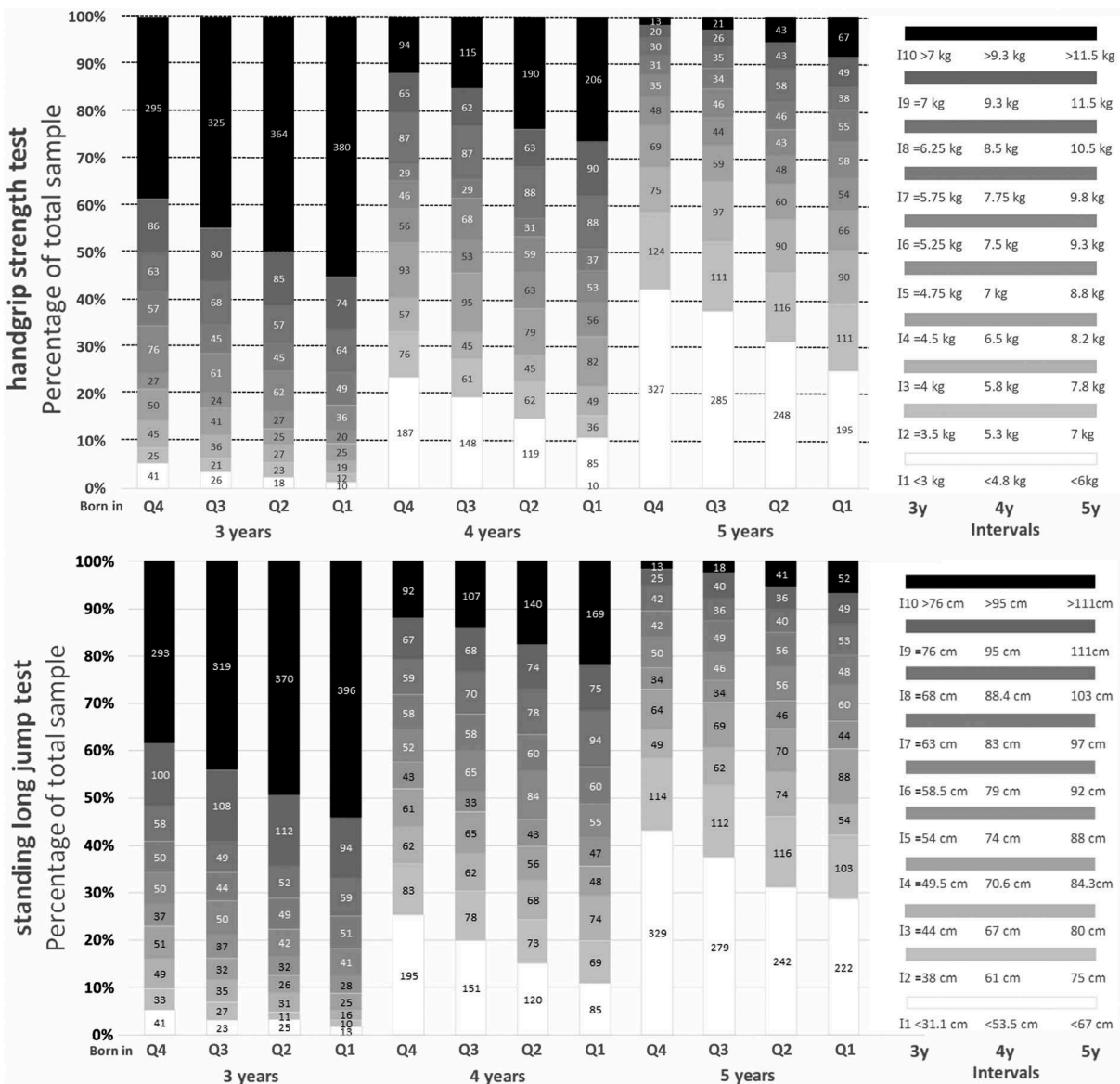


Figure 1. Intervals of performance for each quarter of age in 3-, 4- and 5-years preschoolers, and frequencies of preschoolers in each interval for the handgrip strength test and the standing long jump test. Limit values for intervals are shown on the right. Numbers inside the bars represent the number of preschoolers within each interval, and frequency percentages are represented in the left axis. Q1 = born between January and March (i.e., the eldest within the age group); Q2 = born between April and June; Q3 = born between July and September; Q4 = born between October and December (i.e., the youngest within the age group).

