

Relationship between age and cardiorespiratory fitness in active youth: evidence from the COR-School project

Short title: Age and cardiorespiratory fitness in youth

Saül Aixa-Requena (<https://orcid.org/0009-0007-2034-4600>)^{1*}, Enric Conesa-Milian (<https://orcid.org/0009-0000-1435-1598>)¹, Vicenç Hernández-González (<https://orcid.org/0000-0003-3201-3298>)¹, Teresa Fonseca (<https://orcid.org/0000-0002-2225-4576>)^{2,3,4}, Joaquin Reverter-Masia (<https://orcid.org/0000-0002-9441-2764>)¹

¹ Human Movement Research Group (RGHM) & Physical Education and Sport Section, University of Lleida, 25001 Lleida, Spain.

² Polytechnic Institute of Guarda, Portugal.

³ Sport Physical Activity and Health Research & Innovation Centre (SPRINT).

⁴ Centro de Investigação, Formação, Inovação e Intervenção em Desporto (CIFI2D), Guarda, Portugal.

***Corresponding author:**

E-mail: saul.aixa@udl.cat

DECLARATIONS

Conflicts of Interest:

The authors declare no conflict of interest.

Funding:

This research was funded by the State Program for Research, Development, and Innovation Oriented to the Challenges of Society, within the framework of the State Plan for R + D+I 2020–2024. The project title is as follows: “Evaluación de diversos parámetros de salud y niveles de actividad física en la escuela primaria y secundaria” (grant number PID2020-117932RB-I00). Additionally, the research was supported by the consolidated research group Human Movement, Generalitat de Catalunya, 021 SGR 01619. S.A.-R. was supported by the predoctoral grants program FI SDUR from the Department of Research and Universities of the Generalitat de Catalunya, co-funded by the European Social Fund Plus (2024 FISDU 00122).

CRedit authorship contribution statement:

Saül Aixa-Requena: Conceptualization; Data curation; Formal analysis; Visualization; Writing – original draft.

Enric Conesa-Milian: Data curation; Investigation; Writing – review & editing.

Vicenç Hernández-González: Data curation; Investigation; Methodology; Supervision; Writing – review & editing.

Teresa Fonseca: Supervision; Methodology; Writing – review & editing.

Joaquin Reverter-Masia: Conceptualization; Funding acquisition; Methodology; Project administration; Resources; Supervision; Writing – review & editing.

EDITORIAL INFORMATION

Received: 3 February 2026

Accepted: 28 June 2026

DRAFT

ABSTRACT

Cardiorespiratory fitness is a key health marker in childhood and adolescence, associated with lower future cardiovascular and metabolic risk. This study, conducted within the COR-School project, examined the relationship between age and cardiorespiratory fitness in 685 physically active Spanish children and adolescents (420 boys and 265 girls) aged 8–16 years. All participants completed the 20m shuttle run test following a standardised protocol, with total distance covered and age recorded. Analysis revealed a significant positive correlation ($r = 0.35$; $p < 0.001$), with each additional year of age associated with an average increase of more than 90 meters covered. Boys outperformed girls across all age groups, although age remained the main predictor of performance. Compared with European reference values from the FitBack project, the COR-School cohort achieved higher results. Suggesting that physically active youth participating in organized sports tend to present better cardiorespiratory fitness levels than the reference population. These findings confirm the value of the 20mSRT as a simple and reliable tool for population monitoring, inequality detection, and the design of school- and community-based health promotion strategies.

Keywords: Physical Fitness; Child; Adolescent; Exercise Test; Athletic Performance

INTRODUCTION

Cardiorespiratory fitness (CRF) is an important health indicator in childhood and adolescence, being associated with a more favourable cardiovascular profile and a lower risk of metabolic and chronic diseases later in life (Ortega et al., 2008; Ruiz et al., 2016). Available evidence shows that children and adolescents with low CRF have a higher risk of overweight, blood pressure alterations, and poorer perceived quality of life (García-Hermoso et al., 2020; Mintjens et al., 2018; Ortega et al., 2008). In this regard, the assessment of aerobic capacity, given its strong association with health (Demchenko et al., 2025; Mintjens et al., 2018; Raghuveer et al., 2020), has gained increasing relevance in both research and clinical, educational, and sports practice.