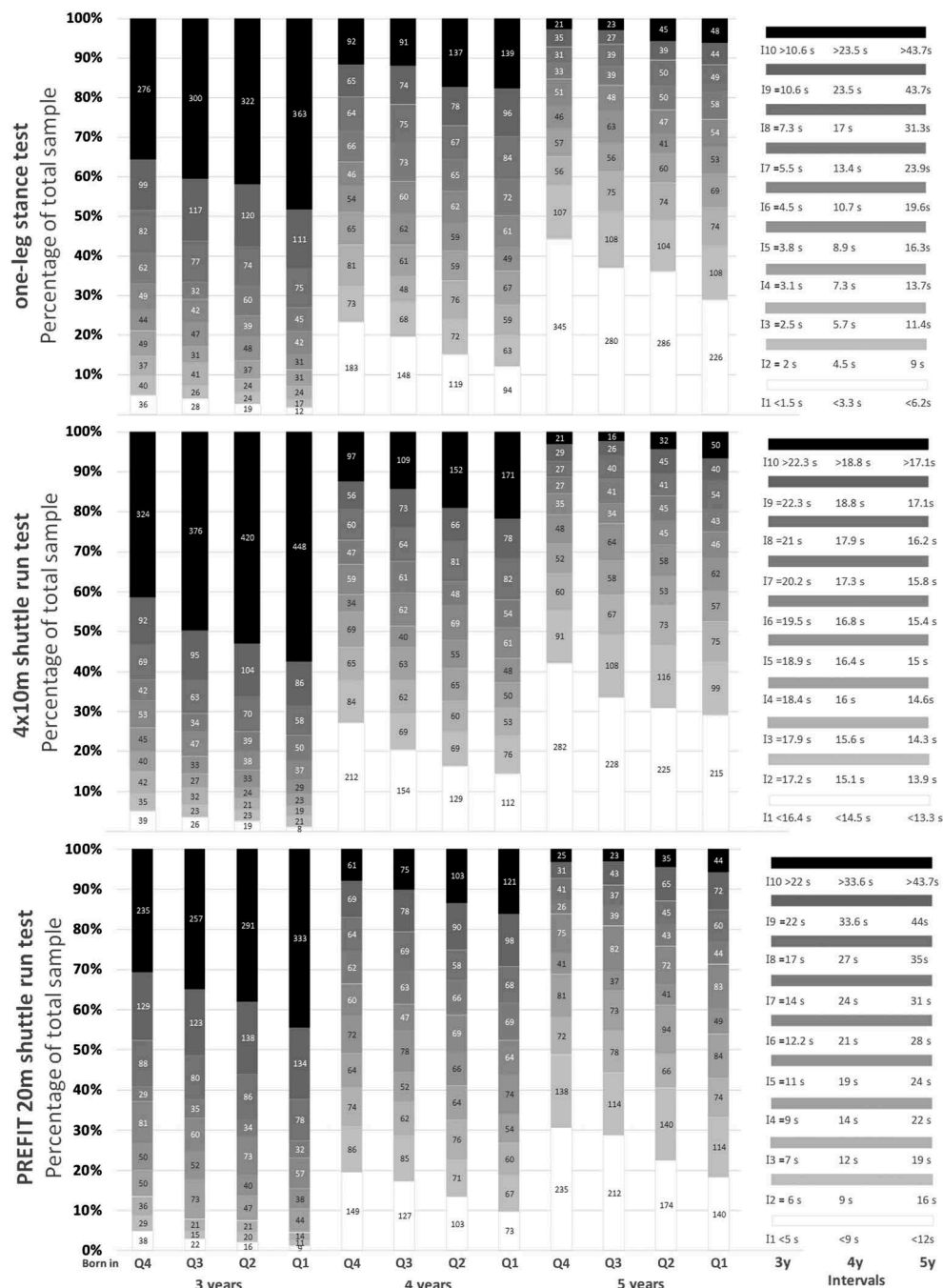


Figure 2. Intervals of performance for each quarter of age in 3-, 4- and 5-years preschoolers, and frequencies of preschoolers in each interval for the one-leg stance test, the 4 × 10 m shuttle run test and the PREFIT 20 m shuttle run test. Limit values for intervals are shown on the right. Numbers inside the bars represent the number of preschoolers within each interval, and frequency percentages are represented in the left axis. Q1 = born between January and March (i.e., the eldest within the age group); Q2 = born between April and June; Q3 = born between July and September; Q4 = born between October and December (i.e., the youngest within the age group).