The Course Navette test, also known as the 20 m shuttle run test (20mSRT), has become the most widely used field-based tool to estimate CRF in children and adolescents (Léger & Lambert, 1982; Ruiz et al., 2011). Its low cost, ease of administration, and adequate validity compared with laboratory measures make it a reference instrument in epidemiological studies and public health programs (Lang et al., 2018; Tomkinson et al., 2017).

Age and biological maturation are key determinants of CRF performance, as somatic growth and pubertal hormonal changes directly influence maximal oxygen uptake, muscular strength, and other components of physical fitness (Albaladejo-Saura et al., 2021; Malina et al., 2004). Recent research confirms that CRF increases progressively throughout childhood and adolescence, although the magnitude of this increase depends on variables such as sex, physical activity level, and sociocultural context (Carayanni et al., 2022; Tomkinson et al., 2017).

While the general trajectories of CRF development across age are documented, evidence specifically focusing on youth engaged in structured, competitive club sports

remains limited. Active cohorts are often underrepresented in large-scale national fitness surveys. The COR-School project provides an opportunity to characterise age-related differences in 20mSRT performance in youth engaged in organised sports and to compare these results with national and European reference values. Therefore, this study aimed to examine the relationship between age and CRF performance in physically active children and adolescents.

METHODS

Study Design

A cross-sectional study was designed within the framework of the COR-School project, a longitudinal program aimed at evaluating physical fitness, cardiovascular biomarkers, and quality of life in Spanish children and adolescents (Aixa-Requena et al., 2024).

Participants

The sample comprised 685 schoolchildren and adolescents (420 boys and 265 girls), aged between 8 and 16 years, recruited via convenience sampling from 29 sports clubs located in north-eastern Spain. Regarding sports modalities, 73.3% engaged in team sports and 25.9% in individual sports, with football (37.3%), basketball (19.4%), handball (14.6%), and swimming (11.5%) being the most prevalent.

Inclusion criteria required participants to be aged 8–16, regularly active in organised sports, and free of cardiovascular risk factors. To ensure safety, parents completed a standardised cardiac health questionnaire based on the AHA 14-element screening (Maron et al., 2014) and the PAR-Q (Rodríguez, 1994). Only youth without known cardiac conditions,

symptoms (e.g., exertional chest pain or syncope), or family history of premature sudden cardiac death were included. Written parental consent and youth assent were obtained.

A sample size estimation was performed using G*Power 3.1 for a multiple linear regression model including two predictors (age and sex). Assuming a small-to-moderate effect size ($f^2 = 0.05$), an alpha level of 0.05, and a statistical power of 0.95, a minimum sample size of 312 participants was required. The final sample included 685 participants, substantially exceeding this requirement.

Written consent was obtained from parents or legal guardians, and verbal assent was provided by the minors. The study protocol (Aixa-Requena et al., 2024) was approved by the Clinical Research Ethics Committee of the Catalan Sports Administration (30/CEICGC/2020) and complied with the principles of the most recent revision of the Declaration of Helsinki (World Medical Association, 2013).

Variables and Instruments

Participants' age (years) and sex were also recorded at the time of testing.

CRF was assessed using the 20mSRT, following the standardised protocol described by Léger et al. (1982) and included in the ALPHA-FIT battery (Ruiz et al., 2011). The test consisted of running back and forth over a 20 m distance in time with audio signals that progressively increased speed by 0.5 km/h each minute, starting at 8.5 km/h, until voluntary exhaustion or inability to maintain the required pace. Total distance covered (in meters) and the final stage achieved were recorded.

The assessments were conducted in person following a standardised protocol established within the COR-School project. Data collection was carried out by trained researchers and research assistants with previous experience in physical fitness assessment.

Prior to data collection, all personnel received specific training regarding the administration of the testing procedures to ensure consistency across participants and testing locations.