380 addressed within the same academic year not only in elementary
 or secondary years, as it has already been recommended (Mann
 & van Ginneken, 2017; Philippaerts et al., 2006; Wattie et al.,
 2015), but also in preschool children. The proposed strategies
 that might be implemented in schools could be applying correc-
 385 tive mathematical adjustments to the results (for example, multi-
 ply the race time, or any other mark, by a corrective factor)
 (Romann et al., 2015); grouping students based on their biological
 age instead on their chronological age (Albuquerque et al.,
 2012; Hurley et al., 2001; Musch & Grondin, 2001); or make the

390 teachers aware in some way about the relative age of the
 students (e.g., by numbering their shirts), so that they keep this
 effect in mind when grading (Mann & van Ginneken, 2017). Other
 solutions seen in previous investigations come from sports con-
 395 texts and may be difficult to apply in educational centres, such as
 shifting selection dates or imposing restrictions on the age in
 which players were invited to attend selection events (Haycraft et
 al., 2018).

Our results show a progressive linear rising of physical fitness
 across the quarters for most of the tests performed. In this

400 regard, we find contradictory results in literature, reporting
 either a well-fitted linear improvement as relative age advances
 (Bell et al., 1997) or non-linear changes in function of relative
 age (Cobley et al., 2008). However, the lack of progressive
 405 increment in performance seen by Cobley et al., as they
 admitted in their work, could be due to the lower sample size,
 the proximity to puberty of their sample and hence the biological
 maturity variation, and also to the heterogeneity of experience
 and practice in physical activities of their sample. In our
 410 results, the only test that seems not to follow this behaviour at
 some point is the balance test, where a double interaction (year
 groups \times quarter) was found in the between-participants
 effects test. This double interaction may probably appear due
 to the absence of differences among quarters within the 3-
 years group, and the different progression seen in 4-year and
 415 5-year-old group performances. In a previous study (Cadenas-
 Sanchez, Martinez-Tellez et al., 2016) this test showed poorer
 reliability when more than 2 measurements separated by a
 period of time are made (for example, in pre-post assessments),
 and the variability error increased as the performance in the
 420 test was higher; so, it may be reasonable that the lowest error
 exists in the group in which we did not observe differences
 among quarters. Maybe the sensibility of the test is not enough
 for reporting the difference in performance within the 3-year-
 old children; or perhaps the differences in balance develop-
 425 ment of this physical ability between 3-year-old and 4-year-old
 preschoolers (Assaïante, 1998) may interfere in the results of
 the test, since significant differences among quarters started to
 appear at the end of age 4. Although the application of this
 specific result regarding the balance test could be limited due
 430 to the reliability of the test, we prefer showing the results in
 order to help professionals, researchers and future studies,
 providing an initial reference. As far as we are aware, no pre-
 vious studies analysing RAE included static balance as a main
 measurement, and therefore more investigation is needed
 435 before assuming any hypothesis in this regard.

The other physical test showing a double interaction (year
 group \times quarter) in the analysis of variance was the 4×10 m
 shuttle run test. However, in this case, the differences among
 each year group for RAE are not as evident as in the balance
 440 test. An attenuation in the magnitude of the change was per-
 ceived between quarters as the year group was older, as well as
 less significant differences among quarters, meaning that the
 changes among quarters in 3 years old are more pronounced
 than in 4 and 5 years old, and the same happens when compar-
 445 ing 4 vs 5 years old. To the best of our knowledge, only
 1 previous work measured agility in preschoolers, but with a
 10×5 m shuttle run test and not analysing differences among
 age groups (Silva-Santos et al., 2017). Moreover, none of the
 works examining RAE and physical performance assess agility
 450 with the 4×10 m shuttle run test. Therefore, it is not possible
 to compare our results with others to confirm the different effect
 of relative age in each year group.

For the remaining univariate tests (i.e., handgrip strength
 test, standing long jump test and the PREFIT 20 m shuttle run
 455 test) no interaction was observed. The analysis showed main
 effects for year group and for quarter of birth. This implies that
 the performance improves as the age group progresses, but the
 effect of relative age is consistent among these different year

groups, and that similar performance changes among children
 born in different quarters but within the same year, are
 460 expected throughout all the preschool stage. The presence of
 RAE in preschoolers supports most of the works performed in
 older samples and using similar tests as those present in the
 PREFIT battery, such as 20 m shuttle run test (Nakata et al., 2017;
 Roberts et al., 2012; Sandercock et al., 2014, 2013), handgrip
 465 strength test (Nakata et al., 2017; Sandercock et al., 2014, 2013;
 Ulbricht et al., 2015) or standing long jump test (Nakata et al.,
 2017). However, none of these studies analysed the interaction
 between year group and quarter. Therefore, we cannot infer if
 the magnitude of the relative age effect varies over the years in
 470 children and adolescents, as we have observed in preschoolers
 with our data and the double interaction reported.