Statistical analysis

Descriptive statistics (mean, standard deviation, minimum, and maximum) were calculated for all variables. Pearson correlation coefficients and linear regression models were used to examine the relationship between age and CRF performance, with sex included as a covariate. Assumptions of normality, homoscedasticity, and linearity were assessed before conducting the analyses. Normality was evaluated using the Shapiro–Wilk test and visual inspection of histograms and Q–Q plots. Homoscedasticity and linearity were examined through residual plots. The strength of associations was expressed using the coefficient of determination (R^2) and unstandardized/standardized beta coefficients with 95% confidence intervals. Statistical significance was set at $p < 0.05$. Analyses were performed using Jamovi software (version 2.6.26.0) for macOS Catalina (The jamovi project, 2025).

RESULTS

A total of 685 participants (420 boys and 265 girls) aged between 8 and 16 years were included. Table 1 presents the descriptive characteristics of the sample and the results obtained in the 20mSRT, expressed as mean $\pm$ standard deviation, minimum, and maximum values.

Table 1. Descriptive characteristics and 20mSRT values of the participants

Variable	n	M $\pm$ SD	Min.	Max.
Age (years)	685	11.7 $\pm$ 1.7	8	16
Overall 20mSRT (m)	685	1312 $\pm$ 449	320	2700
Boys 20mSRT (m)	420	1445 $\pm$ 460	320	2700
Girls 20mSRT (m)	265	1115 $\pm$ 351	360	1960

Table 2 shows the comparison between the mean values obtained in the 20mSRT by the COR-School sample and the European reference values for the 50th percentile provided by the FitBack network (Ortega et al., 2023). Across all age groups between 8 and 16 years, both boys and girls in the study achieved higher values than the European reference values. The differences ranged from 324 to 780 meters in favour of the COR-School sample.

Table 2. Comparison of 20mSRT distance: COR-School vs. FitBack references

	Age	COR-School (n=685)	FitBack (n=1 026 077)	Difference
<i>Girls</i>	8	840	355	+ 485
	9	759	434	+ 324
	10	1060	500	+ 560
	11	1068	550	+ 518
	12	1207	583	+ 623
	13	1219	600	+ 619
	14	1187	600	+ 587
	15	1329	600	+ 729
	16	1380	600	+ 780
<i>Boys</i>	8	1043	450	+ 593
	9	1139	550	+ 589
	10	1295	652	+ 644
	11	1351	722	+ 630
	12	1483	792	+ 691
	13	1602	883	+ 718
	14	1501	994	+ 507
	15	1606	1071	+ 535
	16	1740	1109	+ 631

Note. European values are presented after conversion from completed stages to total meters covered. Difference = COR-School – European reference (FitBack).

Table 3. Correlations and regression models between age and CRF performance

Predictor variable	B (IC95%)	β (IC95%)	R ²	p
Age (years) ^a	r = 0.35 (0.29 – 0.42)	–	–	< 0.001
Age (years) ^b	94.39 (75.67 – 113.11)	0.35 (0.28 – 0.42)	0.12	< 0.001
Age (years) ^c	91.93 (74.41 – 109.45)	0.34 (0.28 – 0.41)	0.24	< 0.001
Sex (Boys vs Girls) ^c	312.79 (252.34 – 373.24)	0.70 (0.56 – 0.83)	0.24	< 0.001

Note. a = Pearson correlation; b = simple linear regression model; c = multiple linear regression model (adjusted for age and sex). r = Pearson correlation coefficient; B = unstandardized regression coefficient; β = standardized regression coefficient; IC95% = 95% confidence interval; R² = coefficient of determination.

The correlation analysis (Table 3) showed that the distance covered in the 20mSRT increased progressively with age in both sexes (Figure 1). The Pearson correlation between

age and meters covered was positive, of moderate magnitude, and statistically significant ($r = 0.35$; 95% CI: 0.29–0.42; $p < 0.001$).