Regarding the frequency distribution in the calculated inter-
 vals, analysis that we performed to complement the MANOVA,
 different nuances of the results can be observed. In general, the
 475 highest intervals (i.e., those reflecting better performance) and
 especially the 10th, increase as the relative age increase, while
 the lowest intervals, primarily the 1st, decrease. That is, the
 relatively older the preschoolers are, the more frequently they
 get results close to the maximum value recorded for their year
 group. Although in most cases this behaviour is progressive
 from quarter to quarter, there are cases in which a small “stand-
 still” is observed, where the frequency is similar between
 480 2 consecutive quarters. This appears to be more common in
 the 5-year age group, such as in the balance test (i.e., quarter
 1 is similar to quarter 2, and quarter 3 to quarter 4), or the
 PREFIT 20 m shuttle run test (quarter 1 is similar to quarter 2).
 Comparing the frequencies year by year, we can see, in all the
 tests, how within the 3-years group there are more children
 close to their maximal value in 3-years, and in the 5-years
 490 group, more children are near the lowest value for 5-years. It
 seems that the relative performance of preschoolers falls when
 they progress to the next grade, suggesting that the perfor-
 mance of preschoolers drops as they move up the school year.
 Physical growth and experience could underlie these observa-
 495 tions: growth may be the limiting factor for performance in 3-
 years, while in 5-years, the range of physical growth is wider
 (Sánchez González et al., 2011; Tanner & Whitehouse, 1976) and
 experience of the least and most active could influence these
 results. 500

In respect to the influence of gender, and going back to the
 results derived from the MANOVA test, no triple interaction
 (quarter \times sex \times year group) and no double interaction between
 sex and birthdate were seen in our multivariate analysis, sug-
 505 gesting that RAE over performance in the PREFIT battery was
 similar between genders. This is in contrast with the results by
 Sandercock et al. (2013) and Roberts and Fairclough (2012),
 since they reported much greater evidence of RAE in male
 than in female participants. However, it is important to highlight
 that the sample in the above-mentioned studies was
 510 much older than our sample, 10 to 16 years old. In fact, Nakata et al.
 found similar RAE in physical fitness data of both genders in
 children from 7 to 10, but a more evident RAE for boys than girls
 in adolescents (i.e., 11–15 years old), supporting the idea of the
 appearance of gender differences for RAE only in older groups
 515 (Nakata et al., 2017). The fact that relative age has a similar effect
 in both genders during the pre-scholar period and elementary

school, but a different effect later in life could reflect the progressive appearance of social/environmental factors that have been proposed to influence RAE in the largest mode (Hancock et al., 2013), also reflecting that these factors could be different for boys and girls.

Finally, the statistical analysis revealed small effect sizes for the multivariate analysis, as well as for the one-leg stance test, the standing long jump test and the PREFIT 20 m shuttle run test. Moderate values were observed for the handgrip strength test and the 4 × 10 m shuttle run test. To the best of our knowledge, we cannot compare these small to moderate values with previous studies. The only work detailing the effect size values is the meta-analysis performed by Cobley et al. (2009), who detected small significant effects across age categories. However, they analysed RAE as the different births frequencies among quarters, while we analyse RAE as the differences in fitness performance among quarters. Although both are consequences of the relative age, and in both cases, most of the effects detected were small but still significant, the comparison may not be correct. Therefore, more research detailing the effect size of RAE in fitness performance is needed to be able to quantify the amount of effect of the relative age.

Several approaches have been proposed for attenuating RAE in physical education and sports contexts (Cobley et al., 2009; Mann & van Ginneken, 2017), but preschoolers are unlikely to be scouted and recruited in any sport. As we said above in this context the most reasonable strategies seem to aware teachers and coaches regarding the existence of diverse motor attainments within the same year group (Cobley et al., 2009; Philippaerts et al., 2006), applying corrective adjustments (Romann et al., 2015); or grouping students based on their biological age (Albuquerque et al., 2012; Hurley et al., 2001; Musch & Grondin, 2001). Since the younger pupils have the potential to achieve the same level as their older peers in the future (Bell & Daniels, 1990), adults should consider the existence of this effect and compensate it in their interaction with children, individualizing the demands or goals in each discipline. These compensation approaches are especially important if we consider that many of these children will go through future sports selection and physical activity participation processes; knowing that RAE is present even before the period of sports selection, it is important to attenuate this effect already at this early stage, controlling and being aware of the constraints (individual, task and environmental) and their relations, which influence the presence of RAE (Wattie et al., 2015).

Regarding limitations, we are aware that the study sample may not be representative of Spain since we did not consider the school type characteristics, and the geographical distribution was not random. However, we selected the sample to be as representative of the average level of demography, cultural, social and economic markers as possible. Therefore, although these results may not be applicable to all of the Spanish settings, and might need more future studies, they could be applied to most of them. Another limitation of the present study is that we did not analyse factors that could explain RAE at this age, such as attendance at sports/physical exercise activities (i.e., supervised activities), skeletal age or anthropometric parameters, or measurement of social/behavioural factors such as the Mathew effect (the best are provided with

more opportunities to practice), Pygmalion effect (the greater the expectation placed on an individual, the greater the result that individual will attain) or Galatea effect (once expectations are placed upon an individual, that individual typically acts congruently with those expectations) which have been proposed to influence RAE (Hancock et al., 2013). However, to the best of our knowledge, this is the first study to report the existence of RAE at as early as the preschool stage, using a statistically powerful sample size and a reliable and valid test for this particular sample.

Acknowledgments

The authors thank the participation of the preschoolers participating in this study, as well as their parents, teachers and the rest of the school's employees.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

CC-S is supported by Spanish Ministry of Science, Innovation and Universities [FJC2018-037925-I]. EGA is supported by grants from the Spanish Ministry of Science and Innovation (RYC-2014-16390). JM-G is supported by the Spanish Ministry of Education, Culture and Sport (FPU14/06837). In addition, this study was further supported by the University of Zaragoza (JIUZ-2014-BIO-08), and by the University of Granada, Plan Propio de Investigación 2016, Excellence actions: Units of Excellence; Unit of Excellence on Exercise and Health (UCEES). Additional funding from the SAMID III network, RETICS, funded by the PN I+D+I 2017-2021 (Spain), ISCIII- Sub-Directorate General for Research Assessment and Promotion, the European Regional Development Fund (ERDF) (Ref. RD16/0022), the EXERNET Research Network on Exercise and Health in Special Populations (DEP2005-00046/ACTI).

ORCID

Julio Conde-Caveda  <http://orcid.org/0000-0002-2788-231X>
 Germán Vicente-Rodríguez  <http://orcid.org/0000-0002-4303-4097>
 Pedro J. Benito  <http://orcid.org/0000-0002-1631-8182>

References

- Albuquerque, M. R., Lage, G. M., da Costa, V. T., Ferreira, R. M., Penna, E. M., Moraes, L. C., & Malloy-Diniz, L. F. (2012). Relative age effect in Olympic Taekwondo athletes. *Perceptual and Motor Skills*, 114(2), 461–468. <https://doi.org/10.2466/05.25.PMS.114.2.461-468>
- Andronikos, G., Elumaro, A. I., Westbury, T., & Martindale, R. J. J. (2016). Relative age effect: Implications for effective practice. *Journal of Sports Sciences*, 34(12), 1124–1131. <https://doi.org/10.1080/02640414.2015.1093647>
- Assaiante, C. (1998). Development of locomotor balance control in healthy children. *Neuroscience & Biobehavioral Reviews*, 22(4), 527–532. [https://doi.org/10.1016/S0149-7634\(97\)00040-7](https://doi.org/10.1016/S0149-7634(97)00040-7)
- Baker, J., Schorer, J., Cobley, S., Schimmer, G., & Wattie, N. (2009). Circumstantial development and athletic excellence: The role of date of birth and birthplace. *European Journal of Sport Science*, 9(6), 329–339. <https://doi.org/10.1080/17461390902933812>
- Bedard, K., & Dhuey, E. (2006). The persistence of early childhood maturity: International evidence of long-run age effects. *The Quarterly Journal of Economics*, 121, 1437–1472.