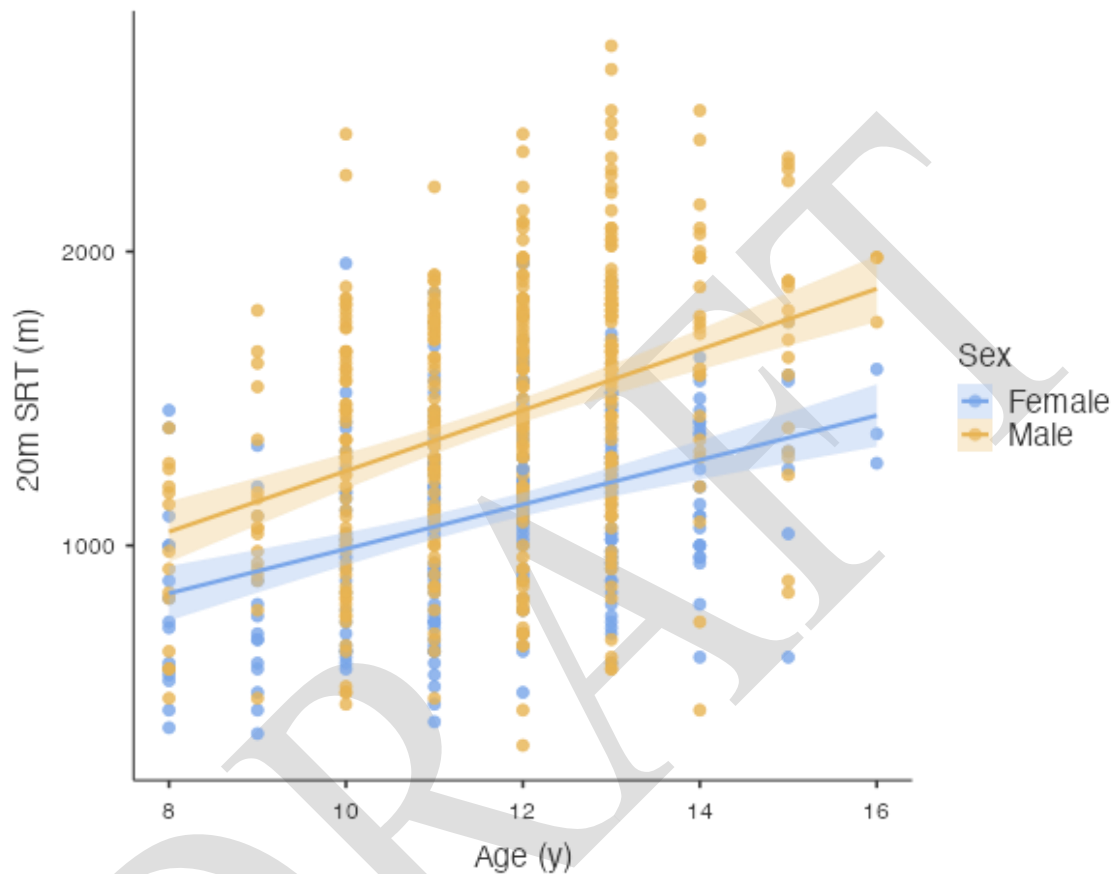


Figure 1. Relationship between age and distance covered in the 20mSRT

The simple linear regression model (Table 3) indicated that age explained 12% of the variance in CRF performance ($R^2 = 0.12$). Each additional year of age was associated with a mean increase of 94.39 meters covered (95% CI: 75–113; $p < 0.001$).

When sex was included as a covariate (Table 3), model fit improved substantially ($R^2 = 0.24$), with age remaining a significant predictor ($B = 91.93$ m; 95% CI: 74–109; $p < 0.001$). The effect of sex was also significant, such that boys covered on average 312.79 meters more than girls after adjusting for age (95% CI: 252–373; $p < 0.001$).