580

585

590

595

600

605

610

615

620

625

Q7
Q8

- 630 Bell, J. F., & Daniels, S. (1990). Are Summer-born children disadvantaged? The birthdate effect in education. *Oxford Review of Education*, 16(1), 67–80. <https://doi.org/10.1080/0305498900160106>
- 635 Bell, J. F., Massey, A., & Dexter, T. (1997). Birthdate and ratings of sporting achievement: Analysis of physical education GCSE results. *European Journal of Physical Education*, 2(2), 160–166. <https://doi.org/10.1080/1740898970020203>
- 640 Birch, S., Cummings, L., Oxford, S. W., & Duncan, M. J. (2016). Examining relative age effects in fundamental skill proficiency in british children Aged 6–11 years. *Journal of Strength and Conditioning Research*, 30(10), 2809–2815. <https://doi.org/10.1519/JSC.0000000000000526>
- 645 Brazo-Sayavera, J., Martínez-Valencia, M. A., Müller, L., Andronikos, G., & Martindale, R. J. J. (2017). Identifying talented track and field athletes: The impact of relative age effect on selection to the Spanish National Athletics Federation training camps. *Journal of Sports Sciences*, 35(22), 2172–2178. <https://doi.org/10.1080/02640414.2016.1260151>
- 650 Cadenas-Sánchez, C., Alcántara-Moral, F., Sánchez-Delgado, G., Mora-González, J., Martínez-Téllez, B., Herrador-Colmenero, M., Jiménez-Pavón, D., Femia, P., Ruiz, J. R., & Ortega, F. B. (2014). Assessment of cardiorespiratory fitness in preschool children: Adaptation of the 20 metres shuttle run test. *Nutricion hospitalaria*, 30(6), 1333–1343. <https://doi.org/10.3305/nh.2014.30.6.7859>
- 655 Cadenas-Sanchez, C., Intemann, T., Labayen, I., Peinado, A. B., Vidal-Conti, J., Sanchis-Moysi, J., Moliner-Urdiales, D., Rodriguez Perez, M. A., Cañete Garcia-Prieto, J., Del Rosario Fernández-Santos, J., Martínez-Tellez, B., Vicente-Rodríguez, G., Löf, M., Ruiz, J. R., & Ortega, F. B. (2019). Physical fitness reference standards for preschool children: The PREFIT project. *Journal of Science and Medicine in Sport*, 22(4), 430–437. <https://doi.org/10.1016/j.jsams.2018.09.227>
- 660 Cadenas-Sanchez, C., Martínez-Tellez, B., Sanchez-Delgado, G., Mora-Gonzalez, J., Castro-Piñero, J., Löf, M., Ruiz, J. R., & Ortega, F. B. (2016). Assessing physical fitness in preschool children: Feasibility, reliability and practical recommendations for the PREFIT battery. *Journal of Science and Medicine in Sport*, 19(11), 910–915. <https://doi.org/10.1016/j.jsams.2016.02.003>
- 665 Cadenas-Sanchez, C., Sanchez-Delgado, G., Martínez-Tellez, B., Mora-Gonzalez, J., Löf, M., España-Romero, V., Ruiz, J. R., & Ortega, F. B. (2016). Reliability and validity of different models of TKK hand dynamometers. *American Journal of Occupational Therapy*, 70(4), 7004300010. <https://doi.org/10.5014/ajot.2016.019117>
- 670 Coble, S., Abraham, C., & Baker, J. (2008). Relative age effects on physical education attainment and school sport representation. *Physical Education & Sport Pedagogy*, 13(3), 267–276. <https://doi.org/10.1080/17408980701711983>
- 675 Coble, S., Baker, J., Wattie, N., & McKenna, J. (2009). Annual age-grouping and athlete development: A meta-analytical review of relative age effects in sport. *Sports Medicine*, 39(3), 235–256. <https://doi.org/10.2165/00007256-200939030-00005>
- 680 Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Routledge.
- 685 Dalen, T., Ingvaldsen, R. P., Roaas, T. V., Pedersen, A. V., Steen, I., & Aune, T. K. (2017). The impact of physical growth and relative age effect on assessment in physical education. *European Journal of Sport Science*, 17(4), 482–487. <https://doi.org/10.1080/17461391.2016.1268651>
- 690 De Miguel-Etayo, P., Gracia-Marco, L., Ortega, F. B., Intemann, T., Foraita, R., Ler, L., Oja, L., Barba, G., Michels, N., Tornaritis, M., Molnár, D., Pitsiladis, Y., Ahrens, W., Moreno, L. A., & IDEFICS consortium. (2014). Physical fitness reference standards in European children: The IDEFICS study. *International Journal of Obesity*, 38(S2), S57–S66. <https://doi.org/10.1038/ijo.2014.136>
- 695 Dutil, C., Tremblay, M. S., Longmuir, P. E., Barnes, J. D., Belanger, K., & Chaput, J.-P. (2018). Influence of the relative age effect on children's scores obtained from the Canadian assessment of physical literacy. *BMC Public Health*, 18(S2), 1040. <https://doi.org/10.1186/s12889-018-5895-6>
- Furley, P., & Memmert, D. (2016). Coaches' implicit associations between size and giftedness: Implications for the relative age effect. *Journal of Sports Sciences*, 34(5), 459–466. <https://doi.org/10.1080/02640414.2015.1061198>
- Gledhill, J., Ford, T., & Goodman, R. (2002). Does season of birth matter? The relationship between age within the school year (Season of Birth) and educational difficulties among a representative general population sample of children and adolescents (aged 5–15) in Great Britain. *Research in Education*, 68(1), 41–47. <https://doi.org/10.7227/RIE.68.4>