DISCUSSION

The present study, conducted within the framework of the COR-School project, analysed the relationship between age and CRF assessed using the 20mSRT in a large sample of physically active Spanish schoolchildren. The results showed a positive and significant correlation of moderate magnitude ($r = 0.35$), such that, on average, each additional year of age was associated with an increase of approximately 90 meters covered in the test. In addition, sex was confirmed as a relevant predictor: after adjusting for age, boys covered approximately 313 meters more than girls.

These findings are consistent with the literature describing age and sex as key determinants of CRF during childhood and adolescence. Malina et al. (2004) and Ortega et al. (2008) previously highlighted that somatic growth and physiological changes associated with puberty have a direct impact on aerobic capacity. More recent longitudinal studies confirm this pattern. Other studies have shown that performance in the 20mSRT increases between 7 and 15 years of age steadily, with more pronounced differences in boys after pubertal onset (Ingvarsdottir et al., 2024). Similarly, a progressive increase in performance associated with age and maturation has been documented in schoolchildren, emphasising the importance of controlling for maturational status in analyses (Järvmägi et al., 2022).

The sex differences observed in this study are in line with those reported in systematic reviews and epidemiological studies (Mintjens et al., 2018; Tomkinson et al., 2017). These differences may be mainly attributed to greater muscle mass, higher haemoglobin concentration, and larger stroke volumes in boys after puberty (Petek et al., 2023; Rowland, 2018). However, when adjusting for biological maturation, previous research has shown that sex-related disparities tend to diminish (Carayanni et al., 2022), suggesting that part of the gap is explained by differences in the timing of peak pubertal growth.

When comparing our results with the European reference values recently published by the FitBack network (Ortega et al., 2023), physically active schoolchildren from the COR-School sample clearly exceeded the European 50th percentile values across all ages between 8 and 16 years, with differences ranging from 324 to 780 meters. This finding indicates a favourable CRF profile in the present sample compared with the general population, as suggested by recent studies linking organised sports participation with higher levels of CRF (Kolunsarka et al., 2024; Zhao et al., 2025). Moreover, it reinforces the usefulness of the 20mSRT as a tool to monitor population differences and detect potential inequalities in physical fitness between active youth and the average school population, as supported by studies highlighting its scalability and application in youth health surveillance (Tomkinson et al., 2019). While these differences are noteworthy, the comparison with FitBack reference values should be interpreted descriptively. The cross-sectional design of the present study does not allow conclusions regarding the factors responsible for the observed differences.

The observed correlation was moderate ($r = 0.35$), indicating that age explains only part of the variability in performance. Other factors, including sports participation, body composition, and socio-educational context, may also contribute to performance variability (Aixa-Requena et al., 2025; Eberhardt et al., 2025; García-Hermoso et al., 2020; Lin et al., 2025).

In addition, recent secular trends point to a global decline in CRF among young populations (Leone et al., 2023), highlighting the need to contextualise results using national and international reference data. In this regard, comparison with European reference values (Ortega et al., 2023) allows the identification of whether active youth in this study fall within or above population averages, providing relevant information on their health profile.

The use of the 20mSRT as a field-based assessment tool represents another strength of the present study. Its validity compared with laboratory measures and its applicability in

large-scale studies have been widely documented (Lang et al., 2018; Léger & Lambert, 1982; Ruiz et al., 2011; Tomkinson et al., 2017). The consistency of the present findings with the international literature further supports its utility as a monitoring instrument in school- and sport-based programs.

Among the main strengths of this study are the large sample size, the inclusion of a wide age range, and the homogeneity of the applied protocol. Nevertheless, some limitations should be acknowledged. The cross-sectional design does not allow the assessment of intra-individual developmental trajectories or the establishment of causal relationships. In addition, objective measures of biological maturation and sports practice volume were not included. This limitation is particularly relevant given the wide age range studied (8–16 years), which encompasses major maturational transitions that may substantially influence CRF and partially explain the age- and sex-related differences observed.

In conclusion, the results confirm that age and sex are significant predictors of CRF performance in physically active Spanish schoolchildren. These findings, consistent with the international literature, reinforce the usefulness of the 20mSRT as a monitoring tool in educational and sports settings and provide reference data that can be compared with national and European standards. Future longitudinal studies will allow the evaluation of the influence of biological maturation and structured sports participation on the development of CRF.