- 700 Gullías-González, R., Sánchez-López, M., Olivás-Bravo, Á., Solera-Martínez, M., & Martínez-Vizcaino, V. (2014). Physical fitness in Spanish school-children aged 6–12 years: Reference values of the battery EUROFIT and associated cardiovascular risk. *Journal of School Health*, 84(10), 625–635. <https://doi.org/10.1111/josh.12192>
- 705 Hancock, D. J., Adler, A. L., & Côté, J. (2013). A proposed theoretical model to explain relative age effects in sport. *European Journal of Sport Science*, 13(6), 630–637. <https://doi.org/10.1080/17461391.2013.775352>
- 710 Haycraft, J. A. Z., Kovalchik, S., Pyne, D. B., Larkin, P., & Robertson, S. (2018). The influence of age-policy changes on the relative age effect across the Australian Rules football talent pathway. *Journal of Science and Medicine in Sport*, 21(10), 1106–1111. <https://doi.org/10.1016/j.jsams.2018.03.008>
- 715 Hurley, W., Lior, D., & Tracze, S. (2001). A proposal to reduce the age discrimination in Canadian Minor Hockey. *Canadian Public Policy / Analyse de Politiques*, 27(1), 65. <https://doi.org/10.2307/3552374>
- 720 Kearney, P. E., Hayes, P. R., & Nevill, A. (2018). Faster, higher, stronger, older: Relative age effects are most influential during the youngest age grade of track and field athletics in the United Kingdom. *Journal of Sports Sciences*, 36(20), 2282–2288. <https://doi.org/10.1080/02640414.2018.1449093>
- Léger, L. A., Mercier, D., Gadoury, C., & Lambert, J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *Journal of Sports Sciences*, 6(2), 93–101. <https://doi.org/10.1080/02640418808729800>
- 725 Mann, D. L., & van Ginneken, P. J. M. A. (2017). Age-ordered shirt numbering reduces the selection bias associated with the relative age effect. *Journal of Sports Sciences*, 35(8), 784–790. <https://doi.org/10.1080/02640414.2016.1189588>
- Müller, L., Hildebrandt, C., & Raschner, C. (2015). The relative age effect and the influence on performance in youth alpine ski racing. *Journal of Sports Science & Medicine*, 14(1), 16–22.
- 730 Musch, J., & Grondin, S. (2001). Unequal competition as an impediment to personal development: A review of the relative age effect in sport. *Developmental Review*, 21(2), 147–167. <https://doi.org/10.1006/drev.2000.0516>
- 735 Nakata, H., Akido, M., Naruse, K., & Fujiwara, M. (2017). Relative age effect in physical fitness among elementary and junior high school students. *Perceptual and Motor Skills*, 124(5), 900–911. <https://doi.org/10.1177/0031512517722284>
- 740 Ortega, F. B., Cadenas-Sánchez, C., Sánchez-Delgado, G., Mora-González, J., Martínez-Téllez, B., Artero, E. G., Castro-Piñero, J., Labayen, I., Chillón, P., Löf, M., Ruiz, J. R., et al (2015). Systematic review and proposal of a field-based physical fitness-test battery in preschool children: The PREFIT battery. *Sports Medicine*, 45(4), 533–555. <https://doi.org/10.1007/s40279-014-0281-8>
- 745 Palou, P., Muntaner-Mas, A., Cantalops, J., Borràs, P. A., Labayen, I., Jiménez-Pavón, D., Dorado García, C., Moliner-Urdiales, D., Rodríguez Pérez, M. A., Rojo-Tirado, M. A., Cadenas-Sanchez, C., Ortega, F. B., & Vidal-Conti, J. (2019). A single question of parent-reported physical activity levels estimates objectively measured physical fitness and body composition in preschool children: The PREFIT project. *Frontiers in Psychology*, 10, 1585. <https://doi.org/10.3389/fpsyg.2019.01585>
- 750 Philippaerts, R. M., Vaeyens, R., Janssens, M., Van Renterghem, B., Matthys, D., Craen, R., Bourgois, J., Vrijens, J., Beunen, G., & Malina, R. M. (2006). The relationship between peak height velocity and physical performance in youth soccer players. *Journal of Sports Sciences*, 24(3), 221–230. <https://doi.org/10.1080/02640410500189371>
- 755 Roberts, S. J., Boddy, L. M., Fairclough, S. J., & Stratton, G. (2012). The influence of relative age effects on the cardiorespiratory fitness levels of children age 9 to 10 and 11 to 12 years of age. *Pediatric Exercise Science*, 24(1), 72–83. <https://doi.org/10.1123/pes.24.1.72>
- 760 Roberts, S. J., & Fairclough, S. J. (2012). The influence of relative age effect in the assessment of high school students in physical education in the United Kingdom. *Journal of Teaching in Physical Education*, 31(1), 56–70. <https://doi.org/10.1123/jtpe.31.1.56>
- 765 Romann, M., Coble, S., & Gonzalez, G. E. (2015). Relative age effects in athletic sprinting and corrective adjustments as a solution for their removal (GE Gonzalez, Ed.). *PLoS One*, 10(4), e0122988. <https://doi.org/10.1371/journal.pone.0122988>

- 770 Roriz De Oliveira, M. S., Seabra, A., Freitas, D., Eisenmann, J. C., & Maia, J. (2014).
 Q12 Physical fitness percentile charts for children aged 6–10 from Portugal. *The
 Journal of Sports medicine and Physical Fitness*, 54(6), 780–792.
- 775 Sánchez González, E., Carrascosa Lezcano, A., Fernández García, J. M.,
 Ferrández Longás, A., López de Lara, D., & López-Siguero, J. P. (2011).
 Estudios españoles de crecimiento: Situación actual, utilidad y recomen-
 daciones de uso. *Anales De Pediatría*, 74(3), 193.e1–193.e16. [https://doi.
 org/10.1016/j.anpedi.2010.10.005](https://doi.org/10.1016/j.anpedi.2010.10.005)
- 780 Sanchez-Delgado, G., Cadenas-Sanchez, C., Mora-Gonzalez, J., Martinez-
 Tellez, B., Chillón, P., Löf, M., Ortega, F. B., & Ruiz, J. R. (2015).
 Assessment of handgrip strength in preschool children aged 3 to 5
 years. *Journal of Hand Surgery (European Volume)*, 40(9), 966–972.
<https://doi.org/10.1177/1753193415592328>
- 785 Sandercock, G. R. H., Ogunleye, A. A., Parry, D. A., Cohen, D. D., Taylor, M. J.
 D., & Voss, C. (2014). Athletic performance and birth month: Is the
 relative age effect more than just selection bias? *International Journal
 of Sports Medicine*, 35(12), 1017–1023. [https://doi.org/10.1055/s-0034-
 1368725](https://doi.org/10.1055/s-0034-1368725)
- 790 Sandercock, G. R. H., Taylor, M. J., Voss, C., Ogunleye, A. A., Cohen, D. D., &
 Parry, D. A. (2013). Quantification of the relative age effect in three
 indices of physical performance. *Journal of Strength and Conditioning
 Research*, 27(12), 3293–3299. [https://doi.org/10.1519/JSC.
 0b013e318291b28d](https://doi.org/10.1519/JSC.0b013e318291b28d)
- Silva-Santos, S., Santos, A., Vale, S., & Mota, J. (2017). Motor fitness and
 preschooler children obesity status. *Journal of Sports Sciences*, 35(17),
 1704–1708. <https://doi.org/10.1080/02640414.2016.1232486>
- Smith, J. J., Eather, N., Morgan, P. J., Plotnikoff, R. C., Faigenbaum, A. D., & 795
 Lubans, D. R. (2014). The health benefits of muscular fitness for children
 and adolescents: A systematic review and meta-analysis. *Sports Medicine*,
 44(9), 1209–1223. <https://doi.org/10.1007/s40279-014-0196-4>
- Tanner, J. M., & Whitehouse, R. H. (1976). Clinical longitudinal standards for
 height, weight, height velocity, weight velocity, and stages of puberty. 800
Archives of Disease in Childhood, 51(3), 170–179. [https://doi.org/10.1136/
 adc.51.3.170](https://doi.org/10.1136/adc.51.3.170)
- Ulbricht, A., Fernandez-Fernandez, J., Mendez-villanueva, A., & Ferrauti, A.
 (2015). The relative age effect and physical fitness characteristics in
 German male tennis players. *Journal of Sports science & Medicine*, 14(3), 805
 634–642. Q13
- Wattie, N., Schorer, J., & Baker, J. (2015). The relative age effect in sport: A
 developmental systems model. *Sports Medicine*, 45(1), 83–94. [https://doi.
 org/10.1007/s40279-014-0248-9](https://doi.org/10.1007/s40279-014-0248-9)
- Wienen, A. W., Batstra, L., Thoutenhoofd, E., de Jonge, P., Bos, E. H., & 810
 Neuenschwander, R. (2018). Teachers' perceptions of behavioral pro-
 blems in Dutch primary education pupils: The role of relative age. (R
 Neuenschwander, Ed.). *PLoS One*, 13(10), e0204718. [https://doi.org/10.
 1371/journal.pone.0204718](https://doi.org/10.1371/journal.pone.0204718)