CONCLUSIONS

Age and sex were confirmed as significant predictors of CRF performance in physically active children and adolescents. The distance covered in the 20mSRT increased progressively with age, with a mean increase of approximately 90 meters per year, and boys achieved higher results than girls after adjusting for age.

Compared with European reference values from the FitBack network, study participants showed superior performance in the 20mSRT across all age groups. However, this comparison is descriptive and should be interpreted with caution given the observational nature of the study.

These findings support the use of the 20mSRT for monitoring CRF in school and sports settings. They also provide reference data that can be compared with national and European standards.

REFERENCES

- Aixa-Requena, S., Hernández-González, V., Conesa-Milian, E., Batalla-Gavaldà, A. & Reverter-Masia, J. (2024). The COR-School Project: Physical Activity and Cardiometabolic Health in Spanish Youth. *Youth*, 5(1), 2. <https://doi.org/10.3390/youth5010002>
- Aixa-Requena, S., Pano-Rodríguez, Á., Hernández-González, V., Conesa-Milian, E., Batalla-Gavaldà, A., Beltrán-Garrido, J. V., López-Laval, I., Corbi, F., Arnau-Salvador, R. & Reverter-Masia, J. (2025). CRF in Spanish Youth: The Roles of Sex, Age, Body Composition, and Healthy Lifestyle Habits in Cor-School Study. *Children*, 12(5), 581. <https://doi.org/10.3390/children12050581>
- Albaladejo-Saura, M., Vaquero-Cristóbal, R., González-Gálvez, N. & Esparza-Ros, F. (2021). Relationship between Biological Maturation, Physical Fitness, and Kinanthropometric Variables of Young Athletes: A Systematic Review and Meta-Analysis. *International Journal of Environmental Research and Public Health*, 18(1), 328. <https://doi.org/10.3390/IJERPH18010328>
- Carayanni, V., Bogdanis, G. C., Vlachopapadopoulou, E., Koutsouki, D., Manios, Y., Karachaliou, F., Psaltopoulou, T. & Michalacos, S. (2022). Predicting VO2max in Children and Adolescents Aged between 6 and 17 Using Physiological Characteristics and Participation in Sport Activities: A Cross-Sectional Study Comparing Different Regression Models Stratified by Gender. *Children*, 9(12), 1935. <https://doi.org/10.3390/CHILDREN9121935>
- Demchenko, I., Prince, S. A., Merucci, K., Cadenas-Sanchez, C., Chaput, J. P., Fraser, B. J., Manyanga, T., McGrath, R., Ortega, F. B., Singh, B., Tomkinson, G. R. & Lang, J. J. (2025). CRF and health in children and adolescents: an overview of systematic reviews with meta-analyses representing over 125 000 observations covering 33 health-related outcomes. *British Journal of Sports Medicine*, 59(12), 856–865. <https://doi.org/10.1136/BJSPORTS-2024-109184>
- Eberhardt, T., Bös, K., Woll, A., Kliegl, R. & Niessner, C. (2025). Secular Trends of Children's Physical Fitness and the Impact of the COVID-Pandemic for Years 2012 to 2023. *Sports Medicine - Open*, 11(1). <https://doi.org/10.1186/S40798-025-00881-2>
- García-Hermoso, A., Ramírez-Vélez, R., García-Alonso, Y., Alonso-Martínez, A. M. & Izquierdo, M. (2020). Association of CRF Levels During Youth With Health Risk Later in Life. *JAMA Pediatrics*, 174(10), 952. <https://doi.org/10.1001/jamapediatrics.2020.2400>
- Ingvarsdottir, T. H., Johannsson, E., Rognvaldsdottir, V., Stefansdottir, R. S. & Arnardottir, N. Y. (2024). Longitudinal development and tracking of CRF from childhood to adolescence. *PLOS ONE*, 19(3), e0299941. <https://doi.org/10.1371/JOURNAL.PONE.0299941>
- Järavamägi, M., Riso, E. M., Reisberg, K. & Jürimäe, J. (2022). Development of CRF in Children in the Transition From Kindergarten to Basic School According to Participation in Organized Sports. *Frontiers in Physiology*, 13, 881364. <https://doi.org/10.3389/FPHYS.2022.881364>

- Kolunsarka, I., Stodden, D., Gråstén, A., Huhtiniemi, M., & Jaakkola, T. (2024). The associations between organized sport participation and physical fitness and weight status development during adolescence. *Journal of Science and Medicine in Sport*, 27(12), 863–868. <https://doi.org/10.1016/J.JSAMS.2024.07.013>
- Lang, J. J., Tremblay, M. S., Léger, L., Olds, T. & Tomkinson, G. R. (2018). International variability in 20 m shuttle run performance in children and youth: who are the fittest from a 50-country comparison? A systematic literature review with pooling of aggregate results. *British Journal of Sports Medicine*, 52(4), 276–276. <https://doi.org/10.1136/bjsports-2016-096224>
- Leone, M., Levesque, P., Bourget-Gaudreault, S., Lemoyne, J., Kalinova, E., Comtois, A. S., Bui, H. T., Léger, L., Frémont, P. & Allisse, M. (2023). Secular trends of CRF in children and adolescents over a 35-year period: Chronicle of a predicted foretold. *Frontiers in Public Health*, 10, 1056484. <https://doi.org/10.3389/FPUBH.2022.1056484>
- Lin, G., Chen, J., Yan, R., Deng, B., Song, W., Guan, B., & Sun, J. (2025). Effects of Maturation Stage on Physical Fitness in Youth Male Team Sports Players After Plyometric Training: A Systematic Review and Meta-Analysis. *Sports Medicine - Open*, 11(1), 1–21. <https://doi.org/10.1186/S40798-025-00907-9>
- Léger, L. A. & Lambert, J. (1982). A maximal multistage 20-m shuttle run test to predict VO₂ max. *European Journal of Applied Physiology and Occupational Physiology*, 49(1), 1–12. <https://doi.org/10.1007/BF00428958>
- Malina, R. M., Eisenmann, J. C., Cumming, S. P., Ribeiro, B., & Aroso, J. (2004). Maturity-associated variation in the growth and functional capacities of youth football (soccer) players 13-15 years. *European Journal of Applied Physiology*, 91(5–6), 555–562. <https://doi.org/10.1007/s00421-003-0995-z>
- Maron, B. J., Friedman, R. A., Kligfield, P., Levine, B. D., Viskin, S., Chaitman, B. R., Okin, P. M., Saul, J. P., Salberg, L., Van Hare, G. F., & et al. (2014). Assessment of the 12-lead ECG as a screening test for detection of cardiovascular disease in healthy general populations of young people (12–25 years of age). *Circulation*, 130(15), 1303–1334. <https://doi.org/10.1161/CIR.0000000000000025>
- Mintjens, S., Menting, M. D., Daams, J. G., van Poppel, M. N. M., Roseboom, T. J. & Gemke, R. J. B. J. (2018). CRF in Childhood and Adolescence Affects Future Cardiovascular Risk Factors: A Systematic Review of Longitudinal Studies. *Sports Medicine*, 48(11), 2577–2605. <https://doi.org/10.1007/s40279-018-0974-5>
- Ortega, F. B., Leskošek, B., Blagus, R., Gil-Cosano, J. J., Mäestu, J., Tomkinson, G. R., Ruiz, J. R., Mäestu, E., Starc, G., Milanovic, I., Tammelin, T. H., Sorić, M., Scheuer, C., Carraro, A., Kaj, M., Csányi, T., Sardinha, L. B., Lenoir, M., Emeljanovas, A., ... Jurak, G. (2023). European fitness landscape for children and adolescents: updated reference values, fitness maps and country rankings based on nearly 8 million test results from 34 countries gathered by the FitBack network. *British Journal of Sports Medicine*, 57(5), 299–310. <https://doi.org/10.1136/bjsports-2022-106176>
- Ortega, F. B., Ruiz, J. R., Castillo, M. J. & Sjörström, M. (2008). Physical fitness in childhood and adolescence: a powerful marker of health. *International Journal of Obesity*, 32(1), 1–11. <https://doi.org/10.1038/sj.ijo.0803774>
- Petek, B. J., Chung, E. H., Kim, J. H., Lampert, R., Levine, B. D., Phelan, D., Danielian, A., Dean, P. N., Dineen, E. H., Fernandez, A. B., Husaini, M., Krishnan, S., Shah, A. B., Stewart, K. M. & Wasfy, M. M. (2023). Impact of Sex on Cardiovascular Adaptations to Exercise: JACC Review Topic of the Week. *Journal of the American College of Cardiology*, 82(10), 1030–1038. <https://doi.org/10.1016/J.JACC.2023.05.070>
- Raghuveer, G., Hartz, J., Lubans, D. R., Takken, T., Wiltz, J. L., Mietus-Snyder, M., Perak, A. M., Baker-Smith, C., Pietris, N., & Edwards, N. M. (2020). CRF in Youth – An Important Marker of Health: A Scientific Statement From the American Heart Association. *Circulation*, 142(7), e101. <https://doi.org/10.1161/CIR.0000000000000866>
- Rodríguez, F. A. (1994). Spanish version of the Physical Activity Readiness Questionnaire (C-AAF/RPAR-Q). *Apunts: Medicina de l'Esport*, 31(120), 301–310.
- Rowland, T. W. (2018). *Cardiopulmonary exercise testing in children and adolescents* (1st ed.). Human Kinetics.
- Ruiz, J. R., Castro-Piñero, J., España-Romero, V., Artero, E. G., Ortega, F. B., Cuenca, M. M., Jimenez-Pavón, D., Chillón, P., Girela-Rejón, M. J., Mora, J., Gutiérrez, Á., Suni, J., Sjörström, M. & Castillo, M. J.

- (2011). Field-based fitness assessment in young people: the ALPHA health-related fitness test battery for children and adolescents. *British Journal of Sports Medicine*, 45(6), 518–524. <https://doi.org/10.1136/bjsm.2010.075341>
- Ruiz, J. R., Caverio-Redondo, I., Ortega, F. B., Welk, G. J., Andersen, L. B. & Martinez-Vizcaino, V. (2016). CRF cut points to avoid cardiovascular disease risk in children and adolescents; what level of fitness should raise a red flag? A systematic review and meta-analysis. *British Journal of Sports Medicine*, 50(23), 1451–1458. <https://doi.org/10.1136/BJSPORTS-2015-095903>
- The Jamovi project. (2025). *Jamovi* (2.6.44 [Mac]). <https://www.jamovi.org/>
- Tomkinson, G. R., Lang, J. J., Blanchard, J., Léger, L. A. & Tremblay, M. S. (2019). The 20-m Shuttle Run: Assessment and Interpretation of Data in Relation to Youth Aerobic Fitness and Health. *Pediatric Exercise Science*, 31(2), 152–163. <https://doi.org/10.1123/PES.2018-0179>
- Tomkinson, G. R., Lang, J. J., Tremblay, M. S., Dale, M., LeBlanc, A. G., Belanger, K., Ortega, F. B. & Léger, L. (2017). International normative 20 m shuttle run values from 1 142 026 children and youth representing 50 countries. *British Journal of Sports Medicine*, 51(21), 1545–1554. <https://doi.org/10.1136/bjsports-2016-095987>
- World Medical Association. (2013). World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. *JAMA*, 310(20), 2191–2194. <https://doi.org/10.1001/jama.2013.281053>
- Zhao, D., Chen, X., Zhang, A., Wang, Y., Gao, Y., He, J., Jiang, L., & Zhang, Y. (2025). A study of the relationship and drivers between participation in sports program diversity and physical fitness. *Scientific Reports*, 15(1), 1–14. <https://doi.org/10.1038/S41598-025-15697-Z>